Prepared for the IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP)

Final Report

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Achievements of Energy Efficiency Appliance and Equipment Standards and Labelling Programs: 2021 update

Prepared by Energy Efficient Strategies and Waide Strategic Efficiency
with Ballarat Consulting (UK) and CLASP

Achievements of Energy Efficiency Appliance and Equipment Standards and Labelling Programs: 2021 update

Final Report, 25 June 2021 (V23)

Electronic copies of this report and The Policy Makers Summary prepared jointly by the IEA and 4E based on this report can be downloaded here: https://www.iea-4e.org/publications (September 2021)

Preface

This study was commissioned by the IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP) and was funded by the Swedish and UK Governments. The report was prepared by Energy Efficient Strategies Pty Ltd (Australia) and Waide Strategic Efficiency Ltd (UK) in collaboration with Ballarat Consulting (UK) and CLASP.

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Efficient Appliances for People & the Planet

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Disclaimers

Executive Summary

Introduction

The objective of this high-level study was to review the available evidence of the achievements of energy efficiency labelling and/or standards[1] (S&L) for appliances and equipment in the commercial, industrial and residential sectors (excluding transport). There are now at least 120 countries that have in such programs in place or are in the process of developing them.

This project involved an extensive global review of nearly 400 published reports, studies and papers and builds on previous 4E studies in 2015 & 2016.

Achievements of S&L – energy and related impacts

The electricity savings recorded from mature S&L programs with the largest product coverage are of the order of 15% of total economy-wide electricity consumption. Savings for fuel use in buildings are an even greater proportion in the EU, accounting for 19% of consumption in 2020, rising to over 35% by 2030. To put this into perspective, the EU electricity savings for 2020 are 14.9% of *total EU electricity consumption*, while the equivalent figure for the US is 15.5%. Other economies report substantial but lower savings, either because their S&L programs are less extensive or less mature than the EU and the US. A summary of savings for different economies is shown in Table ES1.

For the USA, it appears that approximately two-thirds of all savings are from residential sector products and one sixth each for tertiary/commercial sector products and industrial products respectively. The exact breakdown varies by country, but this is broadly reflective of international trends.

Rates of efficiency improvement in products

Typically, the energy performance of new products that are subject to S&L requirements have been found to improve at 2% to 3% per year above the underlying rate of improvement. Although S&L programs affect the performance of new products entering the market, over time this has an impact on the average efficiency of the stock of all products in use.

The average annual rate of stock energy improvement due to MEPS and labelling is around 1.0% for domestic cold appliances, 0.6% for non-ducted air conditioners, 0.83% for lamps and 0.22% for electric motors. If sustained over 10 or 20 years, these stock improvement rates would lead to the following reductions in energy consumption:

- Domestic cold appliances: 10% (10 years), 22% (20 years)
- Non-ducted AC: 6% (10 years), 13% (20 years)
- Lamps: 9% (10 years), 18% (20 years)
- Electric motors: 2.2% (10 years), 4.5% (20 years).

[1] Efficiency standards are also called minimum energy performance standards (MEPS), which is the main nomenclature used in this study.

Table ES1: Summary of EE S&L energy savings at the whole economy level

Economy	Savings (TWh)	Target year	% of BAU in target year	% of 2018 consumption	2018 consumption (TWh)	No. products covered
EU-28 (Electricity)	699	2030	20.0%	24.1%	2900	43
EU 28 (Fuel use in buildings)	1210	2030	35.2%			28
EU-28 (Electricity)	433	2020	12.9%	14.9%	2900	43
EU 28 (Fuel use in buildings)	678	2020	19.1%			28
South Africa	5.5	2030		2.6%	210	9
USA (Electricity)	625	2020		15.5%	4033	73+
USA (Gas)		2020		5.0%	4878	27+
China	405	2020		4.9%	6833	~22
India	55.7	2019		4.4%	1277	27
Brazil (Procel label only)	21.2	2018	4.0%	4.0%	529	
Mexico	16	2015	6.5%	5.9%	271	4
Malaysia	0.4475	2015		0.3%	147	4
Japan					940	26
Korea					571.9	~45
Australia	16.998	2018		7.3%	234	~30

Tables notes: See Table 8 for more detail and notes about sources and coverage.

Figure ES1 shows how the annual rate of improvement in stock efficiency varies by main product grouping, while Figure ES2 shows how the stock efficiency improvement rates compare to the new product efficiency improvement rates for the same set of product groups. Figure ES3 shows the typical total stock energy reductions that can be achieved by each product type, based on the data collected over a typical program analysis period (15 to 20 years). While the potential energy savings varies by product type (due to differences in technical potential and other nuances regarding S&L implementation), these figures show that *stock* energy reductions of 10% to 30% over moderate timeframes have been achieved by most countries. Ambitious targets are more likely to yield energy reductions that are closer to the maximum values.

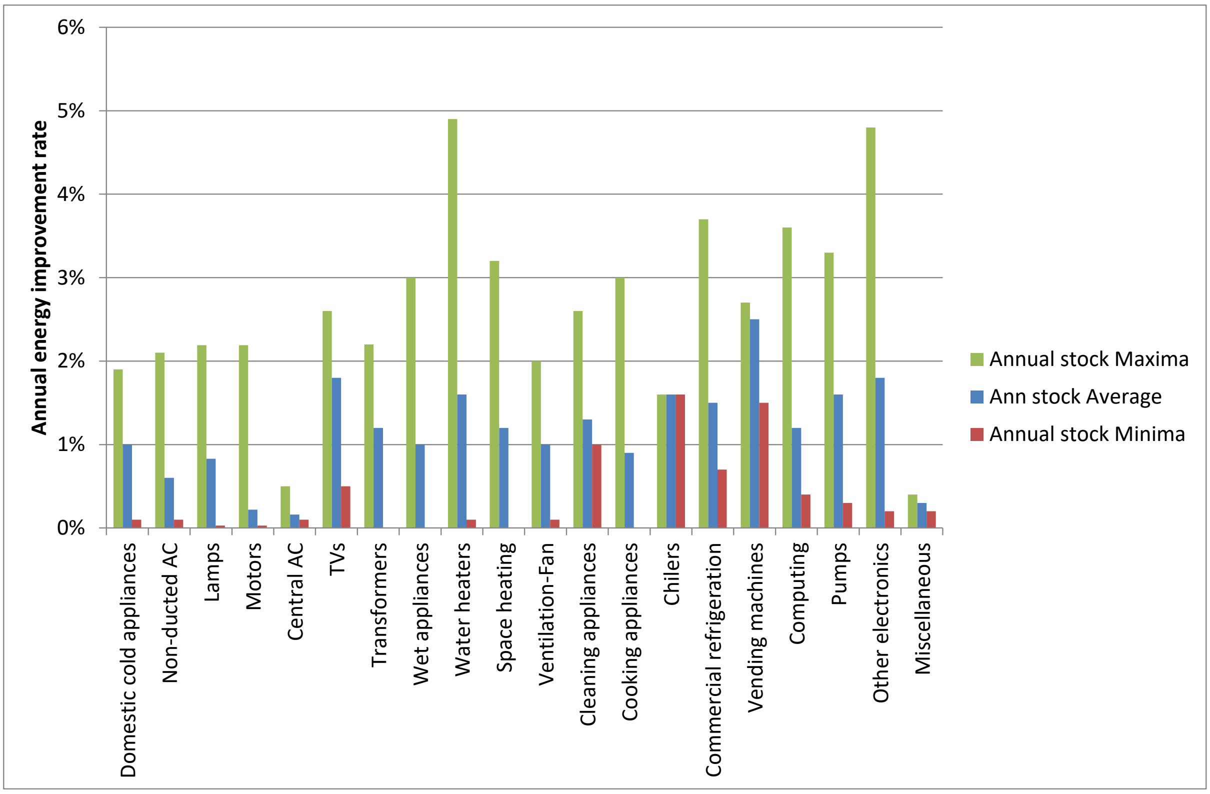

Figure ES1: Annual rate of improvement in stock energy consumption by main product grouping

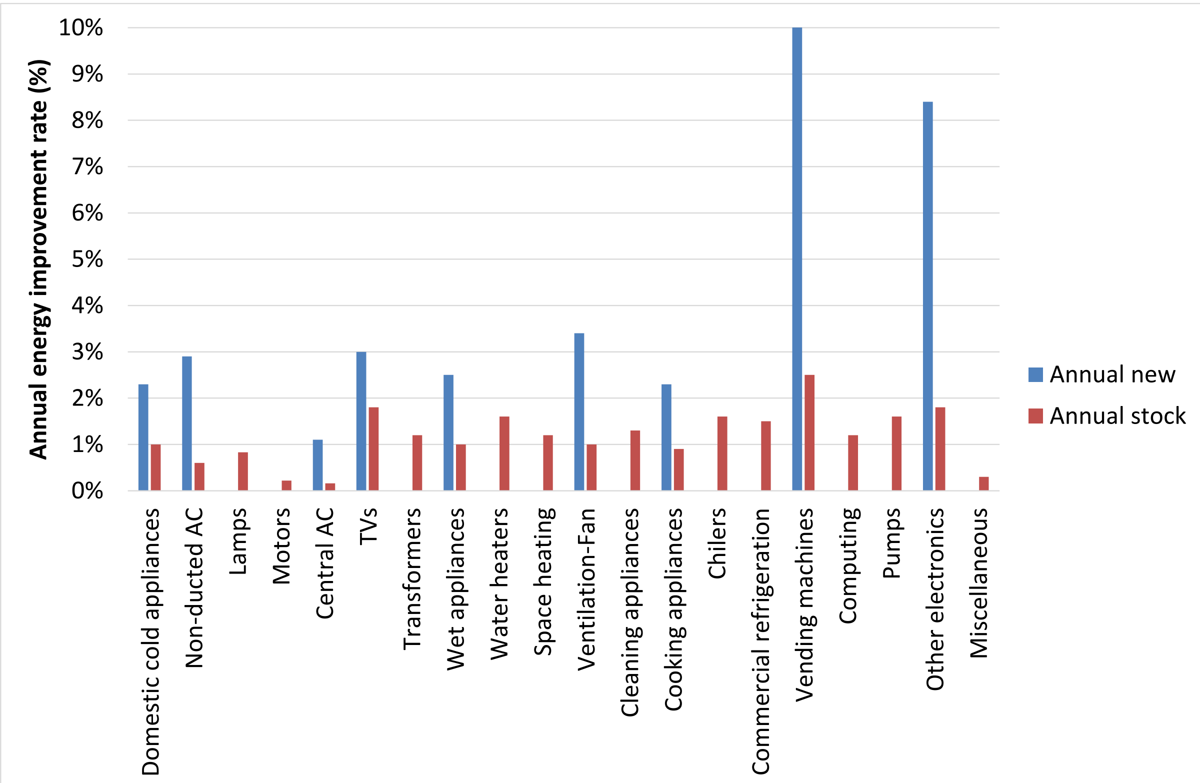

Figure ES2: Annual rate of improvement in new product and stock energy consumption by main product grouping

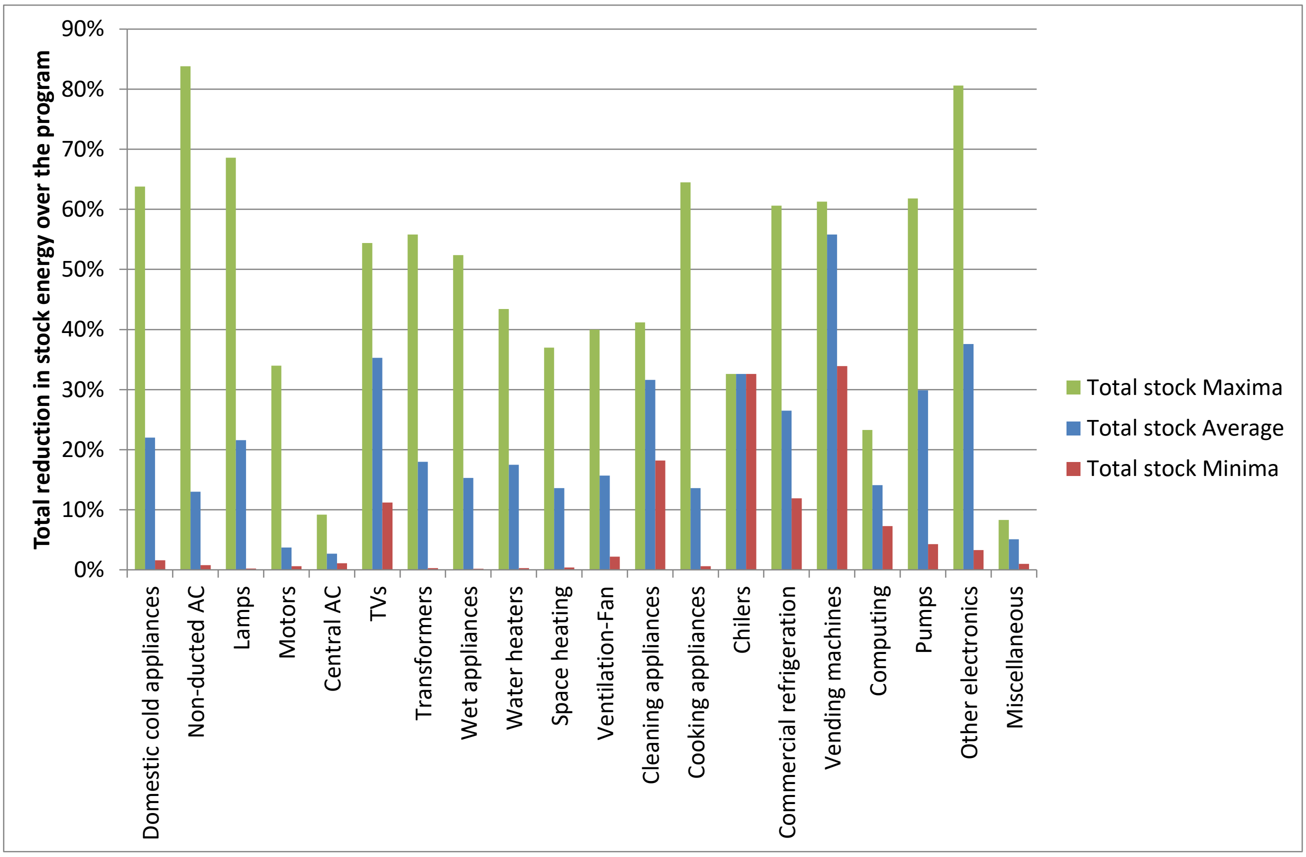

Figure ES3: Total change in stock energy consumption by main product grouping over typical program duration

Greenhouse Gas Emission impacts

For the USA, it is estimated that MEPS alone saved 7.1% of the *all national energy-related emissions* in 2019. For the EU, the EcoDesign and energy labelling program was projected to save 10.7% of the *EU's total energy-related emissions* for 2019, and 7% of the EU's *total CO_2 equivalent emissions from all sources*. This amounts to 15% of the *total emissions from products subject to EcoDesign and labelling requirements*.

Water impacts

Water consumption and sewage output can be considerably reduced through the use of devices that are not only energy efficient but also water efficient, such as low-flow showerheads, dishwashers or washing machines. Almost all economies that have regulated the energy performance of water using products have reported corresponding reductions in both their energy use and their water consumption. This is because the most effective means of improving energy efficiency of such products is to reduce the amount of heated water they require to fulfil their function (where applicable). This leads to a double benefit for the consumer as both their energy and water bills are reduced. Studies in the EU, Australia and Canada showed that water consumption rates for dishwashers and clothes washers fell at between 3% and 4% per annum over

20 years or more and that these reductions were strongly linked to S&L programs, as well as associated water efficiency S&L measures.

Achievements of S&L – costs and benefits

In all programs studied, the financial benefits outweighed the costs. In many cases, the decrease in energy expenditure (the benefit) was many times larger than any increase in product purchase costs (the cost). Many studies have shown that regulatory processes tend to overestimate the cost increases associated with S&L. With more accurate estimates of future product costs, more stringent S&L levels will appear to be cost effective.

Table ES2 shows a summary of benefit cost ratios for a selection of countries and programs. A benefit cost ratio over 1.0 indicates that the program provides a net overall benefit; whereas a ratio less than 1.0 shows that the overall costs exceed the overall benefit. Most countries require a benefit-cost ratio of well above 1.0 before proceeding with program implementation.

Table ES2: Benefit Cost Ratios from EE S&L programs by economy

Economy	Benefit Cost Ratio averaged over all product groups	Notes on end years, products and discounting
Canada	5.1	Mix of 2030 and 2040, all regulated products
Australia	4.5	2030 – all regulated products
New Zealand	2.1	2030 - just refrigerators
Fiji	2.6	2030, all regulated products
Samoa	9.4	2030, all regulated products
Tonga	7.5	2030, all regulated products
Vanuatu	12.6	2030, all regulated products
Cook Islands	9.8	2030, all regulated products
Kiribati	12.5	2030, all regulated products
Japan	1.69	In 2020, 9 selected products
EU	4.7	2030, all regulated products, not discounted
USA	5.3	2050, all regulated products

Achievements of S&L - Employment

A number of studies covered the issues of both employment and energy efficiency. However, most were undertaken at a macro-economic level and did not differentiate the employment impacts of S&L programs from other types of efficiency programs. Direct job creation is driven purely by the net increase in expenditure on equipment and, in the case of the EU, it is estimated that each ~€80k increment in annual expenditure on equipment results in the creation of one job in the manufacturing, wholesale, retail and maintenance value chain. For the US it is estimated that each increment in net consumer savings of between $188k and $225k will result in one job being created in the economy (both direct and indirect job creation). It can be difficult to generalise from these findings to draw lessons for other economies because of variations in the degree of an industrial presence, the cost of labour, and the degree to which expenditure in the economy at large will generate jobs. But there is strong evidence that energy savings from S&L will generate some ongoing employment.

Achievements of S&L - Health

The health benefits of S&L are not often assessed, but there is emerging evidence that they could be very substantial and may become a major part of the overall value proposition of S&L policy measures. Reductions in air pollution are the main sources of health benefits from high efficiency equipment and these can arise from reducing direct emissions (i.e. emissions that are emitted directly by the equipment at the place of installation) but also by reducing indirect emissions due to the transformation of primary energy sources into secondary energy (most notably by the use of fossil fuels in the production of electricity). Quantifying the impacts of S&L on health is generally very indirect, but several studies show that monetised health benefits are often of comparable magnitude to the value of energy benefits.

Recent research has found that globally, 18% of all deaths are attributable to fossil-fuel pollutants, roughly double the total previously ascribed to air pollution. While this research doesn't distinguish the origins of the pollution, much of which will be transport sector related, these findings suggest that previous health impact monetisation exercises may need to be revised.

Achievements of S&L - Innovation

When MEPS apply to all segments of the market and are performance based, rather than prescribing one particular design or technology over another, they help drive innovation. The fact that many regulatory processes have predicted higher costs for more efficient equipment than has actually occurred is evidence of innovation.

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*" (Taylor, Spurlock & Yang 2015).

Analysis of several US MEPS regulations clearly shows that the decline in both the product purchase price and its life cycle cost continues after the implementation of successive MEPS measures, and in most cases at a higher rate of decrease for both parameters. S&L regulation appears to be an important driver of innovation, which results in more rapid reductions in life cycle costs (and in some cases purchase costs) than would happen in the absence of regulation.

Future steps

This report has documented the rate of improvement in energy and other parameters that have resulted from S&L programs. The continued improvement in product performance is a key contributor to an energy-efficient future. While the rates of change appear to be modest for many products (2% to 3% improvement per year for new products, 1% per year for the stock), these will generate very substantial reductions in energy consumption if they persist over the long term. Table ES3 shows the overall reductions that can be achieved from modest annual improvement rates over different time horizons. Even a 2% per annum improvement in the stock energy will result in almost a 50% reduction in energy consumed over a 30-year period. This illustrates the importance of more countries adopting ambitious S&L programs that cover a greater number of products. Evidence collected for this report show that S&L programs are effective and can make an important contribution to Nationally Determined Contributions under the 2015 Paris Climate Agreement.

Table ES3: Long term stock energy reduction from different annual improvement rates

Improvement	10 years	20 years	30 years	50 years
1% per annum	9.6%	18.2%	26.0%	39.5%
2% per annum	18.3%	33.2%	45.5%	63.6%
3% per annum	26.3%	45.6%	59.9%	78.2%

Table notes: Reductions over longer periods are calculated as compound rates.

To encourage more S&L programs covering more products, it is important that the real benefits of existing programs are accurately assessed. It is clear from this project that full ex post evaluations are relatively rare in the published literature. This means that there is a significant gap in the knowledge base for what has (or has not) been effective in the past and why. All governments and research bodies should be encouraged to undertake a wider range of evaluations to expand the evidence base for current and future program managers.

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Glossary and Abbreviations

4E TCP	IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP)
AC	Air-conditioner
APF or ASPF	Annual (seasonal) performance factor (air conditioners)
BCR	Benefit-Cost Ratio (net benefits over net costs)
CLASP	Non-government organisation – see https://www.clasp.ngo/
BAU	Business as Usual
COP	Coefficient of Performance (output energy / input energy for heat pumps)
DR	Demand Response
EcoDesign	The term used to describe the EU MEPS program for energy using products
EE	Energy Efficiency
EER	Energy Efficiency Ratio (cooling performance)
EES	Energy Efficient Strategies (consultants)
EES&L	Energy Efficiency Standards and Labelling (called S&L in this report)
EJ	Exajoules (unit of energy)(joules × 10^{18})
EU	European Union
Ex-ante	Before an event; term used in policy appraisals to indicate that savings estimates (projections) are 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
GHG	Greenhouse gas emissions (usually in tonnes or Megatonnes)
GJ	Gigajoules (unit of energy)(joules × 10^{9})
GWh	Gigawatt hour (unit of energy)(Wh × 10^{9})
IEA	International Energy Agency
kWh	kilowatt hour (unit of energy)(Wh × 10^{3})
MEPS	Minimum Energy Performance Standards (regulated efficiency levels)
$MtCO_{2e}$	Mega-tonnes of carbon dioxide equivalent
Mtoe	Million tonnes of oil equivalent (41.868 PJ)
MW	Megawatt (unit of power)(watts × 10^{6})
NGO	Non-government organisations
NPV	Net Present Value (calculated with a specified discount rate)
PJ	Petajoules (unit of energy)(joules × 10^{15})
RIS	Regulatory Impact Statement
S&L	Standards and labelling (using meaning MEPS and labelling)
SEAD	Super-Efficient Equipment & Appliance Deployment
SEER	Seasonal energy efficiency ratio (air conditioners)
TJ	Terajoules (unit of energy)(joules × 10^{12})
TWh	Terawatt-hour (unit of energy)(Wh × 10^{12})
UEC	Unit energy consumption (typical kWh/year, but other units possible)
W	watt (unit of power)

1 Introduction

1.1 Overview

While there were a range of voluntary programs in a few countries in the 1970s and even as early as the 1960s, the first mandatory energy labelling program for appliances and equipment was introduced in Canada in late 1978. Since then, a range of efficiency programs such as labelling and efficiency standards (referred to as Minimum Energy Performance Standards or MEPS) have been introduced. In 2013 at least 100 countries had adopted requirements that covered more than 60 different product types (Energy Efficient Strategies & Maia Consulting 2014; CLASP 2021). Nor is the pace of adoption slackening off. The United for Efficiency program reports that at least 120 countries in 2020 had such policies or are in the process of developing them.[2]

While the design and coverage of energy efficiency standards and labelling (S&L) programs vary according to national circumstances, they provide the cornerstone of many national energy and climate change mitigation programs. Evidence collected for this report show that S&L programs are effective and can make an important contribution to Nationally Determined Contributions[3] under the 2015 Paris Climate Agreement.

Typically, S&L programs use one or more of the following complementary tools to improve the energy efficiency performance of appliances and equipment:

- 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 (CLASP & Danish Low Carbon Transition Unit 2013).

Energy efficiency is typically defined as ‘the level of service that can be produced for a given amount of energy input’ (e.g. litres of refrigerator capacity / kWh of energy consumed). Increased energy efficiency typically refers to an improvement in this ratio. Energy efficiency is also referred to as the “hidden” or, more recently, the “first fuel” (Study 1028, REF248). Fundamentally, energy efficiency programs are about productivity enhancement, with benefits potentially extending across a wide range of areas including:

- economic (both at the household, business, state and national levels)
- employment
- health
- security (primarily energy security)

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[2] See https://united4efficiency.org/resources/energy-labelling-guidance-for-lighting-and-appliances/

[3] For more detail on detail on Nationally Determined Contributions, see https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/nationally-determined-contributions-ndcs

- environment.

The objective of this high-level study was to review the available evidence of changes in energy efficiency as a result of energy standards and labelling (S&L) programs for appliances and equipment and to understand the nature of the impact that these energy programs have had. In particular, this study focused on evidence of the benefits of such energy programs in relation to:

- increases in rates of energy efficiency improvement over and above autonomous rates of change
- energy savings realised and related energy cost and greenhouse gas emission savings
- positive benefit/cost outcomes i.e. benefits outweighing costs
- driving innovation and market transformations through industry leveraging
- other co-benefits delivered by such programs.

1.2 Scope of study

4E TCP commissioned two previous studies with a similar scope in 2015 and 2016 as follows:

- *Achievements of appliance energy efficiency standards and labelling programs – a global assessment*, released in September 2015 (International Energy Agency 4E 2015)
- *Achievements of Appliance Energy Efficiency Standards and Labelling Programs: A Global Assessment* in 2016 (International Energy Agency 4E 2016).

Together, these studies reviewed around 120 reports and papers specific to the topics of S&L. The scope of the present study is also limited to S&L programs relating to appliances and equipment in the commercial, industrial and residential sectors. Therefore, the impacts of building shell efficiency programs were not generally considered to be within the scope, even though they also deliver considerable energy savings in many countries. Programs that apply to vehicles and transport were also excluded. Three main types of energy efficiency programs included are:

- programs that imposed minimum energy performance standards (MEPS)
- comparative energy labelling programs
- endorsement energy labelling programs.

Predominantly, the programs examined were mandatory programs; however, voluntary programs were also considered, in particular endorsement labelling programs, which by their nature tend to be voluntary.

The current study builds on this previous work and has a refined focus. The scope of benefits was defined as falling into the following categories:

- energy, electricity[4], greenhouse gas (GHG) or peak demand reductions (absolute and/or compared to business as usual or similar proxy)

[4] Reductions in average electric load generally translate into base load reductions, depending on the load profile.

- rates of energy efficiency improvement (absolute and compared to business as usual or similar proxy)
- changes in appliance and equipment purchase prices following implementation of energy efficiency program
- impact on overall consumer costs as a result of program, i.e. capital and running costs
- concrete examples of industry innovation in response to S&L programs, such as the development of markets for new technology and increased industry R&D
- employment effects, including jobs created
- health impacts, such as improvements in air quality, reduced sick days or hospital visits.

The geographical scope is global, such that sources on any national or regional program are included. While standards and labelling programs can be found in over 100 countries, the bulk of these programs, especially the established ones covering a wide range of product types, are located in the most developed economies.

The project terms of reference expressed a preference for ex-post evaluations of benefits (retrospective assessment of what was achieved after implementation)[5].

1.3 Methodology outline

The project methodology involved an extensive international review of the available published reports and conference papers on the topic. The previous two studies compiled data on some 120 reports and papers up to and including those published in early 2016. For this 2021 update, many leading energy efficiency experts from around the world were consulted regarding suitable studies that could be utilised as part of the evidence base for this updated study. Wherever possible, multiple sources have been identified to support and corroborate the findings and to confirm the broad benefits of S&L energy efficiency programs.

For this update, a comprehensive global search uncovered some 275 new reports or papers that may have been potentially suitable for further analysis. All new reports (as well as existing reports from the 2015 and 2016 studies) have been electronically catalogued in an online library. The key information recorded in this catalogue includes:

- Authors
- Title
- Year of publication
- Publisher/ organisation/ customer
- Web link
- Region covered
- Products covered
- Source
- Notes regarding suitability.

[5] See section 2 and section 2.5 in particular for more discussion of these terms and the distinctions between them.

A copy of each source document (usually in PDF format) was also loaded to a cloud drive that can be accessed by the project team and the 4E TCP management team. The aim was to create a complete repository of resources that can be maintained and updated into the future if, and when, future updates occur.

Each of the documents referred to the project team were reviewed carefully to assess the level of data available and the overall quality of the data. Documents with suitable data were tagged for more in-depth analysis. Where documents were not immediately suitable for in depth analysis, notes were prepared on each document regarding their coverage.

In order to allow more comprehensive analysis of the data from those reports with suitable quantitative data, key parameters were extracted and digitised in a Document Analysis Database, developed for this project. This allowed a large number of specific quantitative data to be compiled in a manner that allowed a more in-depth analysis by product and region. Around 60 new reports were found to contain suitable quantitative data suitable for extraction into the Document Analysis Database. In addition, around 20 of the studies identified in the 2015 and 2016 studies were also found to still be relevant and of high quality and were selected for more in-depth analysis.

In selecting published data to include, comprehensive ex-post studies were given a higher 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, it should be understood that formal ex-post evaluation studies, where energy savings are estimated from a review of historical data after program implementation, are relevantly uncommon in the published literature.

More details regarding the type of data extracted and digitised for the Document Analysis Database are set out in Section 2. That section also provides some important background on the key types of parameters extracted and approaches that have been developed for this report to allow key parameters with disparate units to be compared in an international context.

1.4 Structure of this report

The structure of this report is as follows:

- Chapter 2 outlines the data collected and concepts used in this report
- Chapter 3 provides in depth analysis of energy, efficiency and related trends at a high level and for individual products
- Chapter 4 examines monetary costs and benefits from S&L programs
- Chapter 5 looks at employment issues in the context of S&L
- Chapter 6 discusses evidence regarding health related issues
- Chapter 7 compiles a range of data on innovation and other issues
- Chapter 8 provides an index of all studies used in this report
- Chapter 9 lists formal references.

1.5 Referencing systems used in this report

Due to the large number of reports and studies covered, this report uses three different, but related, referencing systems. Documents that are referenced in the main text are generally noted using Harvard style referencing (author, year) and these reports are listed as formal references in Section 9 (References).

The studies that were collected and analysed for the first Achievements of S&L report in 2015 (International Energy Agency 4E 2015) are listed in numerical order in Section 8.3. These reports are numbered as Study 1 to Study 112. The studies that were collected and analysed for the 2016 update (International Energy Agency 4E 2016) are also listed in numerical order in Section 8.3. These reports are numbered as Study 1001 to Study 1041.

As noted, nearly 300 new reports were reviewed for this 2021 update of the Achievements of S&L report. These were allocated a master reference number (in the form REFXXX) as they were entered into the system, so the order is essentially random. These reports, along with their relevant details, are listed in Section 8.2 in REF order. Many of these studies did not have suitable quantitative or qualitative data and so could not be used in this report. The status column indicates how the report was used (or not) as follows:

- Value of -1 indicates that the report has been assessed as having little information that can be used directly in the 2021 update
- Value of 0 indicates that the report has been assessed as likely to contain information of interest, but this cannot be extracted from the published material – in some cases inquiries with the authors are pending in order to access the underlying data
- Value of 0.5 indicates that the report has some qualitative data that this has been used in the 2021 update
- Value of 1 to 2790 is the Study number (see below) and indicates that the report has been subjected to quantitative analysis and that key data has been extracted and entered into the Document Analysis Database and used directly in the 2021 update (see Section 1.3).

All documents reviewed for the 2021 update were documented to make subsequent updates easier.

Documents with quantitative data that could be used as part of the higher level meta-analysis for the 2021 update had key data extracted and entered into the Document Analysis Database. The Study number reflects the record identifier in the database. These are listed in order of Study number in Section 8.1. Around 40 reports from the 2015 and 2016 studies had data extracted and entered into the database. These earlier documents retained their original identifier number (1 to 112, or 1001 to 1041 as applicable). Around 70 new reports in 2021 had data extracted and entered into the database. New reports were allocated a database ID in the form 2XYY where X = region as follows:

- 0 International
- 1 Africa
- 2 Asia
- 3 Central/South America
- 4 Europe

- 5 Middle East
- 6 North America
- 7 Oceania.

YY was a sequential integer that reflected the order of entry into the database (random). In the database, where a study covered several countries, a separate record was created for each country.

1.6 Team member responsibilities

Team members undertook a range of roles and responsibilities as set out below:

- Lloyd Harrington was responsible for project management, preparation of the on-line Document Analysis Database and other on-line tools, some research and discovery, some outreach, screening of some documents, digitisation of some documents, data analysis and report writing
- Paul Waide was responsible for some research and discovery, substantial amounts of outreach, screening of some documents, digitisation of some documents, data analysis and report writing
- Fiona Brocklehurst was responsible for a significant share of research and discovery activities, substantial amounts of outreach, screening of many documents, digitisation of many documents and some input into the report content
- Angellah Wekongo of CLASP was responsible for research and discovery of published materials and conference papers and provided outreach to key contacts in Africa and Asia
- James Wakaba of CLASP was responsible for research and discovery of published materials and coordination and liaison activities
- Stephen Pantano of CLASP provided higher level strategic advice and input into the project.

In addition to the above, Ji Xuan (Senior Researcher) and Ruo Lin Yaw (Researcher) of the Jyukankyo Research Institute Inc., Japan undertook research activities and discovery activities, particularly for Japan and in academic journals under the guidance of Hidetoshi Nakagami (CEO and Founder), Jyukankyo Research Institute Inc., Japan. They also provided advice and assistance in the translation and interpretation of some documents from Asia.

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- Stephane de la Rue du Can, LBNL.

2 Data sources, terms and concepts used in this report

2.1 Nature of reports examined

The reports and papers examined for this study varied enormously from regulatory impact statements, to academic papers, to public reporting of data, to economic assessments and tracking of trends and impacts over time. Therefore, the detail and rigor in each report varied somewhat, depending on its purpose. The majority of the reports and studies examined were either by governments, were commissioned by governments or were prepared with the cooperation of governments. This was not always the case in the USA, where a range of non-government organisations (NGOs), many of which had a strong energy or environmental focus, often prepared reports as part of their advocacy role. Reports by NGOs often used historical published government data for their analysis, particularly for historical (ex post) analyses. NGO ex ante projections were more typically used to encourage governments to take further regulatory steps, so were not endorsed by government. While many of these ex ante projections used credible data sets, they were generally not included in the analysis because of their prospective nature and not being linked to any specific regulatory proposal, which meant they were less likely to be realised. However, some NGO analyses of historical public data sets have been included.

It is important to understand the context in which each report was prepared and its primary purpose. Many of the reports that appeared interesting in terms of their topics and coverage were not used for the more in depth analysis because quantitative data was not reported at all or was only reported in a way that could not be converted into a form suitable for international benchmarking and comparisons. In some cases it was clear that the underlying data used in the reports and papers would have allowed more in depth analysis. For a sub-set of these cases, approaches were made to the authors to request additional data. However, this was a slow, time consuming and sometimes fruitless process, so the project team was unable to follow up and include many of the papers and reports that may have yielded interesting data.

2.2 Parameters tracked and analysed

The Document Analysis Database allows a wide number of parameters to be recorded in a digital format for further analysis. The key parameters that could be recorded for each product type and program in each country included:

- Products (over 100 predefined types available)
- Sector (residential, commercial, industrial, all sectors)
- Start year
- End Year
- Parameter (typically energy related - see below)
- Change rate %pa (new stock)
- Total change % (new stock)
- Period years (calculated)

- Annual new rate (calculated compound rate based on period years)
- Program type (labelling, MEPS, S&L, various other options)
- Evaluation (ex post, ex ante, hybrid ex post/ex ante, trend)
- Fuel (electricity, gas, oil)
- Notes (specific to this product and data)
- Total Savings (stock)
- Saving units (typical energy units, but could be water or currency)
- Total Product BAU (base case energy use before the program measure)
- In year/Cumulative (whether savings are in the final year noted or whether they are cumulative across the whole period)
- Annual rate stock (calculated compound rate based on period years).

For the parameters recorded for each project, the database included options to select any of the following options:

- Energy reductions (energy alone)
- Average UEC (unit energy consumption)
- Average on power (W)
- Efficiency improvements (taking into account energy and energy service provided)
- Emission reductions
- Peak load reductions
- Energy costs reduction (for the end user)
- Equipment cost reduction (nominal) (for the end user)
- Equipment cost reduction (real) (for the end user)
- Water consumption reductions (for the end user)
- Jobs created
- Benefit cost ratio.

A headline count of the key variables in the document analysis database are set out in the following tables. There were many records from Europe and North America, with significant numbers of records from Asia and Oceania. There were relatively few from Central/South America and Africa, despite strong efforts made to acquire sources for those regions. There were no studies found that covered the Middle East,

Table 1: Summary of reports reviewed in 2021 and 2015/16 by region

Region	Reports 2021	Database 2021	Reports 2015/6	Database 2015/16	Total reports	Total database
International	27	2	23	1	50	3
Africa	22	2	0	0	22	2
Asia	66	19	15	5	81	24
Central/South America	18	8	4	2	22	10
Europe	48	7	44	2	92	9
Middle East	0	0	0	0	0	0
North America	53	15	33	5	86	20
Oceania	32	8	10	5	42	13
Total	266	61	129	20	395	81

Table notes: These are counts of reports that were reviewed for this study. While there were nominally 81 database report entries, there were in fact 113 separate database entries as each country was allocated a separate sub-entry to separate data for later analysis. International means that the data covered several countries from more than one region, or the paper was general in nature and applied to many/all countries (most commonly for higher level analyses like economic impacts, employment, health and innovation).

Table 2: Document analysis database record count by region

Region	Code	Count	Share
International	0	9	1.0%
Africa	1	26	2.9%
Asia	2	229	25.2%
Central/South America	3	28	3.1%
Europe	4	306	33.7%
Middle East	5	0	0.0%
North America	6	212	23.3%
Oceania	7	98	10.8%
Total		908	100.0%

Table notes: Region code has been used when numbering studies in the Document Analysis Database.

Table 3: Document analysis database record count by product meta-group

Product meta-group	Count	Notes
Domestic cold	155	Refrigerators, freezers, refrigerator-freezers
Non-ducted AC	137	excludes ducted
Central AC	7	
Motors	40	electric
Lighting	40	
All products	49	Sector wide or program wide
TVs	37	
Transformers	27	distribution/utility
Water heating	39	
Heating	49	Service can be provided by reverse cycle ACs
Wet Products	102	washers, dryers, dishwashers, combinations
Ventilation-fan	25	
Cleaning	17	
Cooking	48	
Chillers	7	commercial buildings
Comm refrigeration	17	includes industrial cool rooms
Vending	16	includes refrigerated and heated
Computing	24	
Pumps	10	
Other electronics	52	other AV and office
Miscellaneous	13	includes JP toilet seats

Table notes: Most records were for domestic cold and non-ducted air conditioners, with significant numbers also for wet appliances (clothes washer, dryers and dishwashers).

Table 4: Document analysis database record count by sector

Sector	Count
Residential	465
Commercial	85
Industrial	59
Other	12
All Sectors	287

Table notes: Residential sector data predominated, reflecting the most common S&L programs, but there were significant multi-sector records (e.g. most air conditioners).

Table 5: Document analysis database record count by energy and related parameters

Energy/ analysis parameter	Count
Energy reductions	580
Average UEC	19
Average on power (W)	2
Efficiency improvements	124
Emission reductions	47
Peak reductions	1
Energy costs reduction	10
Equipment cost reduction (nom)	16
Equipment cost reduction (real)	41
Water reductions	4
Jobs created	2
Share of GWP in non-use phase	4
Benefit cost ratio	50

Table notes: Energy reductions were the most reported parameter, with efficiency improvements also common.

Table 6: Document analysis database record count by program evaluation type

Evaluation type	Count	Share
Ex ante	394	43.6%
Ex post	89	9.9%
Ex post+ante	174	19.3%
Trends (no attribution)	246	27.2%

Table notes: Ex ante (future projections) were most common, usually related to regulatory proposals or other investigations. Ex post were relative unusual. Combination ex post+ante records were mostly from Europe where projections are continuously updated and calibrated with recent historical data (so they were in effect predominantly ex ante projections).

Table 7: Document analysis database record count by fuel type

Fuel	Count	Share
Electricity	820	90.3%
Gas	34	3.7%
Oil	6	0.7%
Gas+oil	35	3.9%
Water	1	0.1%
Multiple	11	1.2%
Other	1	0.1%

Table notes: Electricity was by far the dominant fuel. Gas+oil was either a mixture of both fuels or where the study did not specify or separate which fuels were covered.

Given the wide disparity of possible units reported for energy and related parameters, the general approach taken was to convert the reported data as far as possible into generic parameters which showed percentage changes over time. For example, where an average new refrigerator energy consumption was reported as 500 kWh/year in 2000 and this fell to 400 kWh/year in 2010, then it would be entered as a 20% energy reduction over a period of 10 years. This means that, nominally, the energy consumption has been reducing at around 2% per year. When this is treated as a compound formula, it is calculated as an energy reduction of 1.84% over the 10-year period[6]. Reporting of annual rates of change for any of the parameters allows these to be compared and contrasted across regions and over time.

In order to prepare the most in-depth analysis using the largest range of input data, it was determined that the most suitable data would normally be in the following forms:

- Annual rates for change in **average new products** delivered to the market: typically these would be changes in energy consumption, energy efficiency, product attributes (as noted above). These were converted to a generic percentage rate to allow comparison across products and regions.
- Changes in **stock energy consumption** in a specific year as a result of the S&L program measures: typically these are reported as savings (from a Business as Usual case). Again, to allow a generic comparative measure to be generated, both the savings generated and the BAU (prior to savings) were generally required to generate a change in stock energy per annum as a result of the S&L program.
- **Cumulative energy savings and emissions** over a specified period. Again, to allow a generic comparative measure to be generated, both the cumulative savings for each parameter and the cumulative BAU (prior to savings) were generally required to generate a cumulative change in stock average energy per annum as a result of the S&L program. Note that this cumulative measure generates a lower apparent annual savings rate than the change in stock energy consumption in a particular year – the mathematics behind each of these parameters is explored in more detail in the following section.
- **Costs and benefits** were commonly reported in many ex-ante studies (typically to satisfy regulatory requirements) and these were generally reported as an overall Benefit Cost Ratio (BCR) ratio. Time periods for analysis and parameters such as discount rates varied by jurisdiction, so it was generally only possible to report the stated values, noting that for the most part these were official government documents used to fulfil their local regulatory requirements, so were generally credible and relatively conservative.

In addition to these core parameters of interest, a number of reports covered other topics of key interest for this study, namely economic impacts, innovation, employment and health impacts. Typically reports that covered these topics were prepared at a high level and focused on macroeconomic indicators. This means that, in most cases, the impacts from standards and

[6] All annual rates calculated in this report are based on compound formulae for consistency. For annual rates of below 5%, compound rates and simple rates are similar over shorter periods.

labelling programs were generally not separately identified from impacts of energy efficiency in general. The main exception was the EU, which had extremely detailed levels of impact data at all levels of the economy. The economic effects varied considerably, depending on whether there was a local manufacturing industry covered by the energy efficiency measure. A number of reports identified clear economic and employment impacts from efficiency measures in general (particularly related to building shells) as these are economically intensive activities with a high rate of employment generation per unit of investment. A number of reports show clear linkages between innovation and regulation in general and in some cases, with S&L programs in particular. However, this type of data tended to be at a high-level and it was often difficult to extract clear comparative information from the analysis for use in the document analysis database.

Health impacts fell into macro effects such as a reduction in pollutants related to energy generation and the impact on the death rate and micro impacts such as the improvement in indoor conditions (typically temperature, but also air quality) and the impact on health and related measures (reduced deaths, reduced medical requirements, reduced days lost at work and school). These micro impacts tend to be more related to building shell performance than performance of space conditioning equipment, but S&L programs certainly play some role. These micro impacts are necessarily extremely complex and reporting of comparative quantitative data is limited.

2.3 Differences in reported parameters and basis for comparison

As noted above, the main parameters quantitatively tracked for this study were:

- Changes in average new products
- Changes in the stock of all products installed and operating in a specified year
- Changes in the cumulative stock of products installed and operated over a specified period
- Total costs and benefits (these are cumulative values over a specified period, usually expressed as a net present value at a nominated discount rate).

These parameters are all very different and the values derived from each approach will appear to be very different. However, they are indirectly related to each other and it is important to have some framework against which to interpret these different parameters, as reported throughout this document. In order to illustrate the similarities and differences between these parameters, a simplified hypothetical example has been prepared. Figure 1 illustrates the impact of a hypothetical program on the energy consumption of new products at year 0. For this program implementation, a step change in year 1 is assumed with no further change in new products in later years as shown. This program measure results in a 10% reduction in energy for an average new product. While this is significant, some aggressive MEPS programs can result in changes of 30% or more over a short period, so this is perfectly realistic as an example.

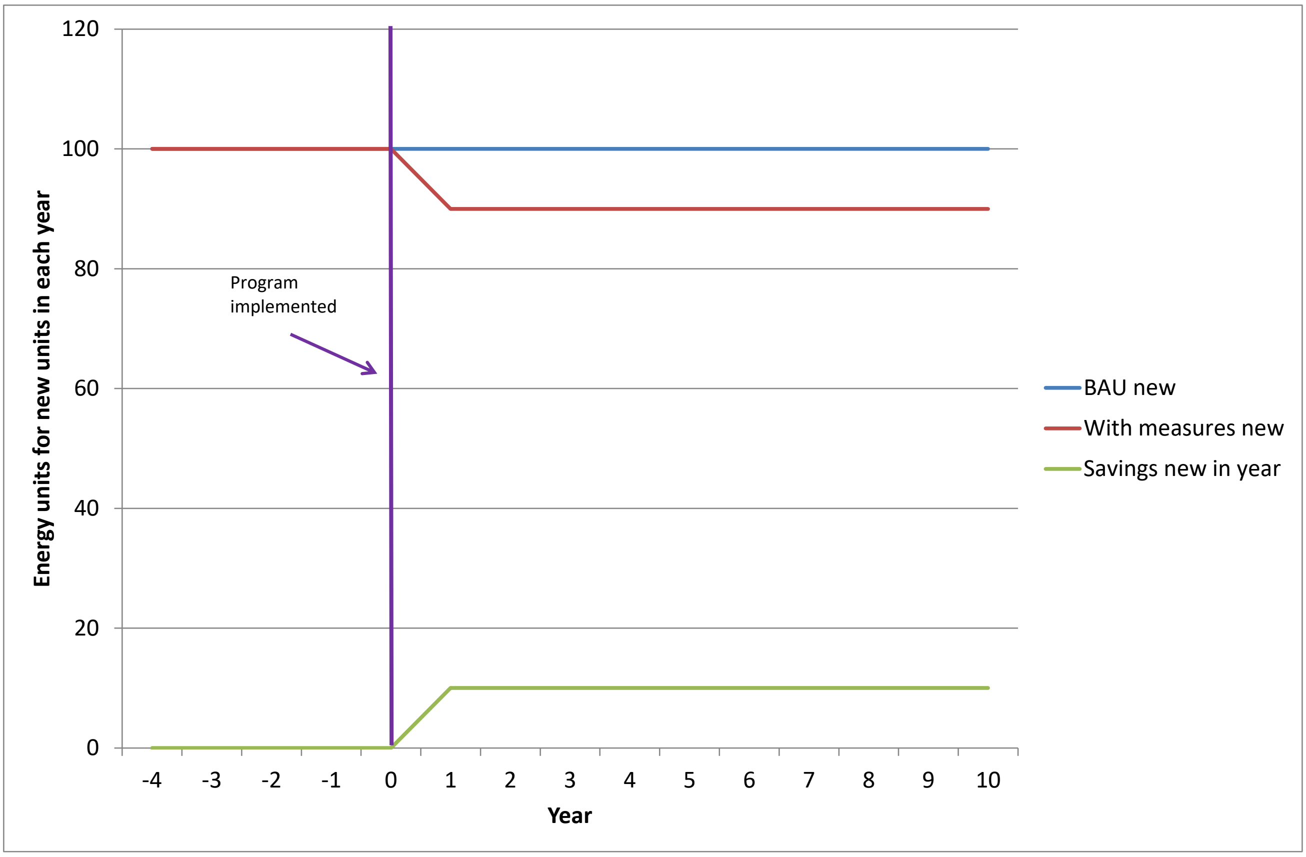

Figure 1: Energy consumption of new units after the implementation of program measure at year 0

Figure notes: Business as Usual new ("BAU new") are the expected characteristics of new sales without any program measure. "With measures new" are the expected characteristics of new sales with the new program measure in place. "Savings new in year" is the difference between "BAU new" and "With measures new".

The same data can then be expressed as stock energy consumption. If we assume for simplicity that the product has a nominal life of 10 years (so 10% of the stock is replaced each year with new products) and that there is no change in the stock levels over time, then the total stock-related parameters for the same data are shown in Figure 2. Under the "with measures case", the stock energy consumption gradually starts to decline as new lower energy products enter the stock and replace existing older units, whereas under Business as Usual (BAU), the stock energy consumption remains constant. In year 10 the stock energy consumption has declined to 900, resulting in savings of 100 from the BAU case. After year 10, the stock consumption "with measures" would become parallel to the BAU as all old stock will have been replaced.

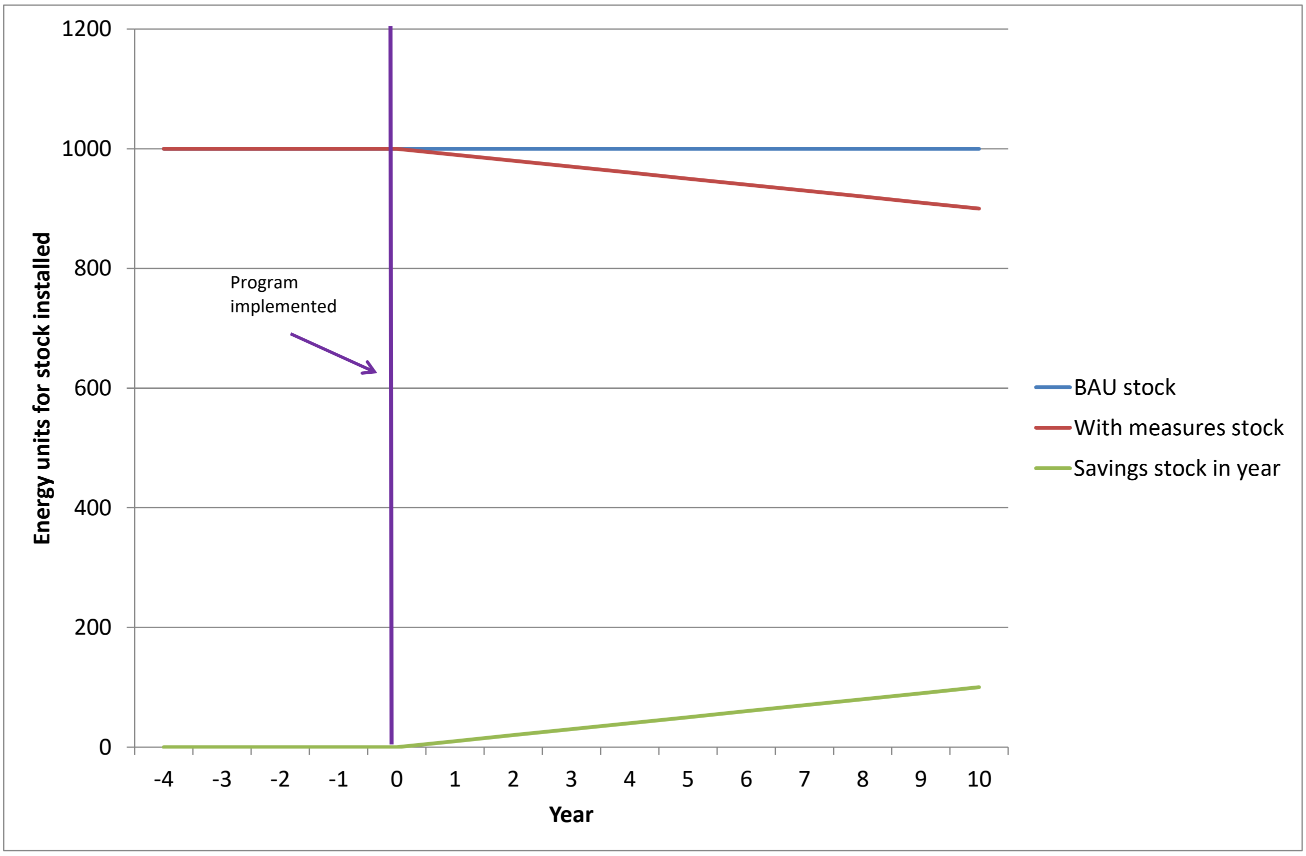

Figure 2: Total stock energy consumption of all units after the implementation of program measure at year 0

Figure notes: Business as Usual stock ("BAU stock") are the expected average characteristics of all operating units in the stock without any program measure. "With measures stock" are the expected average characteristics of all operating units in the stock with the new program measure in place. "Savings stock in year" is the difference between "BAU stock" and "With measures stock".

The third permutation of the same data can be expressed as cumulative energy consumption and cumulative savings as shown in Figure 3. Cumulative measures are sometimes favoured in reports for regulatory analysis as they make the savings over time appear to be very large (commonly used to report greenhouse emission reductions, for example). Cumulative values are almost always used for assessing program costs and benefits (net present value of future cost and benefit streams). Note that the cumulative energy savings appear as a curve that is accelerating over time. The "with measures" total stock energy is also a curve.

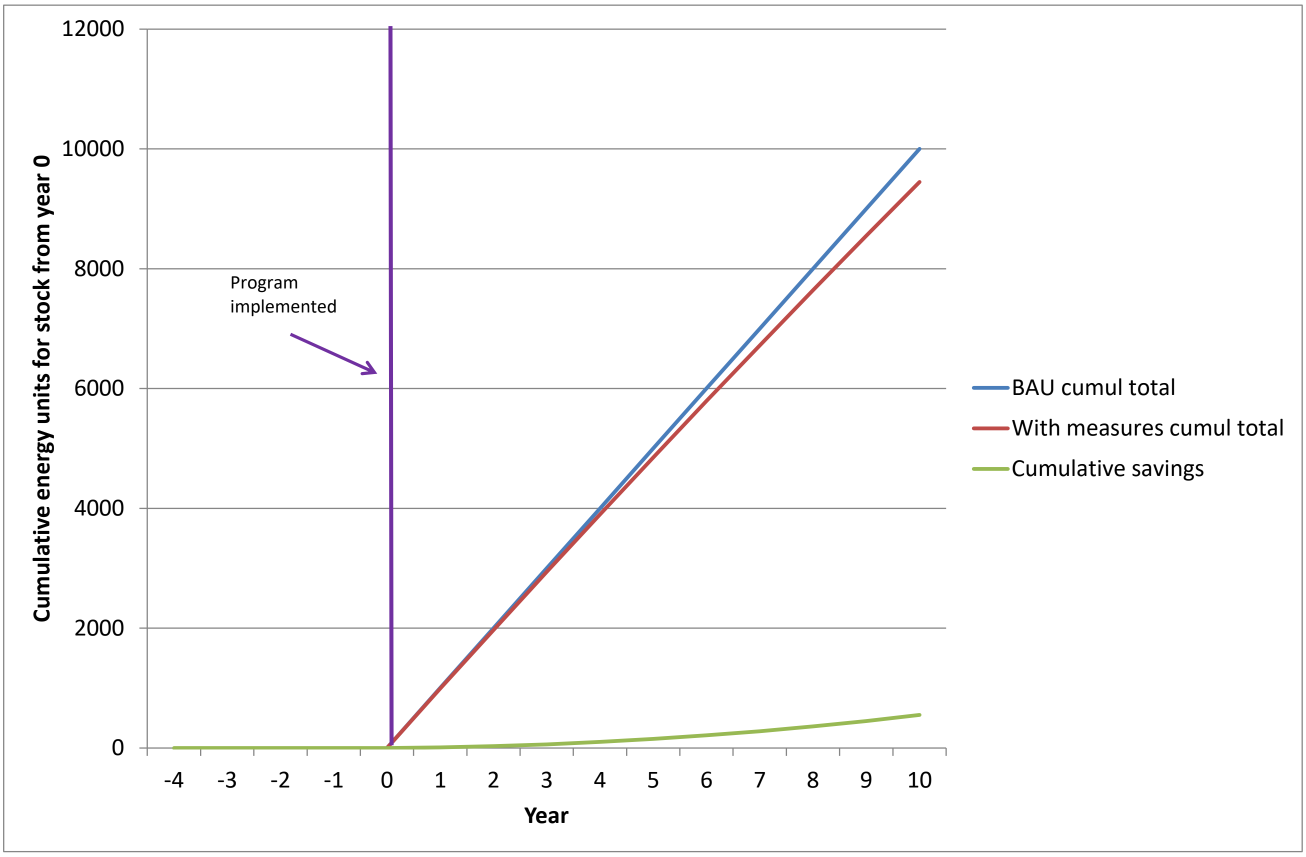

Figure 3: Cumulative stock energy consumption of all units after the implementation of program measure in year 0

Figure notes: Business as Usual cumulative total ("BAU cumul total") is the sum of average characteristics of all operating units in the stock from Year 0 to the current year without any program measure. "With measures stock" is the sum of average characteristics of all operating units in the stock from Year 0 to the current year with the new program measure in place. "Cumulative savings " is the difference between "BAU cumul total" and "With measures cumul total".

It is useful to calculate some key parameters for these different data configurations to illustrate how they are related. This is important as much of the data in this report is expressed as one of these three types of parameters and it is important to understand how to translate (in approximate terms) between them.

The data in Figure 1 shows a new product energy consumption "with measures" is 90 compared to 100 for BAU existing units. In years 1 to 10, the difference in new stock is 90/100 = 10% lower than the base case. If we calculate the annual impact over 10 years (at year 10), this results in approximately a 1% per annum reduction in new energy across the 10 years (0.96% p.a. reduction when calculated as a compound rate). However, if we frame the analysis period as from year 0 to year 1 only (1 year), then this appears to be a 10% reduction in energy (with no further reduction in years that follows). This illustrates that the framing of the data has a large impact on the apparent rate of change, especially around step changes in attributes. In general terms, data over the longest possible period has been used in this report, so the apparent rates of change are more stable but tend to smooth out the impacts of particular regulatory changes over time.

Consider the data in Figure 2, which is the same data presented as total stock energy consumption. In year 10, the stock energy consumption is 900 “with measures”, compared to 1000 under BAU. This equates to an energy reduction of 10% in year 10, or nominally 1% per annum reduction (0.96% p.a. reduction when calculated as a compound rate). This is comparable to the change in average new product calculated previously when calculated over the same period. However, in this case, these values are approximately the same because the nominal product life is 10 years and by year 10, all of the existing BAU stock has been replaced with new stock with the lower energy with measures. If the product lifetime was 20 years (for example) only half of the stock would have been changed in 10 years, so the impact of on the BAU stock energy would have been about half. This, of course, assumes no change in total stock numbers.

Consider the data in Figure 3, which is the same data presented as cumulative stock energy consumption. In year 10, the cumulative stock energy consumption is 9450 “with measures”, compared to 10000 under BAU. This equates to an energy reduction of 5.5% over the 10 years. If this is converted back to an annual rate over the 10 years, this is around 0.5% per annum, or about half the apparent rate when looking at stock energy impacts in a particular year. This is a very important observation – the cumulative stock calculation is in effect estimating the “average” savings over the 10 years, compared to the maximum savings that occur in year 10 under the stock approach.

In general terms, stock and cumulative measures are more robust as they reflect the overall changes in energy or emissions (or whatever parameter is being examined) because they also take into account changes in the stock (number of installed products in use). For the example in Figure 1, the energy consumption of new products decreased by 10%. But if the stock of products in use also increased by 10% over the same period, then the total stock energy would be approximately the same (not 10% less as predicted by the trend in new product energy).

Key learnings and observations from this simple analysis are:

- Changes in average new product attributes over time are widely available and useful measures. However, they can be affected by how the data is framed (start and end year), especially around changes in MEPS levels where these occur over a shorter period of a few years
- Changes in average new product attributes over periods longer than the product lifetime will provide solid data on how stock energy is likely to trend
- However, changes in average new product attributes do not reflect changes in the number of products installed (stock) and their use, so may not accurately reflect overall changes in total energy consumption or emissions
- Stock based measures provide the most robust indicator of how things are changing overall as they take into account product lifetime, changes in attributes for new and retiring stock and changes in total stock numbers
- To be most useful, both the savings and the BAU consumption (without program measures) are required to generate a generic comparative impact measure in percent per annum

- Cumulative savings measures are popular for some regulatory studies as they show a large total cumulative impact of the program measure over time
- The apparent annual rate of change for cumulative data is about half of that calculated from a stock impact in a particular year as the calculations effectively generate an average savings over the period rather than pick up the peak savings in the final year
- Stock and cumulative savings measures are more robust where there are non-linear program effects over time and/or changes in stock or usage parameters over time
- Care is required in the interpretation of stock and cumulative savings measures as studies vary in how time frames are applied regarding the installation of new and replacement units.

It is worth noting that the example above is a highly simplified example for illustrative purposes only. In contrast, real world data sets commonly exhibit the following attributes:

- Total stock is rarely static – it usually increases over time, but can decrease over time if a technology has become obsolete (this type of product is rarely subjected to new S&L programs)
- The average new attributes (e.g. size) are rarely constant over time
- Appliances installed in a particular year will be retired across a range of future years (not just in a single year at the average product lifetime). Retirement functions for modelling typically assume a normal distribution or linear distribution of retirement ages.

2.4 Counterfactual cases, scenarios, attribution and trends

A key focus of this study is to examine and quantify savings[7] that are attributable to S&L programs. The term savings means "a reduction or lessening of expenditure" (or other parameter such as energy) and naturally implies that there is a base case (which is referred to as business as usual or BAU) and an alternative case where savings are made against the base case. This alternative case is often called a counterfactual (meaning "a case that could happen"). When assessing future impacts of a potential program, typically the BAU case is what is expected to occur under the current trends without any change in policy settings. The counterfactual is what is estimated to occur if policy settings were to change. When assessing future impacts, both the BAU and the "with measures" are necessarily counterfactual cases and will be based on a range of data. However, many regulatory programs have been in operation for extensive periods and the methods and techniques used are becoming increasingly sophisticated. These often draw on previous regulatory experience and what has happened in similar circumstances previously.

As illustrated earlier, the generic comparative measures being used for this study rely on the generation of a BAU case, a "with measures" case and the calculation of the difference between these cases (savings). The savings are then expressed as a ratio of the BAU case to get a generic comparative impact parameter (% change or savings).

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[7] The scope of the study is to examine all benefits from S&L, but the discussion here is about quantified savings such as energy where there must be two separate scenarios to quantify these savings.

For many of the studies examined for this report, savings were nearly always reported in absolute units of various types (energy, emissions, water etc.). However, in many instances the study did not report either the expected parameter for the BAU or "with measures" case (or even the parameter after savings - "with measures" case). This made it difficult to use the data reported for regional comparisons. For example, if a country reported savings of 500 GWh in year 2015, this could be seen to be of some interest. But if the BAU is not reported, there is no way to know whether this is a little or a lot of energy relative to the country size and its overall energy consumption and trends for the specific product. Judging from the analysis undertaken, many of these reports will most likely have the underlying BAU data in some shape or form. However, while the study team have approached selected authors for this type of data, this ended up being very resource intensive so it was only possible to follow-up selected cases within the project budget.

Attribution[8] of impacts can be quite challenging 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. As noted above, the BAU case compared to the "with measures" case allows the calculation of the impact of the specific measure being investigated. In this case the differences between the two scenarios are attributed to the particular program measure. This may appear to be simple; however, there are often cases where the BAU already has the impact of previous S&L program measures built-in into it and new program measures are introduced at regular intervals. This makes the separation of impacts for overlapping program attributes more complex and to some extent reliant on judgement. Many jurisdictions do not even attempt to separate the impacts of individual program measures over time – they are all just lumped into a "standards and label" program bucket, so these effects tend to be mixed together. Preparation of accurate and realistic counterfactual scenarios and base cases can be quite complex and requires a great deal of skill and understanding. Unfortunately, the number of studies that prepared credible ex post counterfactuals was found to be relatively few. This is an area where policymakers could usefully focus some future resources.

One of the key skills in the art of developing credible BAU scenarios is to understand changes in product capacity attributes over time (e.g. are products becoming larger or smaller?), autonomous changes in energy efficiency (what is happening to product efficiency in the absence of new S&L program measures?) and what are the expected changes to stock numbers and usage characteristics. Changes in size, stock numbers and usage are likely to apply to both BAU and "with measures" scenarios. However, ascertaining the underlying autonomous efficiency change can be difficult where there is limited or poor data. Some countries use a "frozen efficiency" scenario as a

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[8] Attribution of savings 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 to assess 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.

BAU case, but this very generous in terms of attributing program impact as it allocates all future improvements to the “with measures” S&L scenario, which is unlikely in a global market context.

The other consideration is that S&L programs have been in operation in some countries for 40 years or more. While it is possible to develop a counterfactual that posits what the energy consumption of a particular product would have been today if S&L programs had not started 40 years ago (at least in theory), it is an increasing hypothetical exercise and of diminishing importance. Given the interconnected nature of international commodity markets for many products (especially major appliances, air conditioners, motors and lighting), it is likely that even those markets without S&L programs will benefit from some free rider effects of S&L regulations in major economies. Assessment of spill-over effects from large developed countries (e.g. EU/China/USA/Japan/Korea) to other regions is a potential area of future research.

The other type of data that was readily available was historical trend data (sometimes with projections of trends). This was typically reported as changes in new product attributes over time. Many of these data sets were highly credible in that they used sales weighted figures over very long periods (typically 20 years or more). This long-term trend data is very useful for comparative purposes across regions and products, but it is important to note that this data only shows actual historical changes in energy and/or other attributes (typically price, sometimes efficiency) and will include all S&L program impacts as well as any autonomous changes in energy efficiency over time. Energy values do not take into account the impacts of changes in product size over time (although efficiency metrics can provide some indication of size impact changes as well). It is also important to note that changes in average new product data over time may not reflect changes in the total stock numbers or other changes such as usage over time. Historical data is very important as this is an accurate measure of reality that occurred (actual in an ex post analysis). Using this as a base for analysis, an ex post study would then reconstruct the BAU without measures that aligns with historical market changes (e.g. product size and sales) that are unrelated to the program. This gives the most accurate impact assessment as all data has to fit within the framework of historical measurements. There is a large body of historical data out there, but unfortunately few programs apply this data to make formal ex post assessments.

2.5 Ex post versus ex ante analysis

Ex-post is a Latin term than means "after the fact”. The term is widely used in the field of evaluation to mean re-evaluation of historical data in the light of what actually occurred. In an ex post evaluation, the point prior to implementation is revisited to generate the BAU without measures projection and then to compare this with what actually happened after the program measures were implemented. In ex post analysis, it is common to make adjustments to the BAU projection to take account of any changes that occurred in the actual data (which will be reflected in the “with measures” scenario, which is what actually happened). For example, if the sales or sales share of particular products was higher or lower than originally anticipated, then both historical data projections should be adjusted to take what actually happened into account. Similarly, if there were differences in attributes like product size or usage in the actual case, then both of the historical scenarios should be adjusted to match (on the assumption that the program measure in theory should no impact on these parameters). Once the historical projections have been adjusted, the original BAU case should then accurately reflect what would have happened in the absence of the program measure (other things being equal) and the “with measures” case should match what actually happened. This provides a more robust method to estimate historical savings and other impacts arising from the “with measures” case.

Ex-post has the opposite meaning of ex-ante, which translates as "before the event". Ex ante projections are widely used in regulatory impact statements and other reports where an estimate of the future impacts of a proposed regulatory change is required. Ex ante projections typically cover a wide range of parameters such as energy, product costs, energy costs, emission impacts and projected overall costs and benefits. They can also cover other aspects such as water consumption and peak demand impacts, depending on the product. Occasionally these types of studies also project broader impacts such as impacts on employment and macroeconomic factors. Ex ante projections typically develop a BAU case (what is most likely to occur in the absence of any regulatory change) and at least one (often many) “with measures” counterfactual projection(s). Various counterfactual scenarios may include different stringency levels and different timing options.

Ex ante projections are relatively plentiful, but as noted above, not all studies provide BAU or “with measures” stock or cumulative projections, making the data less useful for this analysis. Ex ante projections are often very sophisticated and long running, established programs have a vast repository of data and experience to draw from, so their projections can be quite accurate. When used in regulatory impact statements, they are also subject to peer review by major stakeholders, which tends to mean that they are carefully crafted (if somewhat conservative). However, ex ante projections are necessarily less robust as they cannot include the impact of unforeseen events (e.g. economic recessions, pandemics etc.) and they may not anticipate technology changes (not yet invented) that can impact on product costs and product energy consumption. One of the main weaknesses of ex ante projections has typically been an overestimation of the impact that policies like MEPS will have on product purchase costs. Several comprehensive studies have illustrated that regulations like MEPS force industry innovation and result in larger energy savings at much lower marginal costs than could have been predicted from existing data sets. Also, the long-term reduction in real product purchase prices (based on learning rates) is becoming better understood, thereby enabling better ex ante projections. These issues are discussed in Section 4 on costs and benefits and Section 7 on innovation.

When comparing ex ante (and ex post) with trend data, it is important to remember that trend data includes all components that may influence energy consumption or other parameters, such as program impacts and autonomous efficiency improvements. Ex ante and ex post evaluations generally take the BAU case or trend into account (which includes any autonomous improvements in efficiency over time) so the stated impacts for ex ante and ex post are generally the incremental impacts associated with the program so appear lower than equivalent trend data.

The brief expressed a preference for ex post studies where possible. While this was strongly supported by the project team in principle, the number of high-quality ex-post evaluations identified was rather limited, even in developed economies with long running standards and labelling programs. There were many high-quality ex-ante studies (those that project future savings from prospective program implementation) and many of these have been included. Ex-post evaluations were generally limited to those programs that are longer running with good ongoing data collection strategies and a clear policy of undertaking ex post evaluations.

2.6 Differentiating program policy measures

The main program policy measures of interest in this study are standards (meaning MEPS) and labels (which could be comparative or endorsement, mandatory or voluntary). A variation of this approach is used in Japan under the Top Runner scheme. Under this approach, market efficiency is assessed and the government then sets a future sales weighted target based on the best available products currently on the market. Over the coming 5 year period, all suppliers are required to lift their fleet weighted average to reach at least the specified target level. While Top Runner is nominally not mandatory, penalties for non-compliance and public reporting of data means that very high levels of compliance are achieved.

Labels are generally seen as a market pull program measure (encouraging demand for and sales of higher efficiency products through disclosure of efficiency data) while MEPS are seen as a market push measure (by removing from the market lower efficiency products, leaving a more efficient pool of products from which consumers can select). Labelling measures tend to exert a gradual pull over longer periods, while MEPS can induce a series of steps in the historical energy or efficiency data. It should be noted that many products have both labelling and MEPS components, so separating these impacts can be difficult (and somewhat arbitrary, if attempted).

MEPS impacts are generally easier to estimate, depending on how aggressively and frequently changes are implemented. Many ex-ante estimates of energy savings have been found to be accurate through ex-post evaluation studies (usually underestimating actual impacts, if anything). This is because MEPS defines an efficiency benchmark that all products must reach, providing some certainty regarding the likely future program impact (assuming that there are adequate resources for monitoring and enforcement[9]). The other observation is that where MEPS levels result in a significant reduction in energy consumption over a shorter period (of say a few years), there is often a period of slower efficiency improvement (or even stagnation in efficiency) following the MEPS implementation. This often appears to be the case even where both MEPS and labelling operate together.

In contrast, it can be more challenging to estimate the likely future impact of labelling programs before they are introduced, 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 have generally been considered to be more robust and accurate at estimating energy savings achieved. But as noted above, many

[9] The issue of monitoring, verification and enforcement of regulations is an extremely important topic but this issue has not been explored in this report. Poor compliance can mean that expected savings may not be achieved.

labelling programs operate in conjunction with MEPS programs, so their effects can be difficult to disentangle.

2.7 Country and regional comparisons

Throughout this report, data is presented for a range of products across a range of countries. The objective of this type of analysis is to illustrate what has been achieved in the past and what could be achieved in the future in terms of energy impacts, emission reductions, economic benefits and other positive outcomes from S&L programs. Even within a single product type, the rate of historical or future rates of improvement will always differ by country and region due to a wide range of local circumstances. The authors have not investigated the underlying reasons for such differences and in no way are making value judgements about the different levels of achievements attained in each country. For example, countries that have new programs will naturally have lower historical impacts compared to countries that have long standing programs in place. Countries that are already highly efficient in terms of end use equipment installed will have less potential to improve efficiency further. Countries with low energy prices will lack some of the underlying economic drivers to achieve higher efficiency levels. Absolute energy consumption levels and level of economic development can also have a strong influence on past achievements and future potential. Many evaluations only examine the incremental impact of a new program and build all previous program impacts into the BAU case. Policy ambition is just one of many factors that influence apparent rates of change.

Another factor to consider when making country comparisons is that the rate of change can be strongly influenced by the way the data is framed (start and end year). While the authors have attempted to examine long term trends in data wherever possible, some reports only present data within windows of limited duration, so it is only possible to document and compare the data that is published. If the rate of change in energy or efficiency is examined just a few years each side of a significant MEPS change (for example), the rate of change will appear to be high. However, the same data may appear to be have quite a low rate of change if 10 years before and 10 years after are included and if there have been no further policy measures introduced in that period.

For the most part, comparisons are made at a product level, on the basis that this is the fairest "apples for apples" type of comparison. For example, a product like a refrigerator is fairly standard global type product and should, in theory, be broadly equivalent across countries. But there are quite different types of products on the market: frost free versus manual defrost, refrigerators with sub-compartments, small under counter products, large side by side and split/multi-door products, multi-compartment products. The most prevalent types and the market share of each will vary significantly by country as well as their sizes. So what is locally classified as a "refrigerator" in published data may in fact be quite different products in India, China, Japan, Australia, Europe and the USA, for example. The potential variation in product definition is also quite significant for air conditioners as well as some other products covered by this report.

Products will vary in their inherent efficiency levels. Refrigerators and air conditioners, for example, tend to have moderately high rates of efficiency achievement in the past (and into the future) because there is significant technical potential, even though they have been regulated in many countries for many years. In contrast, the efficiency levels for electric motors are already high and the technical potential for improvements is generally quite small (but still very valuable in terms of associated benefits). The technical potential percentage improvement for large motors is much smaller than for medium to small motors, but the energy savings are larger due to high power and long operating hours. In contrast, the inherent energy efficiency of small air conditioners is generally much higher than for larger air conditioners. So it is important to have some understanding of these factors when making comparisons. In some cases, reports and papers selectively publish data that is the most favourable or that shows that clearest impacts. The authors of this report have no control over what data is put into the public domain. But data that provides no information about past or future impacts is of low value and has generally been excluded from the analysis.

3 Achievements of S&L – energy and related impacts

3.1 High Level energy impacts

This section presents information on the stock level energy savings impacts attributable to S&L reported in the source studies analysed in the Document Analysis Database prepared for this study, in addition to a range of external sources that were not specifically included in the database.

Table 8 presents a summary of the total energy savings achieved from equipment energy efficiency standards and labelling programs at the whole economy level as reported in studies where this information is available. The reporting year for the energy savings (the evaluation target year) often differs from one economy to another (or sometimes even for the same economy) and only some of the sources provide estimates of the BAU consumption that would have been expected without the EE policy measures being implemented. When BAU energy consumption data is provided, the savings have been always expressed as a percentage of the BAU value in the evaluation target year for consistency. As the BAU data is not always available, in the case of electricity, the savings in the target year are also reported as a percentage of the whole economy's electricity consumption in 2018.

The highest economy-wide savings as a proportion of the national electricity consumption in the economies are reported for the EU and the USA. The projected EU electricity savings for 2020 are 14.9% of total EU electricity consumption in 2018 and 12.9% of the BAU consumption for 2020. The projected US electricity savings for 2020 are 15.5% of total US electricity consumption in 2018. Other economies report lower savings of between 0.3% and 5.9% of the national consumption in 2018 (noting these are for target years that can be even greater temporally distant from 2018 than 2020). There are many explanations for why this is the case:

- many of these economies have less extensive policy coverage (i.e. fewer product types are addressed by MEPS and labelling)
- the proportion of the entire national electricity consumption taken by the industrial sector (which has the least savings potential from MEPS and labelling) may be greater than is the case in the EU and US
- the policy measures may not have been in place as long as is the case in the EU and US (which are long established programs) and hence have not had as long to influence the consumption of the product stock
- some economies may have less ambitious policy settings compared to the case in the EU and US for a range of local reasons.

Nonetheless, the EU and US have attained average electricity savings of the order of ~15% of their total economy consumption and are projected to have a higher savings share in the future. Had the same relative level of savings been achieved at the global level in 2018, it would have avoided demand for approximately 3,560 TWh of electricity, which is almost equivalent to the amount of electricity that was generated from renewable energy sources in the same year.

Table 8: Summary of S&L energy savings at the whole economy level

Economy	Savings (TWh)	Target year	% of BAU in target year	BAU in target year (TWh)	% of 2018 consumption	2018 consumption (TWh)	Products included	No. products covered	Database source
EU (Electricity)	699	2030	20.0%	3501	24.1%	2900	All covered	43	2402.6
EU (Fuel use in buildings)	1210	2030	35.2%	3435			All covered	28	2402.6
EU (Electricity)	433	2020	12.9%	3364	14.9%	2900	All covered	43	2402.6
EU (Fuel use in buildings)	678	2020	19.1%	3541			All covered	28	2402.6
South Africa	5.5	2030			2.6%	210	All covered	9	REF129
USA (Electricity)	625	2020			15.5%	4033	All covered	73+	REF001
USA (Gas)		2020			5.0%	4878	All covered	27+	REF004
China	405	2020			4.9%	6833	Selection of covered	~22	2206, 2219
India	55.7	2019			4.4%	1277	All covered	27	2201
Brazil (Procel label only)	21.2	2018	4.0%		4.0%	529	All covered		2305
Mexico	16	2015	6.5%	247	5.9%	271	RF,RAC,WM,EM	4	2606
Malaysia	0.4475	2015			0.3%	147	All covered	4	2205.1
Japan						940		26	REF036
Korea						571.9		~45	REF245
Australia	16.998	2018			7.3%	234	All covered	~30	SPR 2019

Notes: a) The target year is the year for which the savings are reported. b) “All covered” in the products included column indicates that the values reported are the sum for all of the products subject to the MEPS and labelling program. c) The values reported for the number of products is only indicative e.g. the EU has 43 MEPS and labelling regulations applicable to 27 broad product groups, but the impact evaluation reports savings for the number of product sub-categories indicated in this column i.e. 238 distinct energy using product sub-types, d) Most historical and future data projections for the EU are based on EU-28, which includes the UK as the sources are historic and the UK was a member when the analysis was undertaken. Future data sets may show UK separately. e) The savings values reported for Brazil are only for the voluntary Procel energy label and do not include any additional impacts from MEPS or the mandatory energy labelling program, f) national US total electricity consumption data is taken from the US Energy Information Administration database. g) Korea means the Republic of Korea or South Korea throughout this report. h) SPR 2019 = (Strategy Policy Research 2019). i) Other 2018 electricity consumption data generally taken from IEA Key World Energy Statistics 2020 (International Energy Agency 2020).

Table 9 presents an illustration of estimated savings from the adoption of MEPS by specific product group – in this case it is for MEPS adopted in China.

Table 9: Estimated savings in energy consumption and CO_2 emissions in China from MEPS

	Electricity Savings (TWh)				CO2 Emissions Reductions (Mt CO2)			
	2010	2020	2030	Cumulative	2010	2020	2030	Cumulative
Room AC: Fixed Speed	0.1	0.3	0.0	4.0	0.1	0.3	0.0	4.1
Room AC: Variable Speed	0.0	3.2	6.3	64.4	0.0	3.2	6.0	63.8
TV	0.0	14.0	18.1	235.8	0.0	14.2	17.4	235.0
Clothes Washers: Front Load	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Clothes Washers: Top Load	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3
CFLs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Linear Fluorescent Lamps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Small Motors	0.0	16.5	31.6	333.4	0.0	16.7	30.3	330.9
Medium Motors	0.0	8.8	19.9	192.5	0.0	9.0	19.1	190.7
Large Motors	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
External Power Supplies	0.0	10.5	15.8	186.3	0.0	10.7	15.1	185.6
Microwave	0.1	0.7	1.0	13.0	0.1	0.7	1.0	13.0
Copier Printer and Fax Machine	0.0	8.0	14.5	155.3	0.0	8.2	13.9	154.0
Desktop Computer	0.0	5.8	6.4	98.2	0.0	5.9	6.2	98.5
Laptop Computer	0.0	1.5	2.1	27.5	0.0	1.6	2.0	27.5
Kitchen Rangehood	0.0	3.6	9.0	80.5	0.0	3.6	8.6	79.6
Heat pump water heaters	0.0	0.4	2.0	12.0	0.0	0.4	1.9	11.8
Set-top box	0.6	4.7	7.6	95.0	0.6	4.7	7.3	95.2
Distribution Transformers	0.6	1.0	0.8	18.9	0.6	1.1	0.7	19.1
Total	***1.3***	***78.9***	***135.1***	***1517.2***	***1.4***	***80.2***	***129.5***	***1509.2***

Table notes: LEDs were not evaluated for lighting. CFLs, linear fluorescents, front-load clothes washers and large motors had zero savings through 2030 because the baseline efficiency and revised/new MEPS efficiency were the same. In 2030, annual electricity savings from the one-time implementation of these MEPS would be equivalent to the output of 28 × 1GW typical coal-fired power plants and 1.3 times the annual generation output of the Three Gorges Dam. Source Study 2206, Table ES-1.

A separate study estimated the impact of MEPS and energy labelling in China over the first 10 years of the program (REF211, Study 2219). The estimates of MEPS were comparable to those shown in Table 9, but it found that MEPS only made up around 25% of total savings from S&L programs (meaning that labelling contributed three times the level of savings shown above). Projected savings from all S&L programs by 2020 (based on historical trends) were likely to be over 400 TWh. REF211 broke down savings for MEPS and labelling into four broad categories as shown in Figure 4.

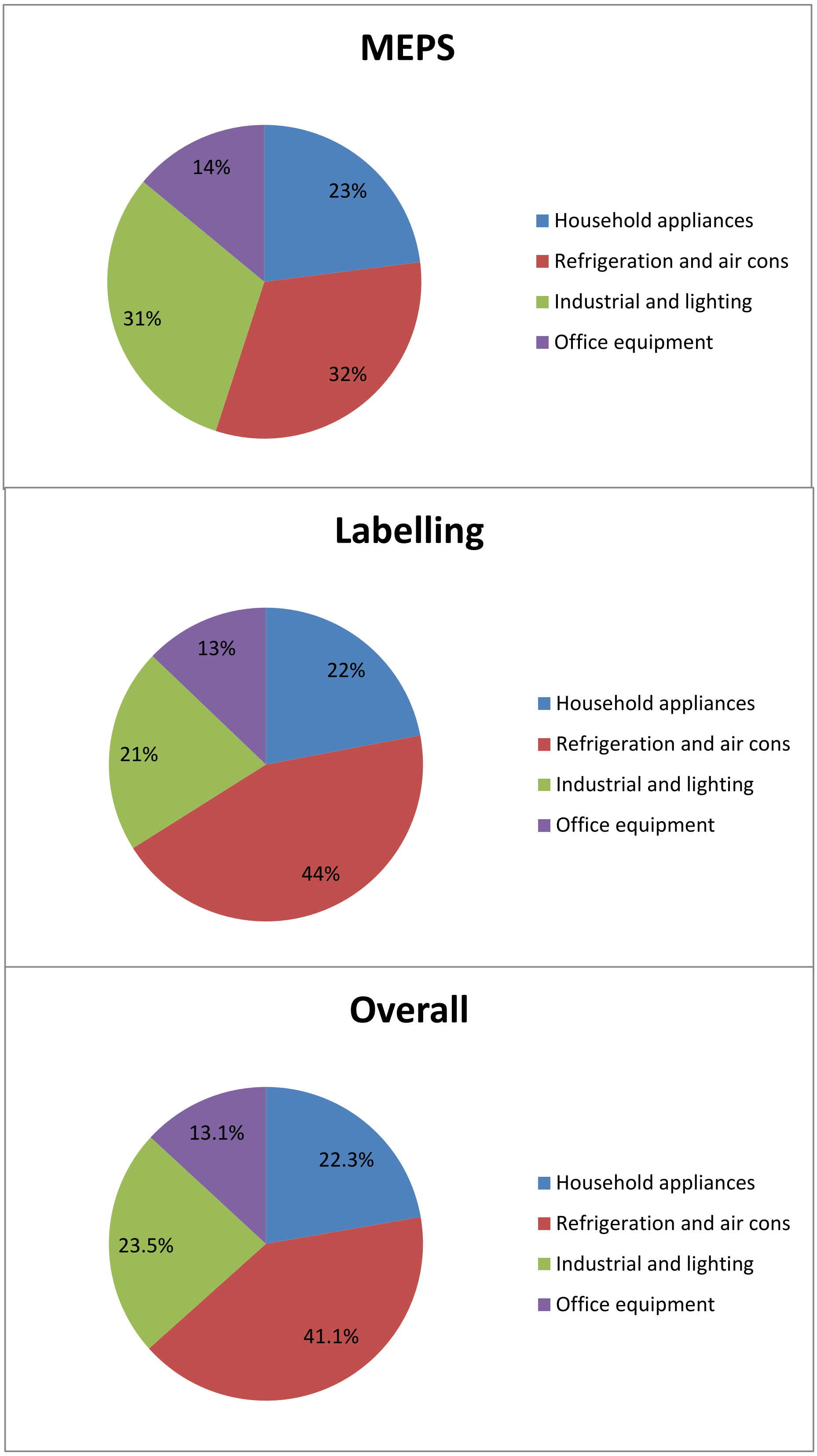

Figure 4: Estimates contribution of savings by sector for standards, labelling and overall in China

Figure notes: Source REF211, Study 2219, Figures 4-22 and 4-25 with author analysis.

A summary of the expected impact of the MEPS and labelling policies adopted in South Africa is shown in the text box below.

South Africa – projected annual savings from the MEPS and labelling program in 2030

- Savings of 5.5 TWh of electricity
- Savings of R12,000,000,000 in annual energy bills
- Reduction of 6 Mt of CO_2 emissions
- Savings of 8 billion litres of water
- Reduction of 3Mt tons of coal burned
- Reduction of 2,000 tons of particulate emissions
- Reduction of 50,000 tons of SO_x emissions
- Reduction of 24,000 tons of NO_x emissions

Source: https://www.savingenergy.org.za/asl/benefits/

MEPS and labelling can also produce substantial savings in fuel consumption, especially in space and water heating applications for buildings. The EU report that MEPS and labelling measures are on course to avoid 19.1% of BAU fuel consumption for these applications in 2020 rising to over 35% by 2030. US figures correspond to savings of 5% of the entire national natural gas end use consumption in 2018 (excluding electricity generation and chemical feedstocks).

Impacts of the Japan Top Runner Program are shown in Table 10. The expected improvement rate was the estimated impact before the announcement of the new energy target, while the actual improvement was the rate actually achieved. In all but three cases (orange cells) the actual achievement exceeded the expected improvement. Across all products the average expected improvement rate was 24%, while the average improvement rate actually achieved was 33.1%. The actual achievement rate across all products was 5.6% per annum.

Table 10: Impacts of the Japan Top Runner Program

Product	Start year	Target year	Expected improvement	Actual improvement	Actual/ expected	Actual rate per year
AC split ≤4kW	2005	2010	22.4%	16.3%	-27.2%	3.1%
AC split >4kW	2006	2010	17.8%	15.6%	-12.4%	3.7%
AC other types	2001	2012	13.6%	15.9%	16.9%	1.4%
Refrigerators	2005	2010	21.0%	43.0%	104.8%	7.4%
Freezers	2005	2010	12.7%	24.9%	96.1%	4.5%
Microwave ovens	2004	2008	8.5%	10.5%	23.5%	2.5%
Electric rice cookers	2003	2008	11.1%	16.7%	50.5%	3.1%
Fluorescent lamp ballasts	2006	2012	7.7%	14.5%	88.3%	2.3%
Self ballasted lamps	2006	2012	3.2%	6.6%	106.3%	1.1%
Electric toilet seats	2006	2012	9.7%	18.8%	93.8%	2.9%
TVs (LCD)	2008	2012	37.0%	60.6%	63.8%	12.6%
VCRs	1997	2003	58.7%	73.6%	25.4%	9.6%
Computers	2007	2011	77.9%	85.0%	9.1%	16.6%
External hard drives	2007	2011	75.8%	75.9%	0.1%	15.2%
Photocopiers	1997	2006	30.9%	72.5%	134.6%	6.2%
Space heaters (oil)	2000	2006	3.8%	5.3%	39.5%	0.9%
Gas cooking (ovens)	2002	2008	20.3%	25.8%	27.1%	3.9%
Gas water heaters	2002	2008	1.1%	7.9%	618.2%	1.3%
Oil water heaters	2000	2006	3.5%	4.0%	14.3%	0.7%
Vending machines	2005	2012	33.9%	48.8%	44.0%	5.8%
DVD recorders	2006	2010	20.5%	45.2%	120.5%	9.8%
Routers	2006	2010	16.3%	40.9%	150.9%	9.0%
Switches (network)	2006	2011	37.7%	53.8%	42.7%	9.0%
Distribution transformers	1999	2006	30.3%	13.1%	-56.8%	1.8%
Average			**24.0%**	**33.1%**	**38.2%**	**5.6%**

Table notes: Source REF036 (Study 2215) Section 2.4 plus author calculations. Data for Japan is based on fiscal years ending in March. Expected improvement was the estimated change before the target was announced. Actual improvement was achieved by the target date.

Figure 5 shows an example of the estimated primary energy consumption of all products under the business as usual case and under the currently adopted policies case for the EU. The energy consumption is shown for each principal end-use under the adopted policy case, but the higher aggregate for the BAU is also illustrated. The total primary energy savings are estimated to be 1,777 TWh in 2020, which amounts to some 15.3% of the BAU energy consumption due to these products and ~12% of the total EU energy consumption in 2010 (study 2402).

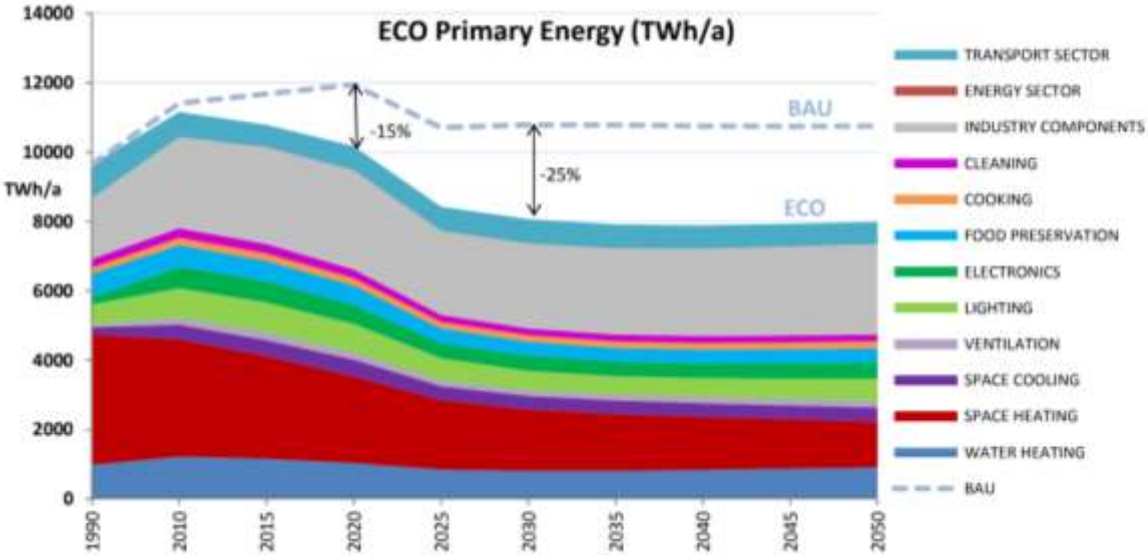

Figure 5: Primary energy consumption of products included in the Eco-design impact accounting 2019

Figure notes: source Study 2402. Data to 2020 has been updated based on a range of measurements and top down data.

The quantity of energy avoided by on-going energy efficiency activities in 11 IEA countries[10] 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 (Study 1004, REF248). As identified elsewhere in this report, energy efficiency programs for appliances and equipment have made a significant contribution to these achievements.

3.2 Emission reductions

While there are 48 entries in the database on CO_2 emissions savings[11], only four reported the reductions attributable to an economy’s entire S&L program. For the USA it is estimated that MEPS will save 343 Mt CO_2 in 2020, which amounts to 7.1% of the national energy-related emissions for 2019 (Study 2616). For Malaysia the S&L program is estimated to have saved emission of 1.73 Mt CO_2 in 2015, which equates to 0.7% of the country’s total emissions in the same year (Study 2205). For the Republic of South Africa the S&L program is projected to save emissions of 6.0 Mt CO_2 in 2030, which equates to 1.3% of the country’s total emissions in 2018 (Study 2101). Lastly, the EU the EcoDesign and energy labelling program is projected to save 311 Mt CO_2 in 2020, which is 10.7% of the EU’s total energy-related emissions for 2019 (2904 Mt) and 7% of the EU’s total CO_2 equivalent emissions from all sources for 2018 (4233 Mt CO_2). The savings equate to 15% of the BAU 2020 total emissions of the all the products subject to EcoDesign and labelling requirements

[10] Australia, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Sweden, the United Kingdom and the United States.

[11] Future emission savings depend on projections of emissions intensity for the specific energy source noted. The projected emissions intensity profile for each country has not been reviewed for this report. But there are often complex interactions between efficiency and renewables in terms of the future emissions intensity profile actually achieved.

(Study 2402). The emissions reductions due to current EcoDesign and labelling requirements are expected to attain 498 Mt CO_2 in 2030, which is a 26% reduction in product-related emissions and 12% of the EU 2018 total for all sources.

The breakdown of the EU's emission reductions by end-use sector due to S&L is shown in Table 11. From this it is clear that the residential sector accounts for the largest proportion of savings, followed by the tertiary/services sector then the industrial sector. Over time the share taken by the industrial and tertiary/services sectors is increasing which reflects that the oldest S&L measures occur in the residential sector and those applicable to the tertiary/services and industrial sectors are newer and hence have had less time to influence the whole stock. Labelling, in particular, is far more prevalent in residential appliances and equipment due to the nature of the purchase process.

Table 11: GHG emissions reductions attributed to the EU's Ecodesign and labelling programs by end-use sector

Sector	Emissions savings		Share of total emissions savings	
	Mt CO_2	Mt CO_2		
	2020	2030	2020	2030
Residential	181	261	59%	53%
Tertiary / Services	79	144	26%	29%
Industry	31	57	10%	12%
Other	7	12	2%	2%
Transport	10	18	3%	4%
Total	311	498	100%	100%

These breakdowns are quite similar to those observed in other economies with extensive and mature programs. For example, the USA appears to have approximately two-thirds of all savings from residential sector products and one sixth each for tertiary/commercial sector products and industrial products respectively.

3.3 Impacts on water consumption

Water consumption and sewage output can be considerably reduced through the use of devices that are not only energy efficient but also water efficient such, as low-flow showerheads or washing machines. All economies that have regulated the energy performance of water using products have reported corresponding reductions in both their energy use and their water consumption. This is because the most effective means of improving energy efficiency of such products is to reduce the amount of heated water they require to fulfil their function. This leads to a double benefit for the consumer as both their energy and water bills are reduced[12].

[12] While broadly reflected in water rates, reduced water consumption and sewage treatment results in lower energy requirements for water supply and waste treatment by water utilities.

The EU first introduced energy labelling for washing machines in 1996 and over the period to 2020 it is projected that labelling and EcoDesign measures have reduced the water consumption at an average rate of 3% per annum (study 2402). This is on top of a projected BAU reduction rate of 0.9% per annum over the same period. For dishwashers (first labelled in 1997) the average annual rate of reduction in water consumption up to 2020 due to labelling and EcoDesign measures is projected to be 3.9%, which is additional to an estimated BAU rate of reduction of 1.1% per annum (study 2402). Figure 6 shows how S&L policies in the EU are in the process of dramatically reducing the water consumed by washing machines (clothes washers) and dishwashers.

Similar figures are reported in other economies. In Australia, the annual average rate of reduction in water consumption for clothes washers is 3.0% and for dishwashers is 3.9% over a period of 22 years of energy labelling (Study 1041) - exactly the same as the values reported in the EU. The change in water consumption of new clothes washers and dishwashers in Australia over a period of 22 years is shown in Figure 7. These are simple trend values and hence are not directly attributed to the Australian labelling programs, which started in the 1980s.

In Canada, the annual average rate of reduction in water consumption for dishwashers from the start of S&L measures in 1990 to 2017 is 3.3% (Study 2611). Again, this is simple trend data, without direct attribution to the S&L policies, but as was the case in the EU, these policies are likely to have been the main driver of these savings.

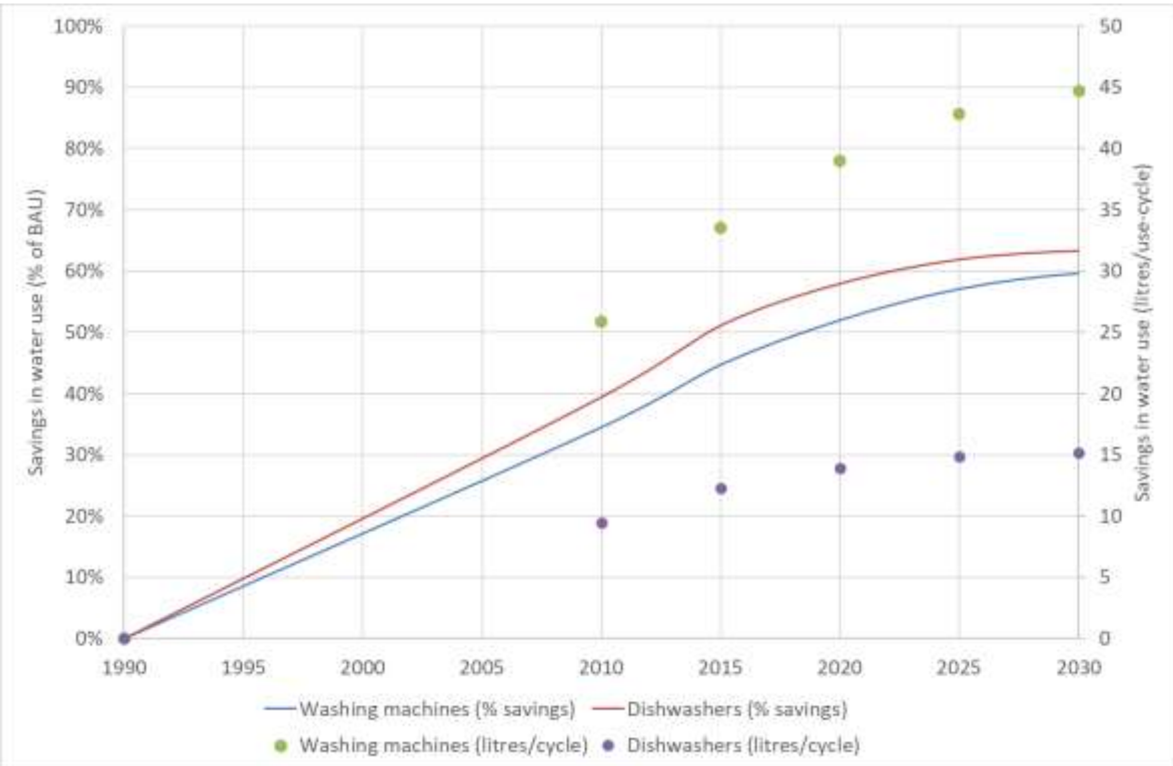

Figure 6: Projected savings in appliance water consumption due to S&L regulations in the EU

Figure notes: source Study 2402. Data to 2020 has been updated based on a range of measurements and top down data.

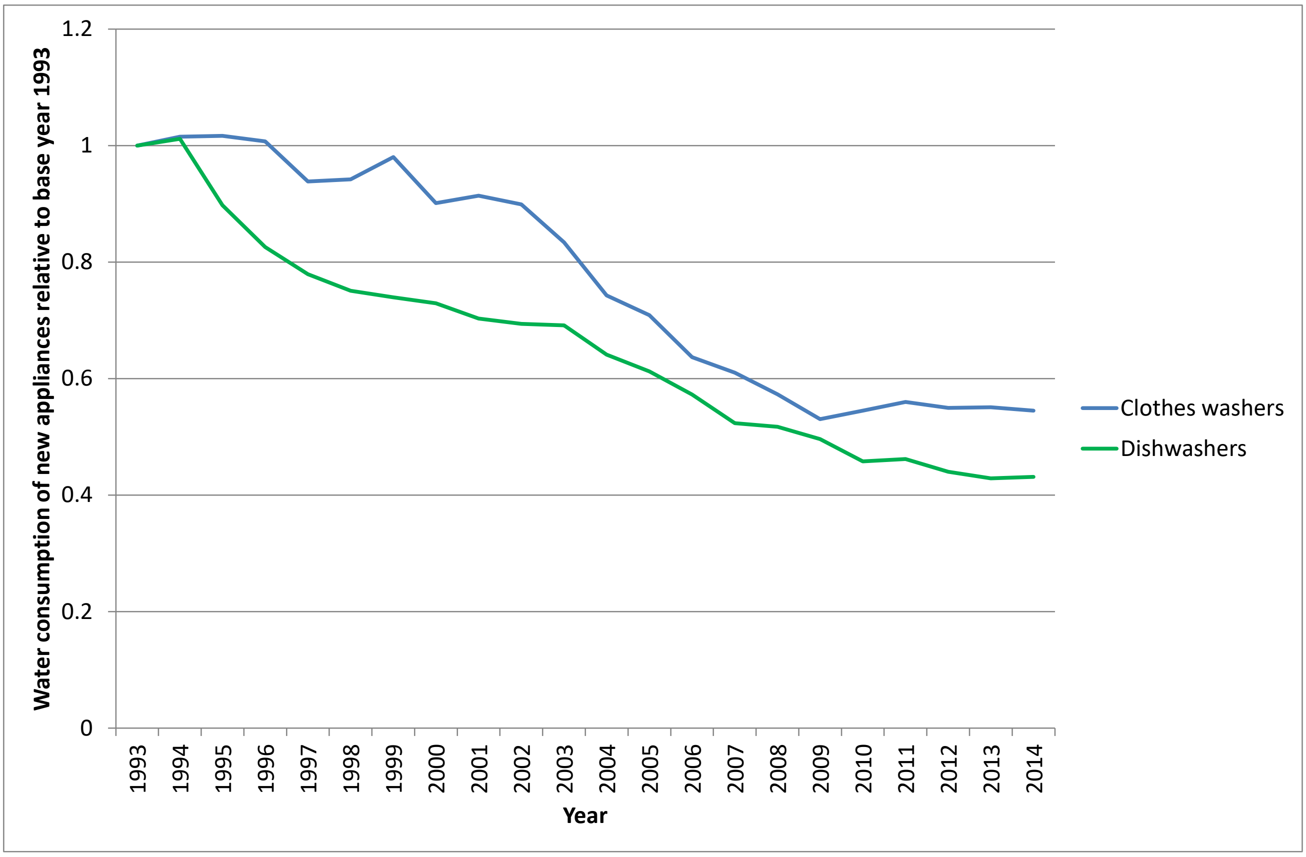

Figure 7: Changes in water consumption of new clothes washers and dishwashers in Australia

Figure notes: Dishwasher capacity remained constant while achieving a water consumption reduction of 57%, Clothes washers achieved a 47% water consumption reduction while capacity increased by 43% over the same period. These products were also subjected to water efficiency labelling from 2005 (AS/NZS 6400 2016). Data source Study 1041 starts in 1993, but energy labelling commenced in 1988 and 1990 respectively for these product types.

Table 12 reports aggregated water savings due to all S&L policy measures in the US and EU. The savings are significantly greater in the US, but this is likely mostly due to showerhead flow rates being regulated in the US (and not in the EU) and also to both the larger average capacity of appliances and a switch from vertical axis to horizontal axis clothes washers in the US over this period. The EU data also includes the value of water savings, which amount to €8.1bn in 2020, which is greater than the corresponding value of the energy savings for these products of €5.3bn (Study 2402).

Table 12: Projected water savings attributed to S&L programs in the US and EU

US water savings in 2020 due to MEPS		
	Gallons (bn)	Litres (bn)
Residential sector	1463	6143
Commercial sector	107	448
Industrial sector	0	0
Total	1569	6591
EU water savings in 2020 due to Ecodesign and labelling policy measures		
	Litres (bn)	Saved cost (€bn)
Dishwashers	354	1.6
Clothes washers	1457	6.5
Total	1811	8.1

Table notes: source Studies 2402, 2609.

3.4 Impacts on peak loads, utilities and large energy users

For many economies, the impact of S&L on peak power demand is a key motivation behind the adoption and nature of the policies adopted. Peak demand is the main driver of costs for transmission and distribution utilities and some electricity supply systems use high emission and the least economically efficient power plants on the margins to supply peaks. Peak load reduction[13] is also an important tool manage grid loads and avoid blackouts. However, the database only contains one study which reports the impact of this parameter[14]. Study (2601) for Mexico reports that peak power demand from the countries S&L policies was reduced by 1.1 GW in 2014.

The value of energy efficiency to utilities depends to a large extent upon the regulatory environment and cost structure. Analysis in South Australia showed that the utility value of peak load reductions was AU$675/kVA when coincident with the system or regional distribution peak (Energy Efficient Strategies 2020). 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 13.

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[13] Peak loads are naturally reduced through the installation of more efficient end use equipment. For a constant load shape, peak load reductions will be in proportion to energy reductions. There are also more active approaches to dynamically manage peak loads when they occur. These so called "demand response" measures can be activated if and when required to manage peak loads, but these are not (usually) part of S&L programs. In many cases demand response measures (especially associated with load shifting) can result in increased energy consumption. Electrical storage also increases overall electricity consumption but demand response and storage can optimise the use of the transmission and distribution network and utilisation of variable renewable energy sources.

[14] The reason for this is unclear. Peak demand issues tend to examined by electricity transmission and distribution companies and often these issues are examined in isolation from energy issues, so were rarely mentioned in the reports covered for this study. While potentially relevant, most S&L reports don't document peak load impacts.

Table 13: Utility-specific multiple benefits of energy efficiency programs

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 effects (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 (MWh)

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

Table notes: Source, Table 6 from Study 1019.

The following benefits from improved energy efficiency that accrue to commercial and industrial end users 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 (Study 1019). Direct cost reductions from reduced energy purchases are examined in more details in Section 4.

3.5 Product level data

This section documents much of the evidence collected and analysed at a product level for this report. Specific data was collected from over 110 studies and data extracted from these reports generated a database with 920 separate entries at a product, country and attribute level. The main focus is on energy, efficiency and emission impacts for the key products of interest (domestic cold, air conditioning, electric motors and lighting). A further section then goes on to examine key data for a range of other product types where S&L programs are prevalent.

3.5.1 Domestic cold

3.5.1.1 Overview

Household refrigeration products (generally grouped under the heading *domestic cold* for this project) are one of the most widely regulated products for energy efficiency, predominantly using standards and labelling programs of various types. A global review in 2013 found that more than 75 countries had standards and labelling programs for domestic cold products, made up of some 280 separate program measures (Energy Efficient Strategies & Maia Consulting 2014), making this product the most widely regulated globally. It is believed that around 100 countries now have labelling and standards programs for domestic cold appliances (CLASP 2021).

The database compiled for this study has around 150 separate records documenting key performance parameters for household cold appliances. As with some other products, domestic cold appliances are typically subjected to both comparative energy labelling and MEPS, often with endorsement labelling as well. Many of these programs can overlap in terms of their impact, so disaggregating the data into specific program impacts can be difficult. Domestic cold appliances were also one of the first product groups to be regulated under S&L programs, with the first national mandatory programs being in Canada (1978), USA (1980) and Australia (1986) (Harrington & Wilkenfeld 1997). Europe had various S&L programs in a few countries prior to 1990 but these were local and not very long lived. It was not until 1995 that EU-wide mandatory labels were introduced for domestic cold and other appliances.

One of the most important parameters with respect to any product subject to S&L programs is the so-called autonomous rate of energy efficiency improvement. Two studies examined early data on efficiency rates from the 1970s to the 1990s and established that, in the absence of energy labelling or other S&L measures, the autonomous efficiency rates for domestic cold were in the range 0.6% to 1.2% (Weiss et al. 2010; Harrington & Lane 2010). This is also supported by early data from the US prior to their first MEPS levels in 1990 (McMahon 2011). One reason why the autonomous efficiency improvement rate is slow for domestic cold appliances (despite the large efficiency potential) is that consumers cannot make any judgement on the likely energy consumption of an appliance by visual inspection alone, or any other markings. Energy measurement is complex and expensive and suppliers tend to provide no standardised information, except where they are obliged to do so.

One of the most famous figures for refrigerator energy consumption over time, and showing the implied impact of S&L programs, is shown in Figure 8. While this figure does not attempt to formally attribute the impact to each of the policy measures shown, there is clearly a connection between more stringent MEPS levels and a reduction in energy consumption. This style of chart has been replicated in many countries around the world.

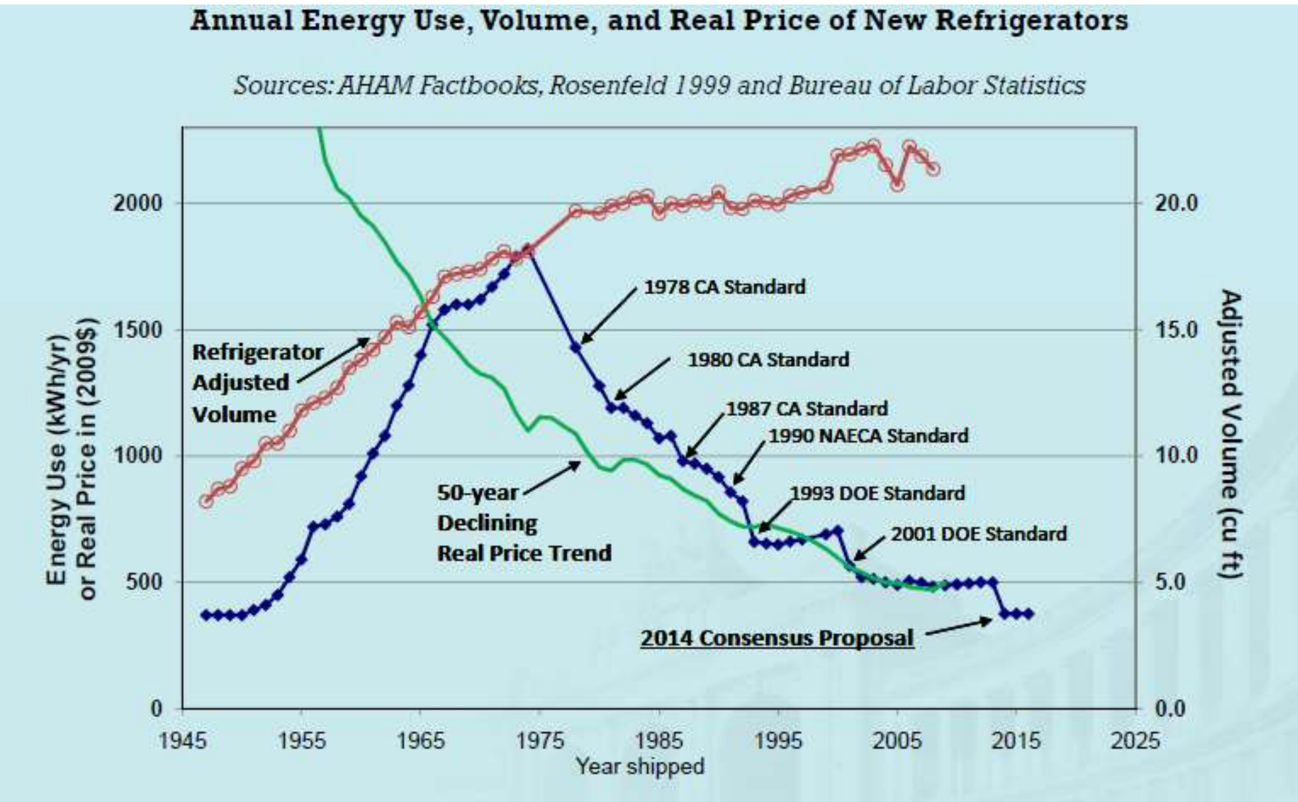

Figure 8: Long term trends in energy, price and size of US household refrigerators

Figure notes: Sourced from McMahon (2011).

Similar data is shown for Australia in Figure 9 for refrigerators. While this represents a 48% reduction in energy over a period of 24 years, the average rate of energy reduction is only 1.65%. Note that product sizes have been increasing over the same period (at around 1.5% per annum), so the rate of efficiency improvement is higher at around 3% (Energy Efficient Strategies 2016). In this case, some of the energy saving from improved efficiency are being taken up as increased energy service.

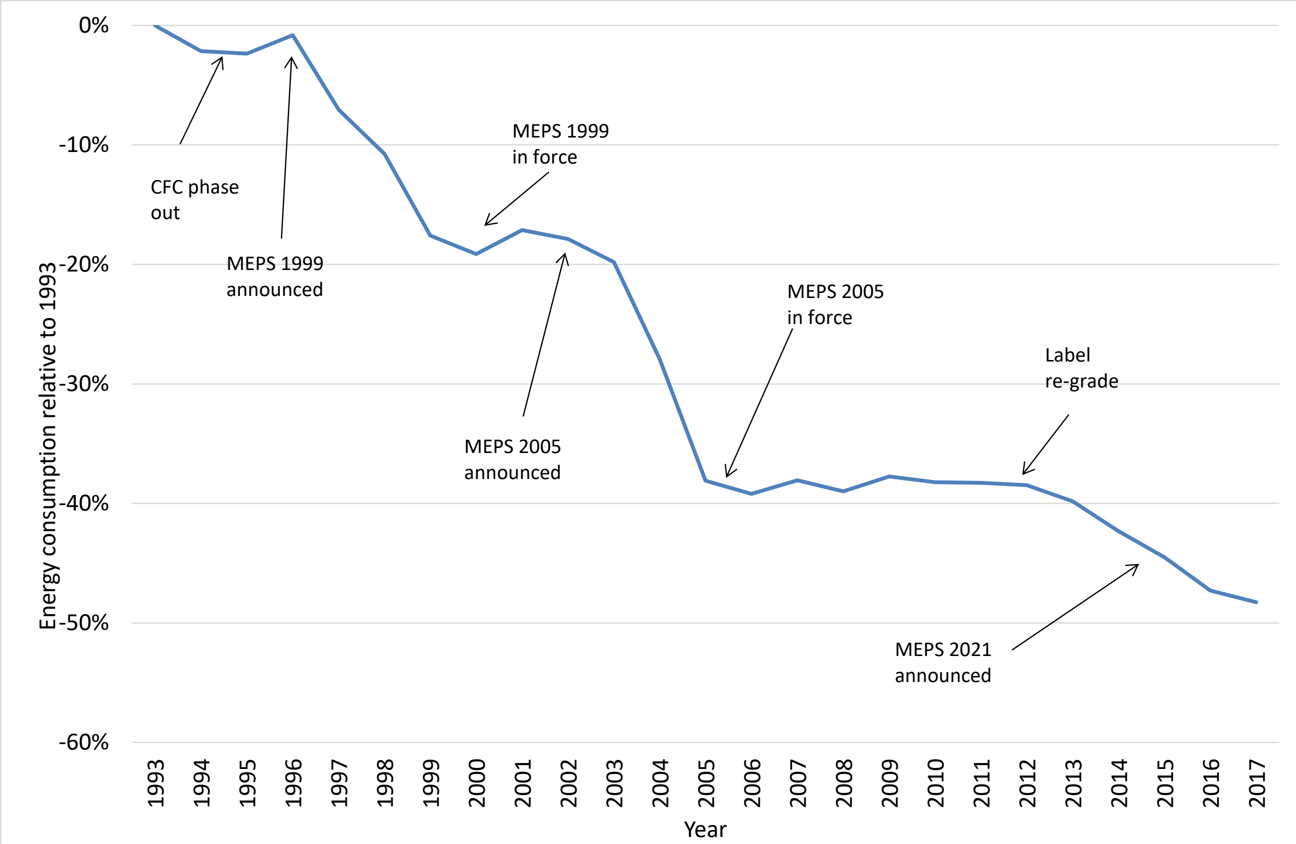

Figure 9: Sales weighted average energy consumption of refrigerators in Australia from 1993 to 2017

Source: (E3 2017).

With so many possible interactions between different program elements, it can be difficult to attribute change to specific program measures. Figure 10 shows the reduction in energy consumption on a yearly basis over a period of 24 years for refrigerators and freezers in Australia. The impacts of the program elements shown in Figure 9 can be clearly seen. In the lead up to regulatory changes, the improvement rate can increase to as much as 6% per annum for a moderate regulatory change and could be more than 20% per annum (for a short period) for a stringent regulatory change. After stringent MEPS, the rate of improvement may decline to low levels for some years (stagnation period), until the next program element comes into force. Note the increase in energy in Figure 8 after the implementation of the DOE 1993 standard (due to increases in average product size with no further efficiency improvement).

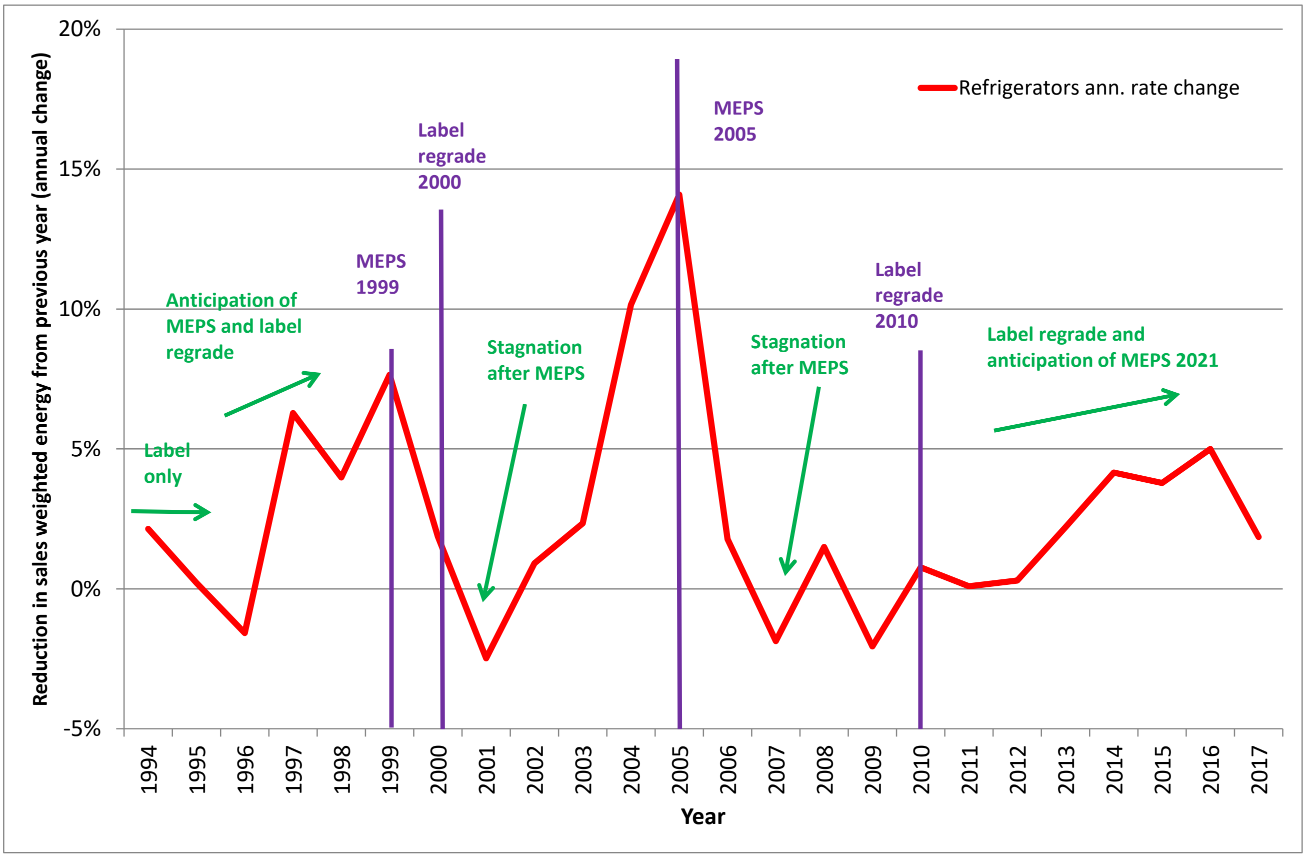

Figure 10: Changes in annual reduction in energy consumption for new refrigerators in Australia from 1994 to 2017

Source: Author analysis of data from (Energy Efficient Strategies 2016). The changes in energy consumption for new refrigerators in Figure 9 are reflected in the year to year changes shown in this figure (steep energy falls equate to higher annual energy reductions). All values are sales weighted for all refrigerator and refrigerator-freezer types.

3.5.1.2 Domestic cold – outline of the data

The quantitative data collected in present study covered 25 countries: Argentina, Australia, Canada, Chile, China, Cook Islands, Denmark, European Union, Fiji, India, Japan, Kenya, Kiribati, Korea[15], Malaysia, Mexico, Netherlands, New Zealand, Samoa, South Africa, Sweden, Switzerland, Tonga, USA and Vanuatu. Data was extracted from 34 separate technical reports and resulted in 146 quantitative records. Data was collected on energy reductions (and related measures), emission impacts, efficiency improvements, product purchase cost trends and benefit cost ratios. As this was one of the first products ever regulated for energy efficiency, and is the most widely regulated for S&L programs globally, it generated one of the largest datasets. Many of these datasets span very long periods.

[15] "Korea" means the Republic of Korea or South Korea throughout this report.

3.5.1.3 Domestic cold – energy and related impacts

The average rate of overall energy reduction per year for new products entering the market is typically in the range 1% to 3% per annum, depending on the country, the number of program elements applied during the period and their stringency[16]. A small sample of data is shown in Figure 11. It is important to note that these long-term trends often cover periods with no S&L programs or only minimum requirements, as well as periods where programs have been upgraded. So these rates tend to understate the impact of S&L programs on energy consumption and energy efficiency.

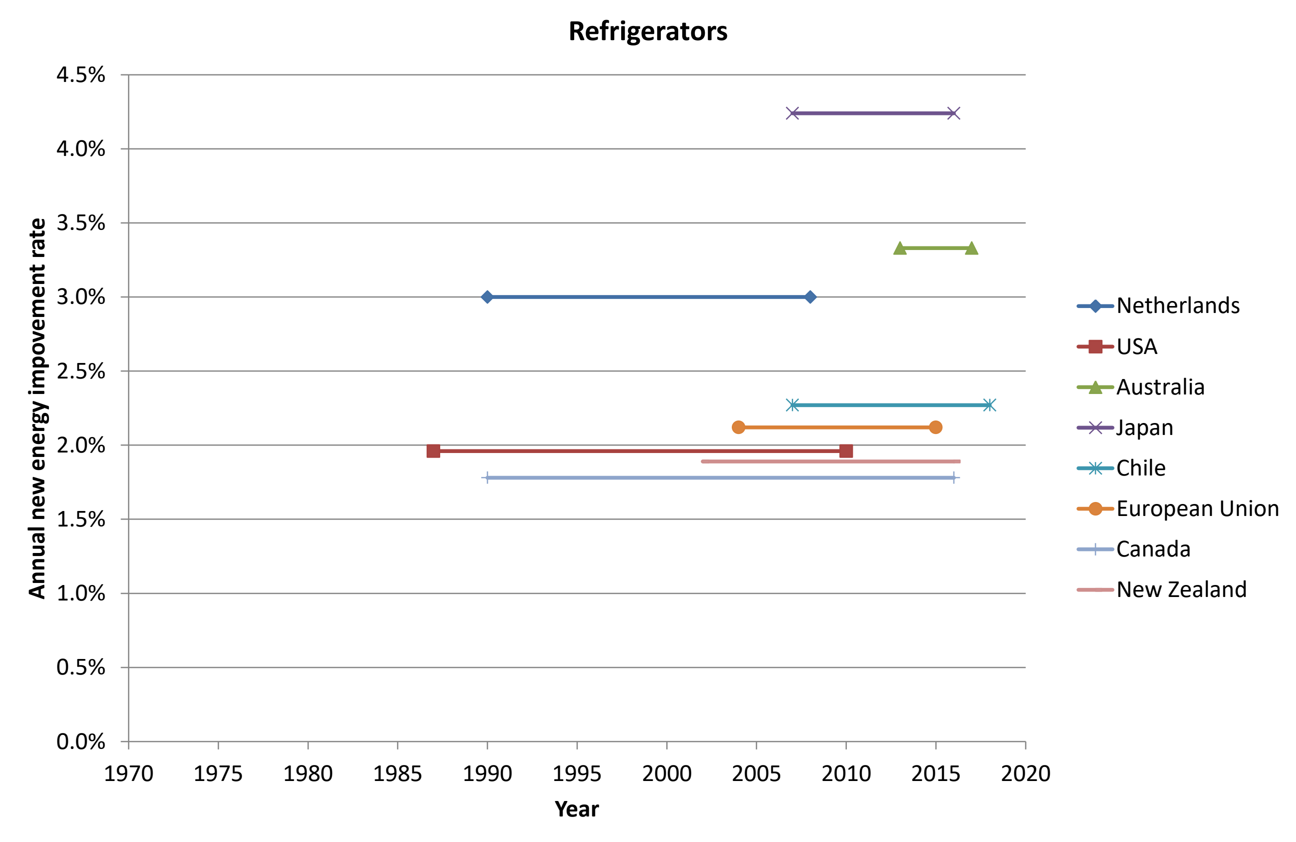

Figure 11: Selection of long term historical energy reductions for new domestic cold products

Figure notes: Sources from Studies 18, 80, 2207, 2208, 2303, 2611, 2701. A full list of references and database studies is included in Section 8. The rate for Japan is through the Top Runner target period from 2007 to 2017 and is based on fiscal years ending in March.

A range of studies have also published future energy savings from new and upgraded S&L programs. A selection of these ex ante projections are illustrated in Figure 12. There are several important points to note regarding these ex ante projections. The annual rates appear to be lower, but these are stock energy changes, and so would generally be expected to be much smaller than the average new rate. The second important point is that these changes are typically incremental to

[16] With all country comparisons presented in this report, there are a wide range of factors that can influence the apparent rates of change. These are set out in Section 2.7.

the BAU case – they represent **increases** in energy efficiency projected from specific program measures in addition to any existing measures. Stock energy changes also take into account increased numbers of products in use, so this can make the apparent rate of savings appear smaller where households, population and/or ownership are growing. Stock energy changes also include the impacts of changes in product sizes as well. For cold products, there is a general tendency towards increased product sizes, which tends to increase the unit energy consumption. The rate of impact will also depend on the relative stringency of the program measure and how quickly this can be implemented as well as the projection horizon.

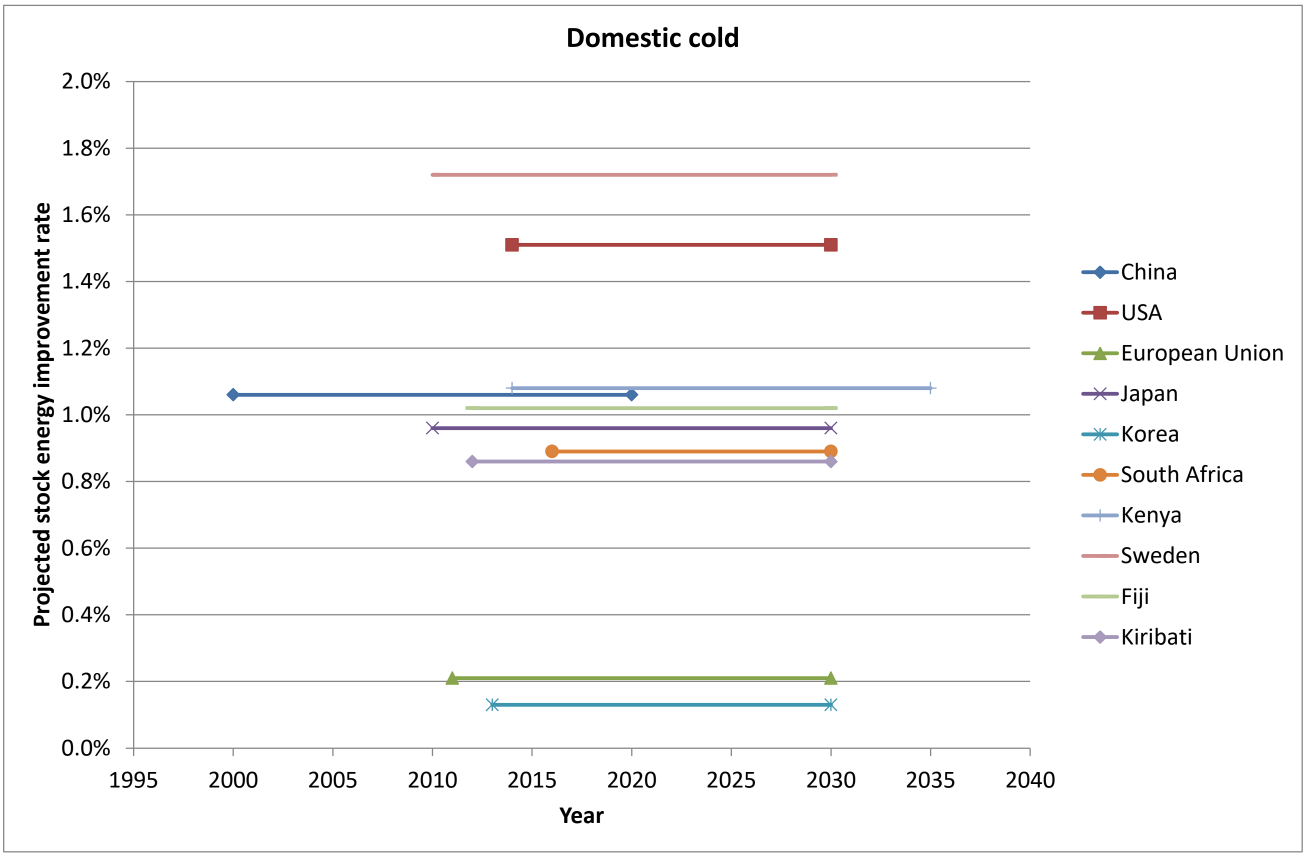

Figure 12: Projected stock energy improvement rates from S&L domestic cold programs in selected countries

Figure notes: Sources from Studies 108, 2001, 2102, 2407, 2707. A full list of references and database studies is included in Section 8.

Analysis of all the data extracted from reports for this study yielded the following results for domestic cold products as shown in Table 14 and Table 15.

Table 14: Average rates of energy improvement for new domestic cold – historical and trend

Records	49
New min rate per annum	-0.20%
New average rate per annum	2.33%
New max rate per annum	8.17%

Table notes: Negative value was for the US for freezers from 2001 to 2010 from Study 2602. Includes various refrigerator and freezer configurations.

Table 15: Projected average rates of energy improvement for the stock of domestic cold from new S&L measures – ex ante

Records	50
Stock min rate per annum	0.13%
Stock average rate per annum	1.00%
Stock max rate per annum	1.94%

3.5.1.4 Domestic cold – efficiency impacts

Domestic cold products are typically subjected to both energy labelling and some form of efficiency standards (MEPS) in most countries. Many energy labelling schemes use a categorical approach, where the overall product efficiency (typically based on a function of kWh/litre of cooled volume), can be conveyed to consumers through a simple rating system like letters (Europe, South America, South Africa), numbers (much of Asia) or stars (Australia, New Zealand, Japan and India). When the sales share of these are tracked, the improvement in energy efficiency is obvious over time. Between 2004-2014, the average sales weighted efficiency of new refrigerators in the EU improved by 3.4% per annum, as indicated by the market share of labelled products[17] shown in Figure 13. This resulted in a 25% reduction in energy consumption over this period.

[17] Quite a few studies published data on the share of label efficiency grades over time. While these are visually interesting and qualitatively show improvement trends, these are generally very difficult to convert into quantified improvements in energy or efficiency per annum due to the widely varying break points for each efficiency level in each country and even for each product.

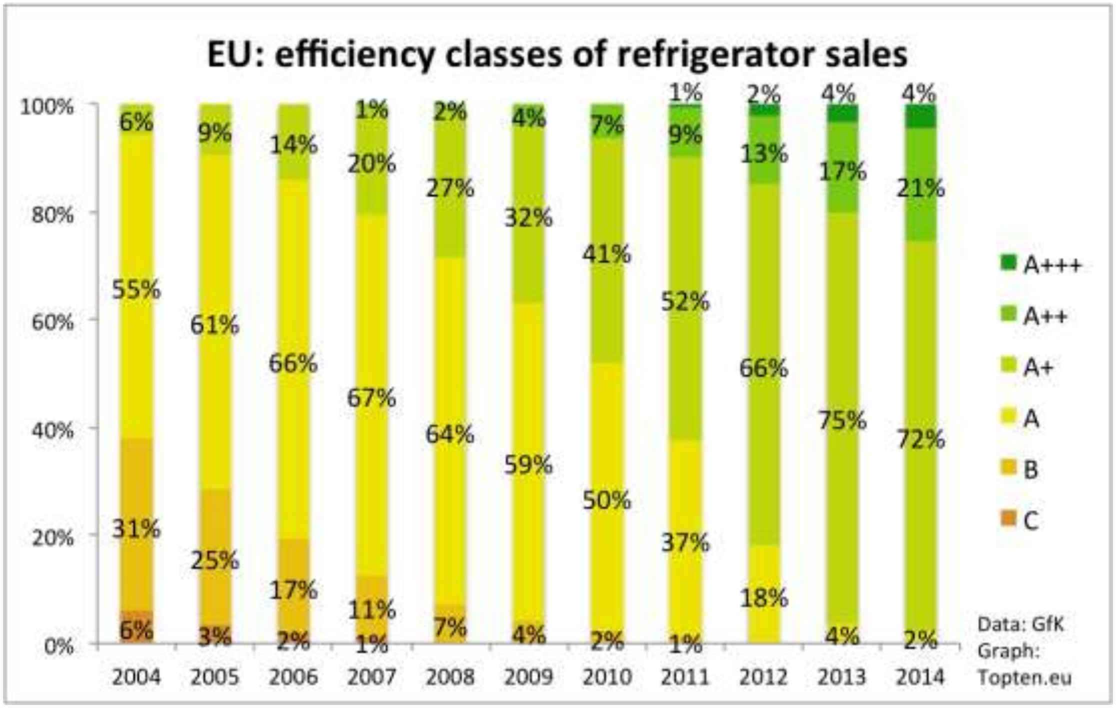

Figure 13: Efficiency class distribution of new refrigerators sold in the EU-28 from 2004 to 2014

Source: Study 109 (Michel et al. 2015).

Similar trends in progression of efficiency grades over time are shown in the following figures for Argentina, Australia and Japan.

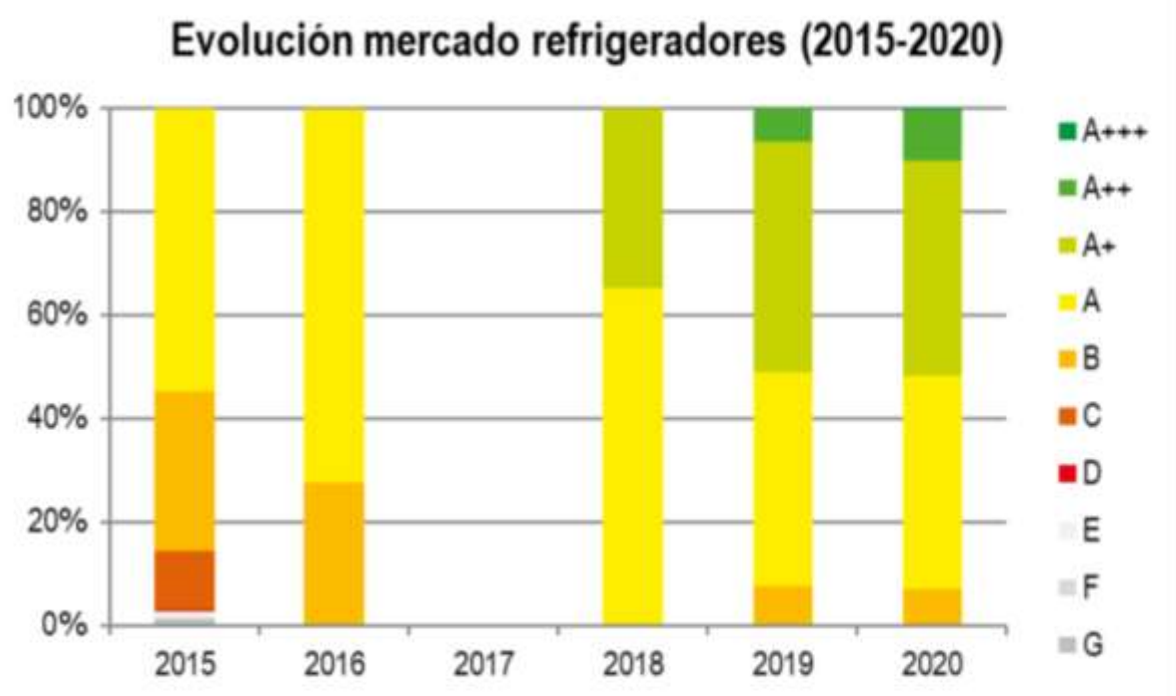

Figure 14: Efficiency class distribution of new refrigerators sold in Argentina

Source: REF177, Study 2301

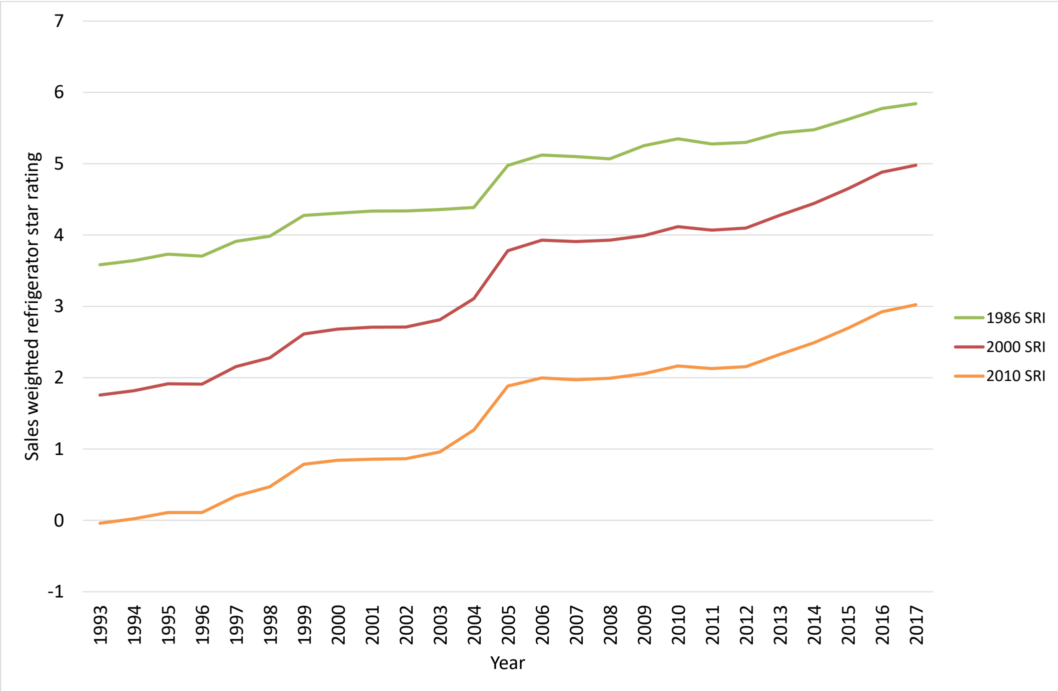

Figure 15: New refrigerator star rating by year in Australia, three grading systems

Figure notes: Source (E3 2017). Star Rating Index (SRI) is the decimal star rating shown on the Australia and NZ energy rating label. Each increase in SRI in this figure reflects a period of steeper energy reduction as shown in Figure 9.

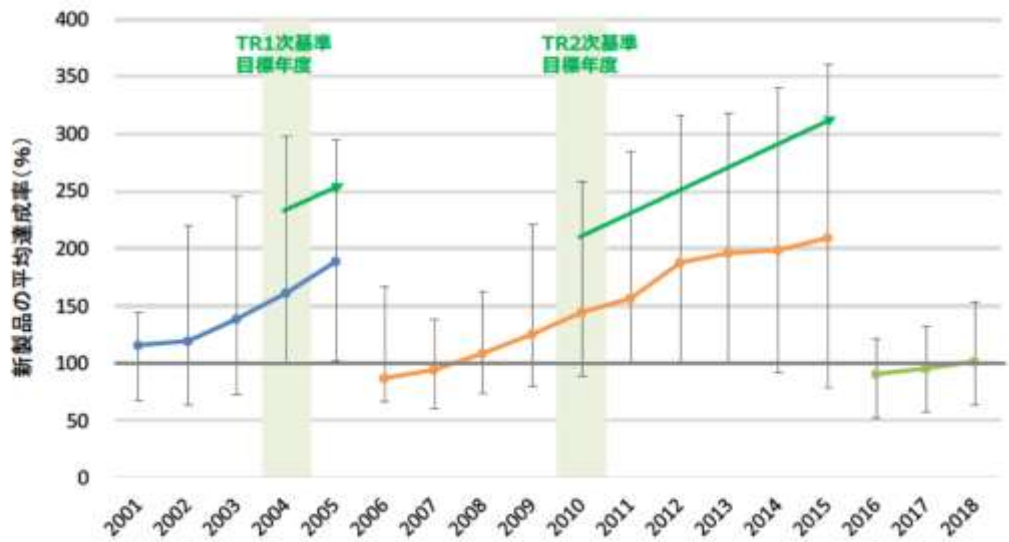

Figure 16: Average standard value achievement rate of new refrigerators each year in Japan

Figure notes: Source Study 2212 Figure 5. Top Runner target 1 in 2004 (olive shading) with blue line average and Top Runner target 2 in 2010 (olive shading) with orange line average (base index 100 is reset in each case). The solid olive line from 2016 is market data for the new target set for 2020. Y axis is the Top Runner achievement rate, 100 means that the average product has achieved the specified efficiency target. Sales weighted average values shown with error bars indicating highest and lowest performance products each year. Target efficiency level is regraded for each new target. The light green arrows above the 2004 and 2010 targets indicate that product efficiency continues to improve markedly even after all suppliers have achieved the Top Runner target.

In Japan, several product types (including refrigerators) are graded against forthcoming Top Runner target efficiency levels using the unified energy consumption label. Star levels are adjusted from time to time to reflect the distribution of products offered on the market, so the break points differ by product and over time. Products that exceed the current Top Runner level have a white "e" on a green circle in the lower half of the label as shown on the unified energy label example in Figure 17.

Figure 17: Unified energy efficiency/conservation label for Japan

Figure notes: Sample labels for air conditioner (left) and refrigerators (right). The label shows information on energy/efficiency and energy costs. The panel under the stars for air conditioners indicates that products that exceed the Top Runner target earn 2 or more stars, while for refrigerators, only 5 star products currently exceed the new Top Runner target. This label is used for used for air conditioners (household), televisions, electric refrigerators and freezers, electric toilet seats and fluorescent lighting (household). Data for each product type can be found at:

https://www.enecho.meti.go.jp/category/saving_and_new/saving/general/replacement/enelabel/

As the size of domestic cold products are increasing in many countries, a number of studies tracked the changes in energy efficiency[18] over time, as illustrated in Table 16. The rate of energy efficiency improvement is somewhat faster than the rate of energy reduction, with some of this efficiency being taken as increased energy service (e.g. larger or more feature rich products) and some taken as reduced energy consumption.

[18] Each country has its own metrics for defining efficiency. For domestic cold products, this is typically defined as L/kWh (or as an intensity = 1/efficiency or kWh/L or per adjusted litre, or a similar variation). This simple metric tends to have a strong size bias, which makes larger products look more "efficient" than smaller products with the same technical performance. Some countries have developed size neutral efficiency metrics. But it is beyond the scope of this study to explore the approach in each country. In practical terms, size, energy consumption and efficiency are all inter-related, especially for small changes in size over time.

Table 16: Average rates of efficiency improvement for new domestic cold – historical and trend

Records	21
New min rate per annum	0.41%
New average rate per annum	3.84%
New max rate per annum	15.13%

As the population and number of households is increasing, along with increases in ownership in many countries, overall efficiency changes are not able to fully offset overall increases in energy consumption (McNeil, Letschert & de la Rue du Can 2008).

3.5.1.5 Domestic cold – emission impacts

Only two domestic cold appliance studies in the database examined emission impacts. One was an historical assessment for the European Union from 1995 to 2020, which found all programs (labelling and EcoDesign) had resulted in emission reductions of 0.8% to 1.5% per annum on overall stock emissions over this period (Study 2404). The other study estimated future emission impacts to 2030 from new efficiency standards being introduced in Australia and New Zealand in 2021, which found cumulative emission impacts of around 0.3% per annum for Australia and less than 0.1% per annum for New Zealand. On an equivalent stock basis these are about 0.6% per annum and 0.2% per annum respectively from 2014 to 2030, noting that these are additional impacts on top of the existing S&L programs already in place. Needless to say, in most cases emission impacts will be in line with energy impacts after any changes in emission intensity are factored into the calculations.

3.5.2 Air conditioners

3.5.2.1 Overview

Air conditioners are now widely used in the residential and commercial sectors and many types of S&L programs cover both sectors. Similar to domestic cold, air conditioners are also very widely regulated products for energy efficiency. A global review in 2013 found that more than 70 countries had standards and labelling programs for air conditioners, made up of some 250 separate program measures (Energy Efficient Strategies & Maia Consulting 2014). It is believed that more than 90 countries now have labelling and standards programs for air conditioners (CLASP 2021).

The database compiled for this study has around 137 separate records documenting key performance parameters for air conditioners. As with some other products, air conditioners are typically subjected to both comparative energy labelling and MEPS, often with endorsement labelling as well. Many of these programs can overlap in terms of their impact, so disaggregating the data into specific program impacts can be difficult.

One of the most important parameters with respect to any product subjected to S&L programs is the so called autonomous rate of energy efficiency improvement. Given the air conditioners are a globally traded commodity and that a large number of countries have S&L programs for air conditioners, it is somewhat hypothetical to attempt to estimate such a rate for this product in the current global market. Air conditioners have traditionally displayed their rated output capacity and their rated electrical input, meaning that there has been at least some basis for selecting and comparing products, even without comparative labelling programs.

3.5.2.2 Air conditioners – outline of the data

The quantitative data collected for the present study covered 20 countries: Argentina, Australia, Canada, China, Cook Islands, Denmark, European Union, Fiji, India, Japan, Kenya, Kiribati, Korea, Malaysia, Mexico, Samoa, South Africa, Tonga, USA, Vanuatu. Data was extracted from 29 separate technical reports and resulted in 137 quantitative records. Data was collected on energy reductions (and related measures), emission impacts, efficiency improvements, product purchase cost trends and benefit cost ratios. As this was one of the early products to be regulated for energy efficiency and is also widely regulated for S&L programs globally, it also generated one of the largest datasets. Many of the data entries span very long periods.

3.5.2.3 Air conditioner – energy and related impacts

Because one of the key parameters for air conditioners is efficiency, either the energy efficiency ratio (EER) for cooling or the coefficient of performance (COP) for heating[19], much of the focus on air conditioners is efficiency rather than energy. While it does appear that the average capacity installed may be increasing in some countries, this is not a parameter that is often tracked.

Only five studies from four countries (Japan, China, Malaysia, USA) tracked and published the energy consumption of new air conditioners over time. These found that energy consumption was decreasing at 2.2% per year on average (range from 1.1% to 3.5%).

Most energy related studies for air conditioners are ex ante stock projections to assess the impact of future S&L measures. The vast majority related to smaller room air conditioners, mostly split systems, but occasionally other types. A summary of the future stock projections for energy are summarised in Table 17.

Table 17: Projected average rates of energy improvement for the stock of air conditioners from new S&L measures – ex ante

Records	61
Stock min rate per annum	0.04%
Stock average rate per annum	0.64%
Stock max rate per annum	2.05%

[19] Air conditioners used for heating are called reverse cycle systems or heat pumps, depending on the region.

The study with the highest rate was in fact a global study that examined the potential impact of super high efficiency standards for air conditioners, at so called Best Available Technology (BAT) levels, with a minimum EER/COP of BAT1 of 5.4 W/W EER from 2025, with an additional step of BAT2 with a minimum EER/COP of BAT2 of 6.9 W/W EER from 2030. While somewhat speculative and hypothetical (and this is only one of a couple of such studies included in the analysis), this case study was useful as it showed that BAU global air conditioner energy consumption in 2050 (4,450 TWh) could be reduced under a BAT1 scenario by some 59.6% and under a BAT1/BAT2 scenario by some 83.8% (Phadke et al. 2020). This is equivalent to a reduction from 2020 global energy consumption of 10% by 2050 for BAT1 and a reduction from 2020 of 52% for BAT1/BAT2, showing that far reaching and ambitious MEPS policies can have substantial long term impacts (Study 2002).

3.5.2.4 Air conditioners – efficiency impacts

Historically, the energy, power input and efficiency of air conditioners were only measured at their rated capacity. This was perfectly sensible as almost all units had single speed compressors. One aspect of air conditioner efficiency metrics that is changing is the way that air conditioners are rated. Because so many air conditioners now have inverter driven compressors, many countries and regions now use a seasonal energy performance to assess their efficiency. This includes periods of part load and full load, as well as different operating temperatures. This type of metric, known as seasonal performance factors (also called SEER and SCOP or Annual Performance Factors APF), are now used to rate and compare many types of air conditioners (e.g. USA, Europe, Japan, Korea and Australia).

Air conditioners are often subjected to both energy labelling and some form of MEPS in most countries, especially for smaller products used in the residential sector. A good example that illustrates the impact of new standards on efficiency of air conditioners comes from Japan as illustrated in Figure 18. While the impact is visible in the figure, no studies that formally quantified this through an ex post evaluation could be found.

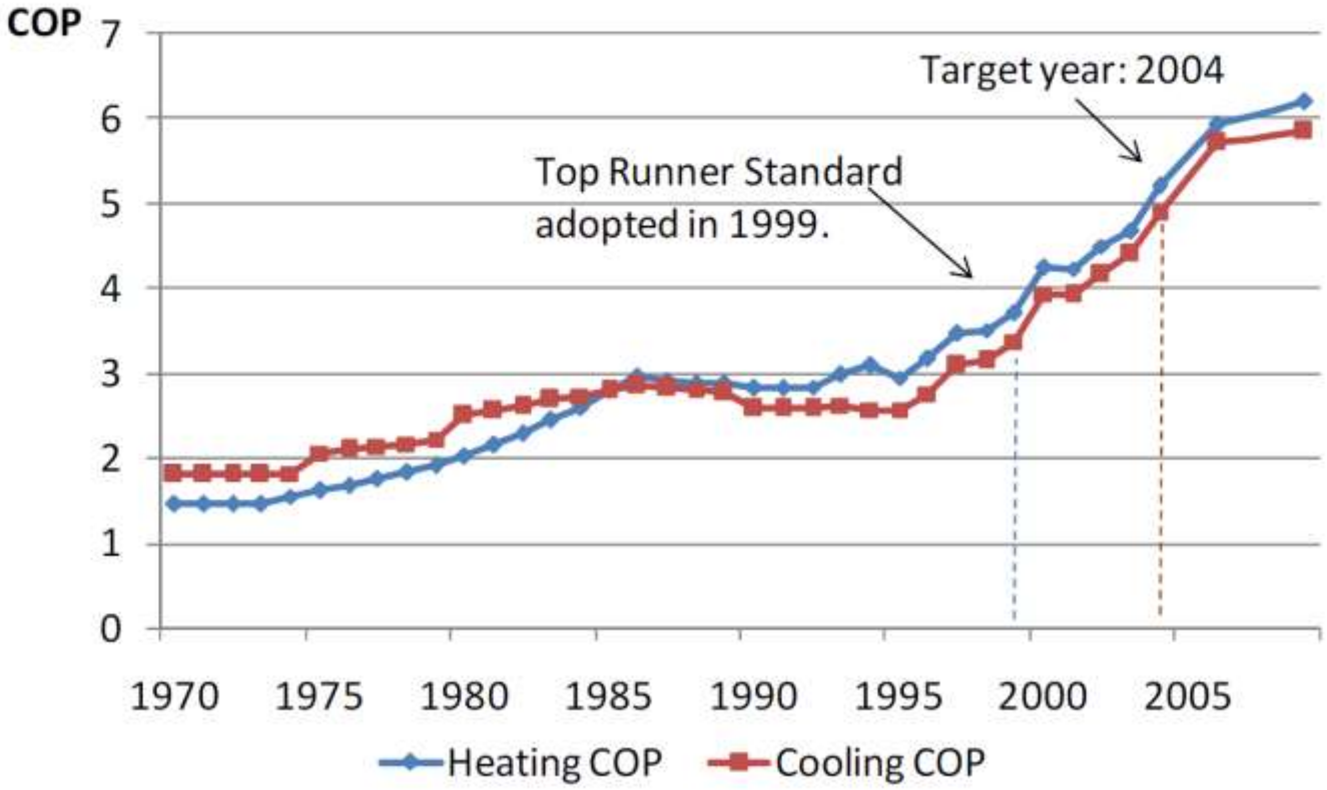

Figure 18: Long term trends in energy efficiency of new air conditioners in Japan (2.8kW)

Source: Study 47. The annual rate of improvement to from 1970 to 1995 was 1.2% pa for cooling and 2.8% pa for heating. From 1995 to 2006, through the first Top Runner target year in 2004, the annual rate of improvement was 7.9% pa for cooling and 6.6% pa for heating. All values sales weighted for the product category. Based on fiscal years ending in March.

A separate example for Australia is shown in Figure 19 for small air conditioners. There is no doubt that Top Runner targets in Japan have had spill-over effects into other regions, even if this occurred some years later.

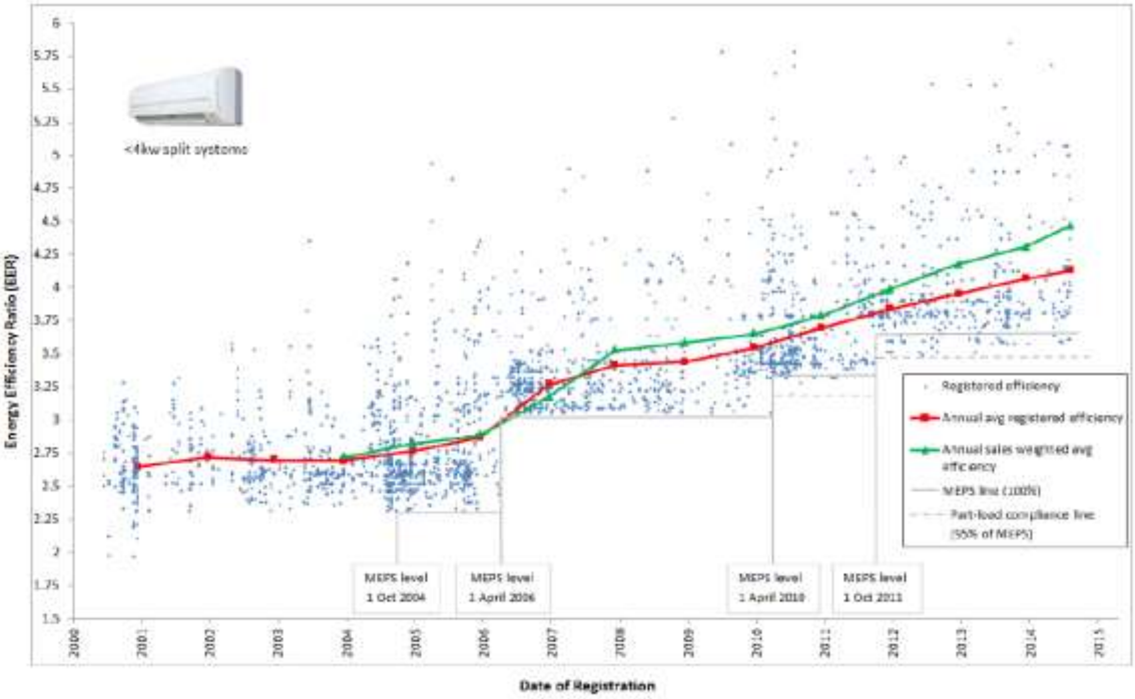

Figure 19: Trends in sales weighted new air conditioner efficiency in Australia and MEPS impacts

Figure notes: MEPS levels are progressively increased over time. New models registered (blue dots) cannot be below grey MEPS lines as levels increase. A labelling regrade also occurred in 2010 (E3 2018a).

As with all data summaries provided in this report, the annual rate of new efficiency is affected to some extent by the stringency of the measure and how tightly framed around the change the annual rate is calculated. The data in Figure 20 shows a 5% improvement in energy efficiency as a result of a new MEPS requirement in Mexico. However, the impact appears smaller if no further changes are made in subsequent years and a longer time frame is used. For example, this could be calculated as a 1.5% per annum improvement if a three-year fame was used.

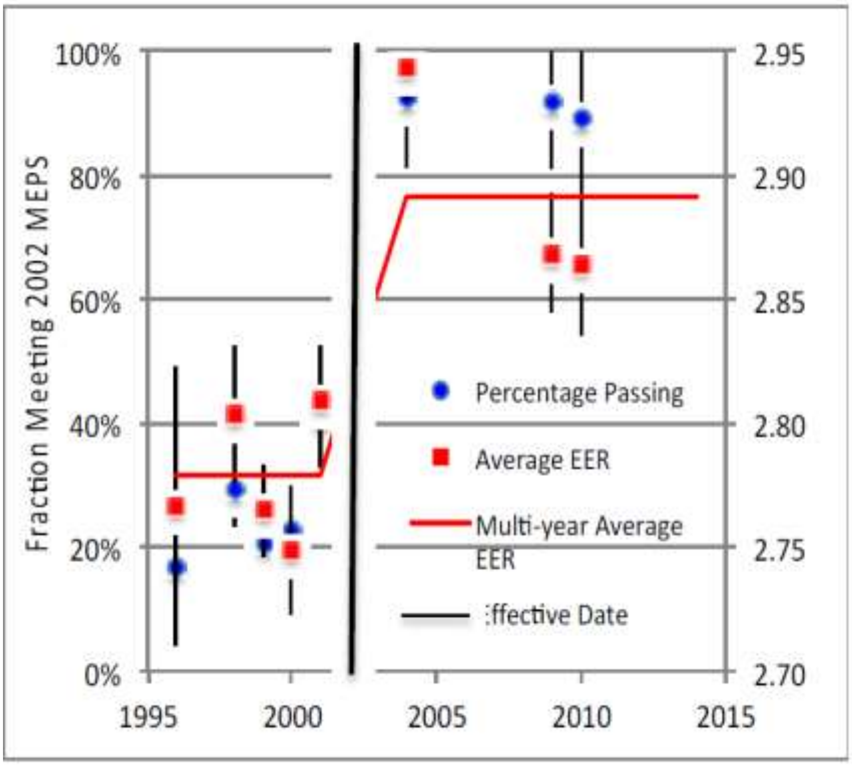

Figure 20: Market average efficiency for new window air conditioners in Mexico as a result of MEPS

Source: Study 2601 [REF002]

Some long term efficiency improvement data for new air conditioners from the document analysis database is illustrated in Figure 21.

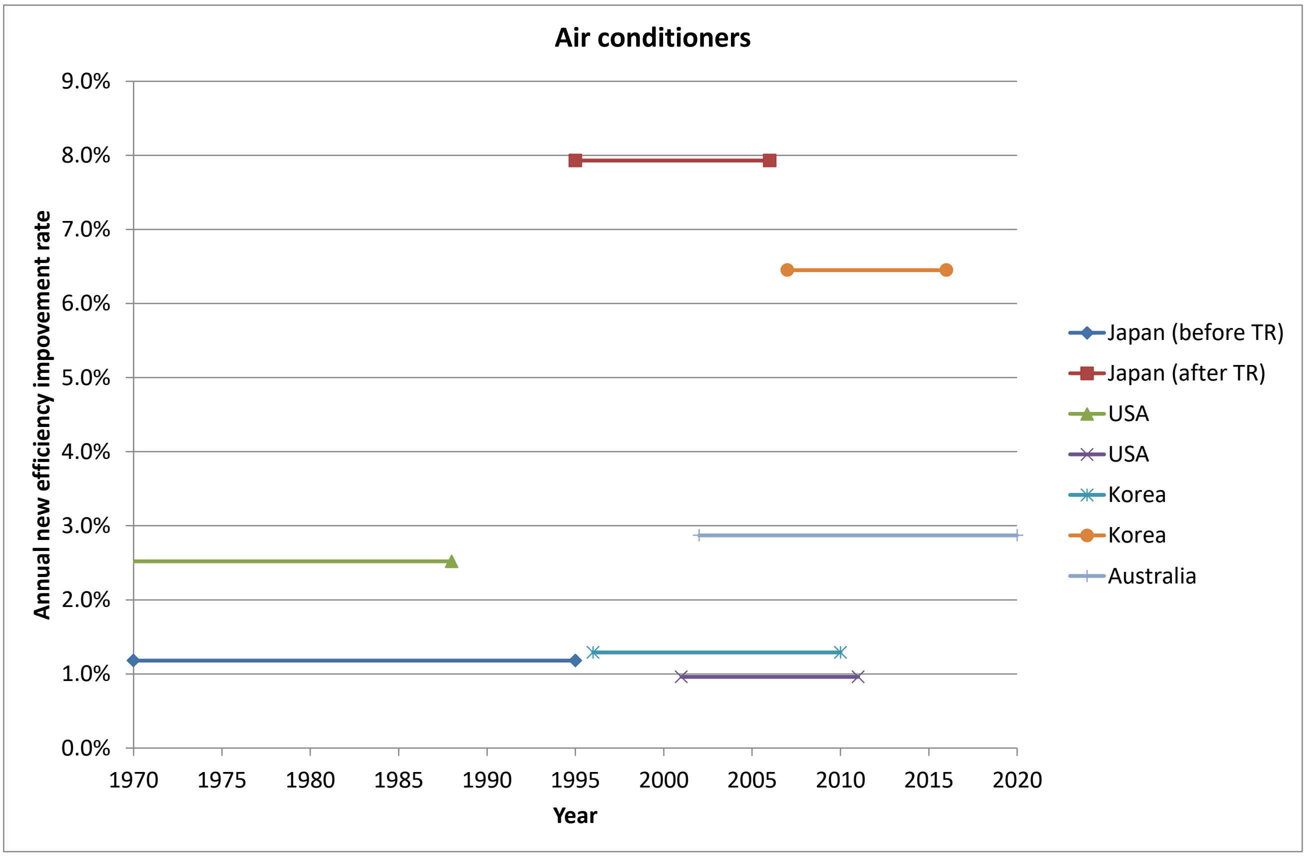

Figure 21: Selection of long-term historical energy efficiency improvement data for new air conditioners

Notes: The high rate for Japan after 1995 is as illustrated in Figure 18.

Almost all of the data collected for this study on energy efficiency improvements is for impacts on average new products sold, either historically or as projected. A summary of the data in the document analysis database is shown in Table 18.

Table 18: Average rates of efficiency improvement for new air conditioners – historical and trends

Records	50
New min rate per annum	0.20%
New average rate per annum	2.86%
New max rate per annum	7.93%

3.5.2.5 Air conditioner – emission impacts

A total of four separate air conditioner studies examined emissions, plus one global study. One was an historical assessment for the European Union from 2010 to 2020, which found all programs (labelling and EcoDesign) had resulted in reductions of 0.4% to 0.5% per annum on overall stock emissions over this period (Study 2404). The two studies examined various MEPS levels in China. As mentioned previously, a global study was also examined that made world estimates for potential emission impacts to 2050. A summary of these studies is shown in Table 19. In most cases emission impacts will be in line with energy impacts after any changes in emission intensity are factored into the calculations.

Table 19: Projected average rates of emission reductions for the stock of air conditioners from new S&L measures – ex ante

Records	11
Stock min rate per annum	0.17%
Stock average rate per annum	0.74%
Stock max rate per annum	1.97%

3.5.3 Electric motors

3.5.3.1 Overview

Electric motors are a large and important end use in all sectors, but particularly the industrial and commercial sectors. Most programs involve MEPS for 3 phase induction motors from 0.75kW to 150kW or more. There is generally no consumer type labelling for electric motors as they are not purchased by consumers in a showroom like appliances and other consumer equipment. However, there is an international efficiency marking scheme for electric motors that has been widely adopted. There are around 50 countries that have MEPS for 3 phase motors in place (21 countries plus EU 28), plus some have additional policies for other types of motors (CLASP 2021).

Electric motors come in a wide range of physical sizes from the size of a football to the size of a car. Rated outputs are standardised and products are measured and rated at one of these outputs under IEC test standards IEC 60034-1: *Rating and performance* and IEC 60034-2-1: *Rotating electrical machines - Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*. The ratio of the mechanical power delivered to the shaft to the electrical power supplied defines the efficiency of an electric motor. This data is usually listed for the rated output (100% load) on the rating plate and typically catalogue data also provides efficiency data for 25%, 50% and 75% of the rated output. The maximum efficiency of an electric motor is usually between 75% and 100% of the rated output. An internal system of motor efficiency classes has been developed under IEC60034 *Rotating electrical machines* - Part 30-1: *Efficiency classes of line operated AC motors (IE Code)*. This provides a coherent platform from which other countries can adopt motor MEPS within an existing technical framework. The advantage of this approach is that the efficiency metric and MEPS levels have been well defined using a wide range of international expertise. Countries can adopt levels that are suited to their economy at their own timetable. Suppliers understand this international framework and can readily supply compliant products once they know the relevant IE level that has been implemented in each region. A recent U4E study mapped out a timeline of MEPS levels by IE efficiency class as shown in Figure 22.

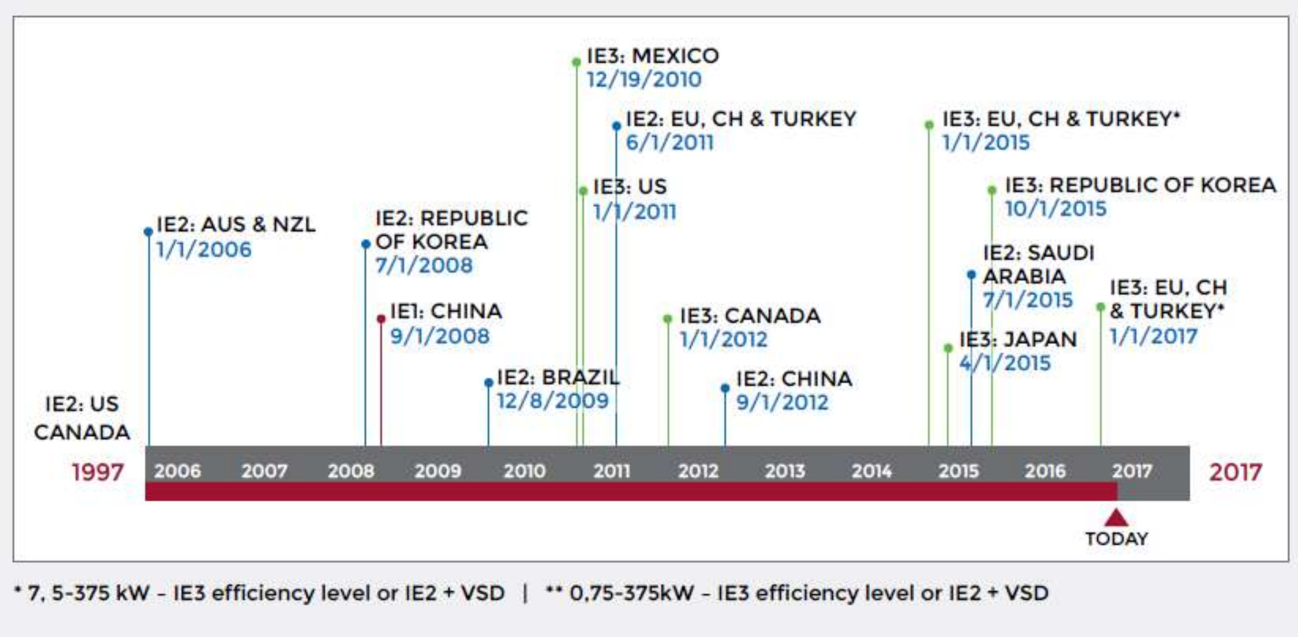

Figure 22: Worldwide MEPS time line for electric motors as of 2017

Source: Figure 15 (United for Efficiency 2017).

The efficiency of electric motors is generally already quite high, with large motors reaching nominal efficiency levels at rated capacity of around 95%. While the differences between lower and higher efficiency motors are generally small in terms of absolute percentage points, the energy savings that are gained from increased efficiency in electric motors are usually very large. This is because their power input is large and many have very long annual operating periods, meaning that even small changes in efficiency can have a large energy impact.

3.5.3.2 Electric motors – outline of the data

The database compiled for this study has around 35 separate records documenting key parameters for electric motors. Most of these were from a large Super-Efficient Equipment & Appliance Deployment (SEAD[20]) study that examined future impact of more stringent MEPS in six countries (Brazil, Canada, European Union, Japan, Mexico, USA) (Study 2001, REF138) plus three other studies that examined impacts in Kenya, China and the EU. All of the studies were effectively ex-ante projections of improved S&L policies, except for the EU, which did have some ex post historical estimates built into the data. In most cases, the studies estimated the impact of the introduction of new MEPS at a defined level that was higher than the existing market average.

3.5.3.3 Electric motor – energy and related impacts

Each of the countries analysed for the SEAD study (Study 2001, REF138) looked at detailed impacts by motor size and motor type. This is important because the potential efficiency differences

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20 See http://www.cleanenergyministerial.org/initiative-clean-energy-ministerial/super-efficient-equipment-and-appliance-deployment

as a result of MEPS differ by motor size. The absolute energy savings for large motors are larger due to their high power input and longer operating hours, but the relative savings, which is the measure primarily adopted for this report to allow cross jurisdiction comparisons, tend to be smaller as the incremental changes between standard and high efficiency are smaller. Overall results for large, medium and small 3 phase motors are shown in Table 20, Table 21 and Table 22.

Table 20: Projected average rates of energy improvement for the stock of large electric motors new MEPS measures – ex ante

Records	6
Stock min rate per annum	0.03%
Stock average rate per annum	0.06%
Stock max rate per annum	0.11%

Source: For this study large is defined as >75kW. Study 2001, REF138

Table 21: Projected average rates of energy improvement for the stock of medium electric motors new MEPS measures – ex ante

Records	8
Stock min rate per annum	0.07%
Stock average rate per annum	0.10%
Stock max rate per annum	0.20%

Source: For this study large is defined as 7.5kW to 75kW inclusive. Study 2001, REF138

Table 22: Projected average rates of energy improvement for the stock of small electric motors new MEPS measures – ex ante

Records	8
Stock min rate per annum	0.11%
Stock average rate per annum	0.16%
Stock max rate per annum	0.31%

Source: For this study small is defined as <7.5kW. Study 2001, REF138

A US study also found large potential stock energy changes from MEPS for single phase and small motors (up to 1.9% per annum), but noted that the absolute energy consumption of these motors is also relatively small due to short hours of operation in many cases. Importantly, an ex post/ex ante EU estimate of three phase motor MEPS found ***that annual stock savings rate was around 0.38% per annum*** from 2009 to 2025 (Study 2401, REF126) for an average mix of motors sizes being installed, which is higher than the rates reported in other studies.

3.5.3.4 Electric motor – efficiency impacts

None of the studies examined recorded changes in motor efficiency, as was common for other types of products. However, there is clearly some change in the efficiency of new motors over time. This will vary by jurisdiction and their regulatory timetable (see Figure 22) but will also be influenced by other factors such as energy costs. This study has therefore been unable to track motor efficiency as a specific parameter from the analysis of the literature. However, analysis by the 4E TCP Electric Motor Systems Annex shows that the share of high efficiency motors has been increasing over time as illustrated in Figure 23.

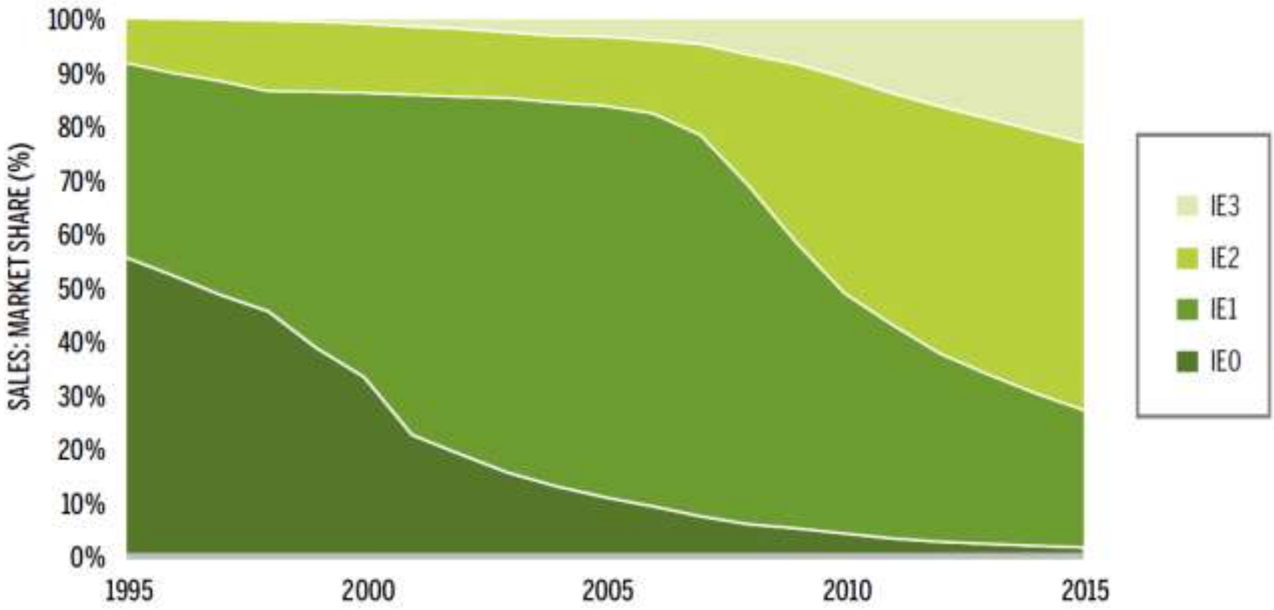

Figure 23: Estimated global sales share of motors by efficiency IE class, 1995 to 2015

Notes: IE0 represents all motors below class IE1. Source (IEA 4E Electric Motor Systems Annex 2015).

3.5.3.5 Electric motor – emission reductions

Two separate electric motor studies examined emissions. One was an historical assessment for the European Union from 2009 to 2020, which found that the EcoDesign program had resulted in reductions of 0.34% per annum in overall stock-related emissions over this period (Study 2404). The other study was for China, which estimated an annual change in stock-related emissions of 0.05% per annum for medium motors and 0.25% per annum for small motors.

3.5.4 Lighting

3.5.4.1 Overview

Lighting is one of the most important and ubiquitous electricity end uses across the globe. Improving efficiency of lighting is an essential component in the challenge to bring energy consumption down to sustainable levels. Despite being a critical component of future efficiency strategy, lighting is a sector for which it is difficult to ascribe unambiguous impacts from S&L policies.

Up to 2010, the technologies used for lighting were well established. These were tungsten filament lamps (essentially a heater that emits a small amount of light), halogen lamps (similar design but very slightly more efficient), linear fluorescent lamps, compact fluorescent lamps (a squashed down version of linear lamps) and various types of high intensity discharge lamps. The selection and application of lamp technology depends on a range of factors such as the amount of light required (lumens) and various aspects of lighting quality (colour, direct/diffuse and so on) and durability. Historically, the residential sector focused on incandescent lamps (tungsten filament or halogen, low purchase cost), and since the 1990s, compact fluorescent lamps, and to a smaller extent linear fluorescent lamps (although this depended on prevalent cultural practices). The commercial sector was dominated by linear fluorescent lamps. The industrial sector and outdoor lighting requirements tended to use various types of high intensity discharge lamps, depending on the application (mercury vapour, metal halide, low and high pressure sodium). These technologies were all well established and their efficiency had changed relatively little in more than 100 years in most cases. The exception was the advent of the compact fluorescent lamp (CFL) circa 1990, which offered a more efficient alternative to incandescent lamps.

The application of S&L programs for lighting equipment, naturally, tended to focus on the efficiency requirements of individual components. So early S&L lighting programs consisted of MEPS for linear fluorescent ballasts and linear fluorescent lamps, MEPS for CFLs, MEPS for HID ballasts and so forth. Because most of these technologies were very mature, the impact of MEPS on their overall energy efficiency tended to be relatively modest, but nonetheless significant and worthwhile in their own terms. Attention to the potential to improve lighting efficiency increased from 2005 to 2007 and around the year 2008, a number of countries banned incandescent lamps (mainly tungsten filament lamps plus some restrictions on halogen lamps) with a view to forcing the market to CFLs or other alternatives. This undoubtedly had a large impact on energy consumption, although there are only a handful of studies that attempt to quantify this impact systematically.

Circa 2007 to 2010, a major technology breakthrough occurred with the commercial development of LED (light emitting diode or solid state) lighting. Initially the lighting outputs for LED lamps were relatively low and costs were high, while the efficiency gains were also only modest (comparable to a good CFL lamp). But by 2015 the cost of these lamps fell quickly and their efficiency climbed rapidly. In addition, designs with higher total lumen output were appearing. The other relevant performance factor is that the rated lifetime of LED lamps was often very long (this depends on product quality and is slow and difficult to measure in a laboratory). So all the makings of a market transformation were in place – to a new technology that was as cheap or cheaper, much more efficient, lasts longer and can be more versatile. LEDs are well on the way to transforming the lighting market with very large impacts. The typical efficacy range for different lighting sources is shown in Figure 24.

In many countries, LED lamps have now largely displaced incandescent lamps in the residential sector and they are making large inroads into the commercial sector as well. As LED light output has also improved dramatically, they are increasingly being used in outdoor lighting applications and some industrial settings.

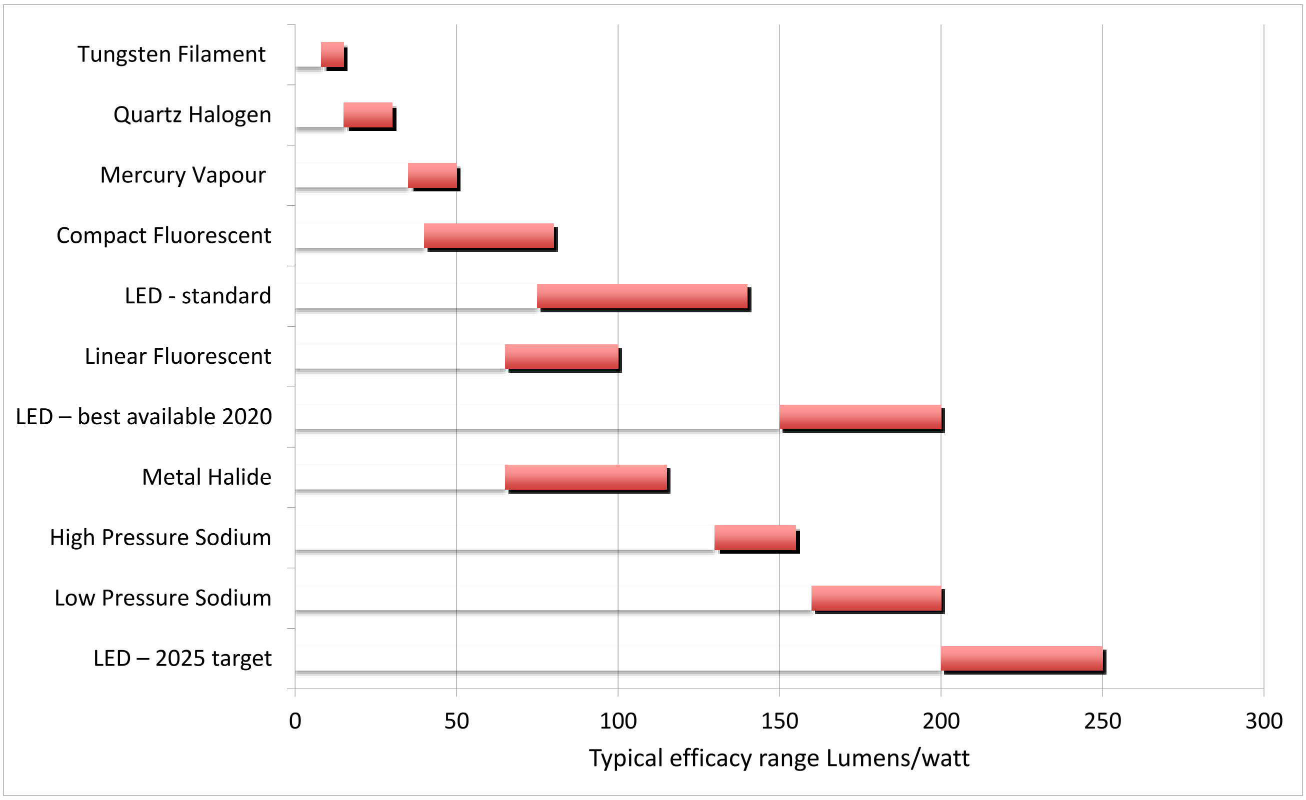

Figure 24: Typical range of efficacy for different lighting technologies

Figure notes: Data compiled by the authors from various sources including Energy Star lighting database, E3 (2018b) and Navigant (2016). The efficacy range is also affected by the luminaire and application.

There are always problems with the evaluation of the impact of MEPS and labelling for any end uses where there are multiple competing technologies on the market. This is clearly evident in lighting. If MEPS are applied to a linear fluorescent ballast, then the impacts of that MEPS can be quantified as long as that technology continues to be used in comparable numbers into the future. There are many countries that still have MEPS for linear fluorescent lamps ballasts in their regulations. Yet, it is not a simple matter to assess the savings from this S&L measure if the sales share of the product has dramatically decreased or has even been eliminated. The concept behind most S&L programs is to make improvements to the energy efficiency of an end use. It is certainly true that the banning of incandescent lamps by a number of countries was an attempt to force end users to switch to (or substitute) a more efficient technology (that may or may not be covered by an S&L program). But banning of specific whole technologies from sales tends to be an exception rather than the rule for S&L programs. Evaluating a technology ban requires one to quantify the energy impact of all substitute technologies and to quantify the extent of the various technology substitutions. In general terms, evaluation studies rarely attempt to attack the problem from such a broad perspective.

The problem that the authors for this study confronted is that traditional lighting technologies, which were formerly common and covered by S&L programs to date, are rapidly vanishing from the market. So there are only a few evaluations of the specific S&L programs still in place, which now have little relevance. The other issue is that, while there are a number of consumer-oriented efficiency labelling programs that are technology neutral (such as the EU lamp labelling program), very few countries have set MEPS for LED lamps (EU Ecodesign requirements to apply to LED lamps but few, if any, are affected at the current stringency levels). And even where specific LED requirements have been attempted, the technology is evolving so fast that a MEPS program might struggle to keep pace.

There is no doubt that there are massive global changes in the lighting market under way and that the current technology transformation to LEDs across the board will result in immense energy savings into the future. However, clearly quantifying and attributing the part of this change to S&L programs can be problematic.

3.5.4.2 Lighting – outline of the data

The quantitative data collected for this project covered nine countries: Australia, Canada, China, Denmark, European Union, Japan, Kenya, South Africa and the USA. Data was extracted from nine separate technical reports and resulted in 33 quantitative records. The data collected was mostly on energy reductions, with a couple of studies looking at emission impacts and a couple examining equipment costs and benefit/costs. Only one study from Japan, which is very old (1997 to 2005), looked at changes in lighting efficacy.

3.5.4.3 Lighting – energy and related impacts

An old study from China looked at CFL energy savings impacts from MEPS and concluded that they were very small (0.03% per annum from 2003 to 2010). Another study in the USA looked at cost impacts of the conversion from ferromagnetic to electronic ballasts for linear fluorescent lamps in 2006 and concluded that these were significant but a one off. A study in Kenya (Study 2102) estimated that future impact from MEPS on fluorescent lamp ballasts and tubes were 1% per annum and 0.79% per annum respectively. But given the recent technology changes and the fact that this study was completed in 2016, this may now mean that these results are less relevant.

Figure 25 shows the energy savings from S&L policy measures in the EU by lighting technology and application. This figure illustrates the point made in the preceding discussion, that S&L policy measures should drive up the adoption of efficient technologies and drive down the adoption of inefficient technologies. In this case there have been large energy savings from declining use of less efficient lighting technologies (incandescent, some High Intensity Discharge) and later on from declining use of intermediate efficiency technologies (linear and compact fluorescent lamps, other High Intensity Discharge). This is due to the increasing use of LED technologies, whose energy use is more than offset by the savings in the other technologies. Overall there is estimated to be a saving of 94 TWh for lighting in 2020 and of 109 TWh in 2030 compared to the BAU, which equates to a relative saving of 22% and 29% respectively (Study 2402). This is despite the estimated average efficacy of the stock of LEDs in the lighting stock being only fractionally higher under the S&L policies case compared to the BAU case i.e. the largest impact of the S&L policies is to encourage adoption of LED lighting solutions rather than to drive up the efficiency of LEDs per se). Note, the EU policy settings for lighting (as for other products) are framed in a technology neutral manner in that they do not prescribe the use of one technology versus another but simply specify performance thresholds (in labels and MEPS) that in practice cannot be met by old inefficient lighting technologies. This is the logical way to frame S&L programs for complex end uses like lighting with multiple technologies that can be substituted. But this type of integrated approach to an end use is relatively unusual and can be difficult to frame in a totally neutral manner.

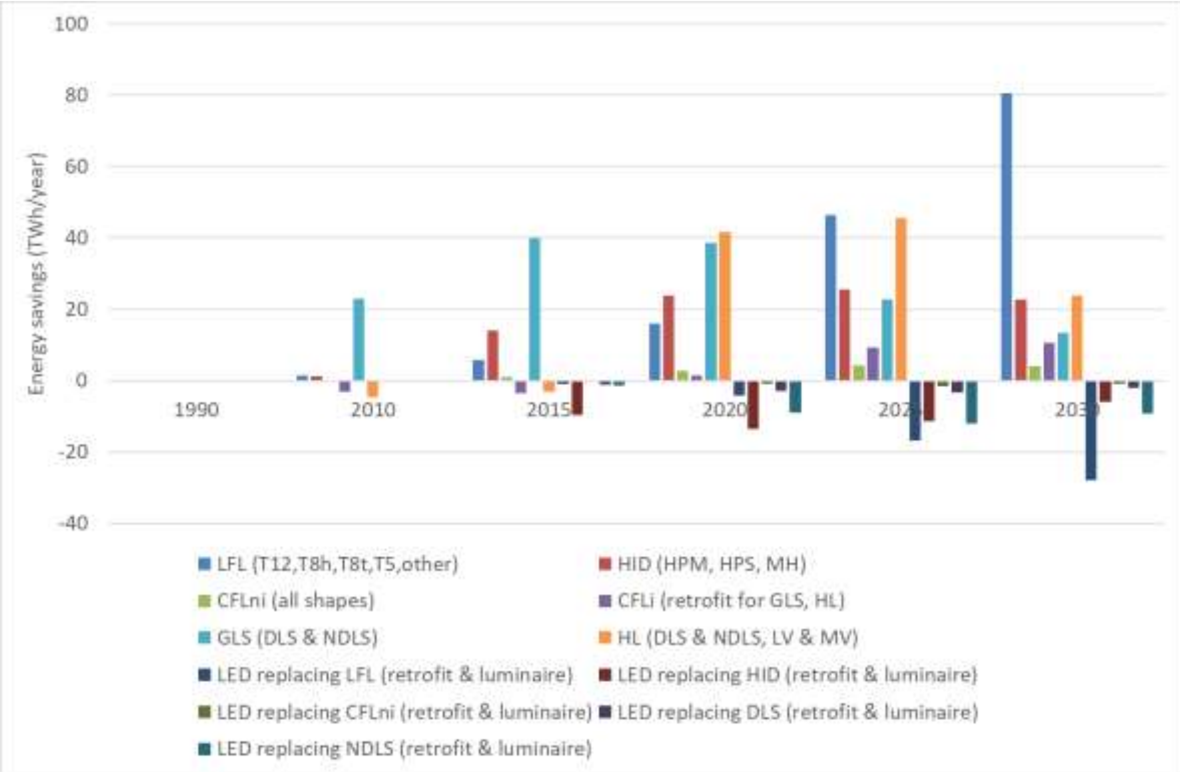

Figure 25: Energy savings by lighting technology in the EU due to S&L policies

Key: LFL = linear fluorescent lamps; CFLni = compact fluorescent lamps, non-integrated; GLS = general lighting service (incandescent); HID = high intensity discharge; CFLi = compact fluorescent lamps, integrated; HL = halogen lamps; LED = Light Emitting Diode; DLS = directional lamps; NDLS = non-directional lamps; LV = low voltage; MV = mains voltage. Source: Study 2402.

The impact of the Top Runner Target for 2020 for LED lamps in Japan can be seen in the historical and projected luminous efficacy as shown in Figure 26. The rate of improvement for new products over the 11 years shown varies from 8.5% per annum for daylight LEDs (brown line) to 9.2% per annum for warm white high CRI LEDs (red line).

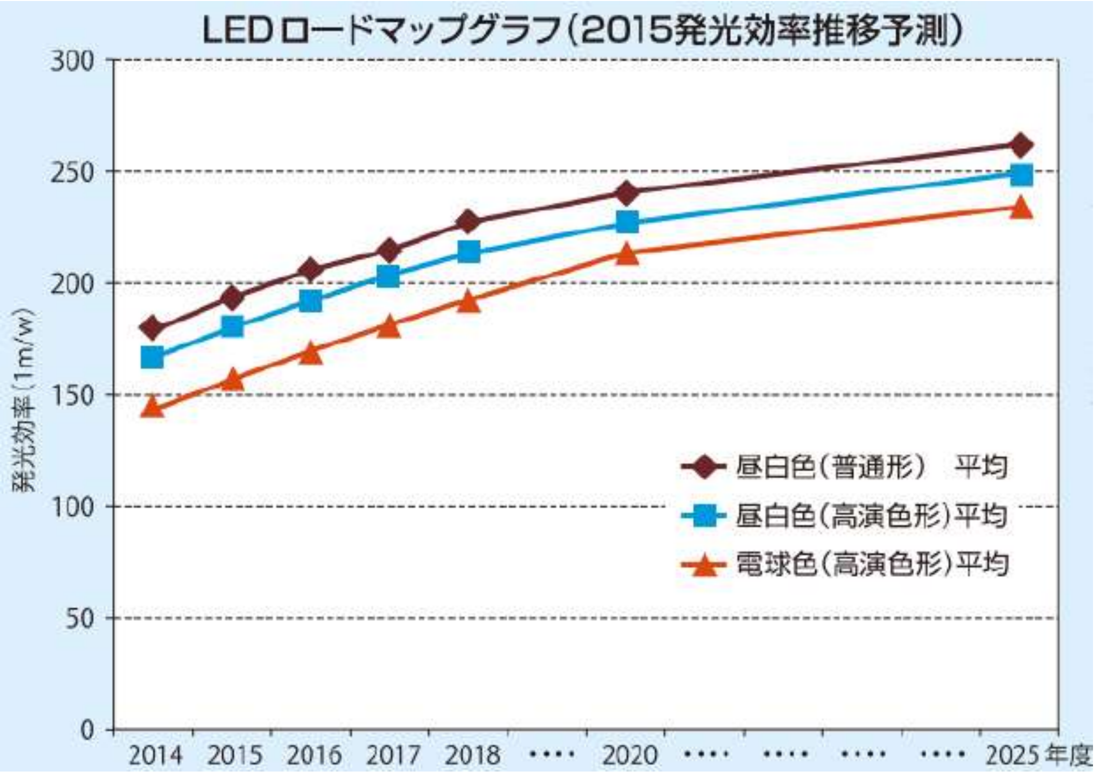

Figure 26: Changes in luminous efficacy in Japan in the lead up to 2020 Top Runner targets

Figure notes: Source REF279 (Study 2211) Figure 4-7. Brown line is daylight, blue line is daylight high colour rendering, red line is warm white high colour rendering. Y axis is luminous efficacy lm/W. The projection of luminous efficacy is by Japan LED Association (JLEDS).

3.5.5 Wet products

3.5.5.1 Overview

Household appliances clothes washers, dishwashers and clothes dryers, collectively called wet products for this report, are widely covered by S&L programs around the world. They make up a moderate but significant component of residential sector energy use in most countries. As water consumption and energy consumption are closely linked for clothes washers and dishwashers, many S&L programs have generated substantial reductions in both energy and water consumption for these products (see Section 3.3).

3.5.5.2 Wet products – outline of the data

The quantitative data collected for this project covered 12 countries: Australia, Canada, China, Denmark, European Union, Korea, Mexico, Netherlands, South Africa, Sweden, Switzerland, USA. Data was extracted from 18 separate technical reports and resulted in 94 quantitative records. Data was collected on energy reductions (and related measures), emission impacts, efficiency improvements, product purchase cost trends. There was no published data on benefit cost ratios. However, several studies included water impacts. The following sections provide a brief overview of each of the main three products.

3.5.5.3 Clothes washers – overview of all impacts

There are two main technologies that can provide residential clothes washer services: these are drum machines (also called horizontal axis, which are usually front loaders) and non-drum machines (also called vertical axis, which are usually top loaders). There are several variants with vertical axis machines such as impeller and agitators used to provide mechanical action to the immersed clothes load. The characteristics of these two technologies are somewhat different, with key contrasts being set out in Table 23.

Table 23: Qualitative differences in the performance of the main clothes washer technologies

Performance parameter	Horizontal axis	Vertical axis
Energy consumption	Tend to be lower energy, but depends on wash temperature	Tend to be higher energy, but depends on wash temperature
Water consumption	Tends to be lower as loads are wetted then flopped on themselves	Higher as clothes usually need to be fully or partly immersed
Gentleness of action	Usually more gentle	Harsher on clothes, especially impeller
Time	Can be quite long (>1h)	Generally short (<30 min)
Rinsing performance	Comparable	Comparable
Spinning performance	Historically better, but varies a lot by model	Improving over time and best models are comparable to best HA
Washing performance	Comparable	Comparable

The European market has long been dominated by horizontal axis machines, while the North American market has traditionally been predominantly vertical axis machines, but horizontal axis exceeded 50% market share in 2019[21]. The Asia and Oceania market have also traditionally been mostly vertical axis, although horizontal axis is now making significant inroads in Korea, Japan, and to some extent, China. In Australia and New Zealand, the market share is also now more than 50% horizontal axis. Analysis of market trends is made more complex where there are changes in the share of these main technologies over time. For example, there have been significant energy consumption improvements over time in Australia for clothes washers, but these have been mostly the result of an increased share of horizontal axis machines rather than substantial improvements in the efficiency of either washer technology. Improvements in the USA have been partly through increased penetration and competition from horizontal axis machines.

The other complexity with clothes washers is that the direct energy use is usually dominated by the wash temperature, as much of the energy required is embodied in the heated water. With so many program and temperature options available on most modern washing machines, many S&L programs struggle to provide a realistic representation of wash temperatures and associated energy during normal use, so there may not be a good correlation between the energy shown on an energy

[21] See https://www.grandviewresearch.com/industry-analysis/smart-washing-machine-market

label and the energy actually consumed during normal use. North American approaches also include the implied dryer energy use based on the washer spin performance (on the assumption that most washer loads are dried in a clothes dryer) so not all of the energy is directly used in the washing machine in some cases. There is also the factor of internally heated water versus water heated in an external water heater, which adds complexity. The energy service provided by clothes washers; nominally clean clothes, is also quite difficult to define and this is a topic where there are significant global variations in S&L programs. The reported long-term rate of energy reduction in new washers from five separate reports are illustrated in Figure 27.

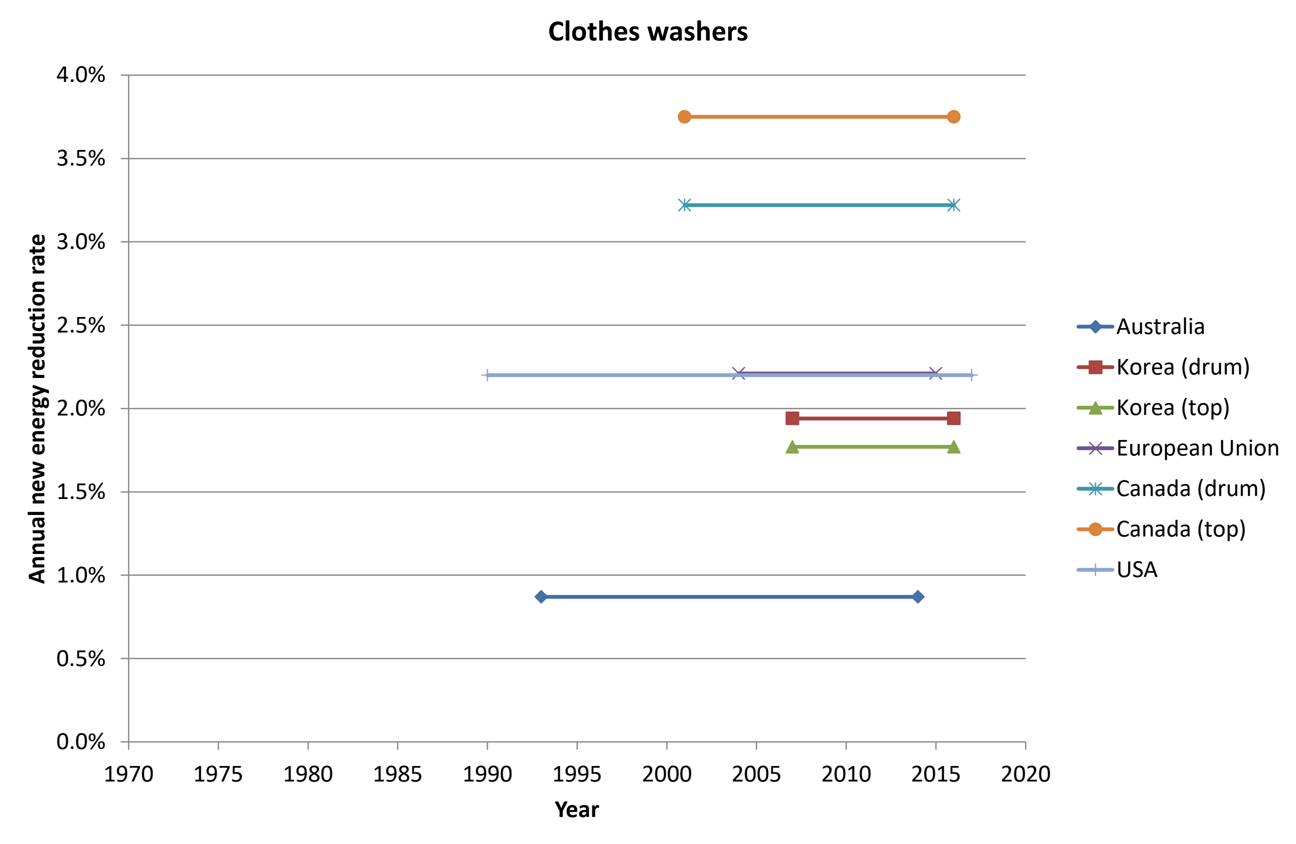

Figure 27: Annual historical reductions in energy consumption for new clothes washers in selected countries

Figure notes: These energy reductions are despite increases in capacity in many jurisdictions. Sources Studies 1041, 2214, 2406, 2611, 2612. Many countries experienced a significant increase in capacity over the reporting period.

A summary of all average new data for clothes washers is shown in Table 24.

Table 24: Average rates of improvement for new clothes washers – historical and trends

Parameter	Energy reductions	Efficiency improvement
Records	11	9
New min rate per annum	0.87%	1.26%
New average rate per annum	3.00%	3.54%
New max rate per annum	6.39%	6.26%

A number of studies projected future ex ante energy savings from a range of S&L programs, are summarised in Table 25. This illustrates that there are still significant energy savings that could be achieved through new S&L programs.

Table 25: Projected average rates of energy reductions for the stock of clothes washers from new S&L measures – ex ante

Records	18
Stock min rate per annum	0.01%
Stock average rate per annum	0.92%
Stock max rate per annum	1.90%

Only one study quantified emission reductions from clothes washers S&L programs and these were very small (Study 2206).

3.5.5.4 Dishwashers – overview of all impacts

Dishwashers are reasonably common in developed countries, with ownership gradually increasing over time. They are relatively rare in developing countries. Historically, there were two basic global designs of dishwashers: North American designs, which tended to use more water and energy but were developed to process substantial food loads on dirty plates, and; European designs which tended to be more focused on removal of adhered food and tended to use less water and energy. These distinctions are much less clear now as water and energy improvements are tending to push all designs in a similar direction.

The energy service provided by dishwasher (clean and dry crockery and cutlery) is complex to measure and there are also some variations in how this parameter is handled in different S&L programs, In principle, a dishwasher is more self-contained in terms of its measured energy than some other products (although there is still the vexed issue of how to treat energy from externally supplied hot water, which is common in North America but rare elsewhere).

As with clothes washers, dishwasher energy consumption is strongly linked to water consumption so many low energy designs have been reducing fill volumes and the number of fills per program. Some newer products have a facility to retain final rinse water to use as the initial rinse in the next cycle – this saves water but has no practical impact on energy consumption.

The reported long-term rate of energy reduction in new dishwashers from five separate reports are illustrated in Figure 28.

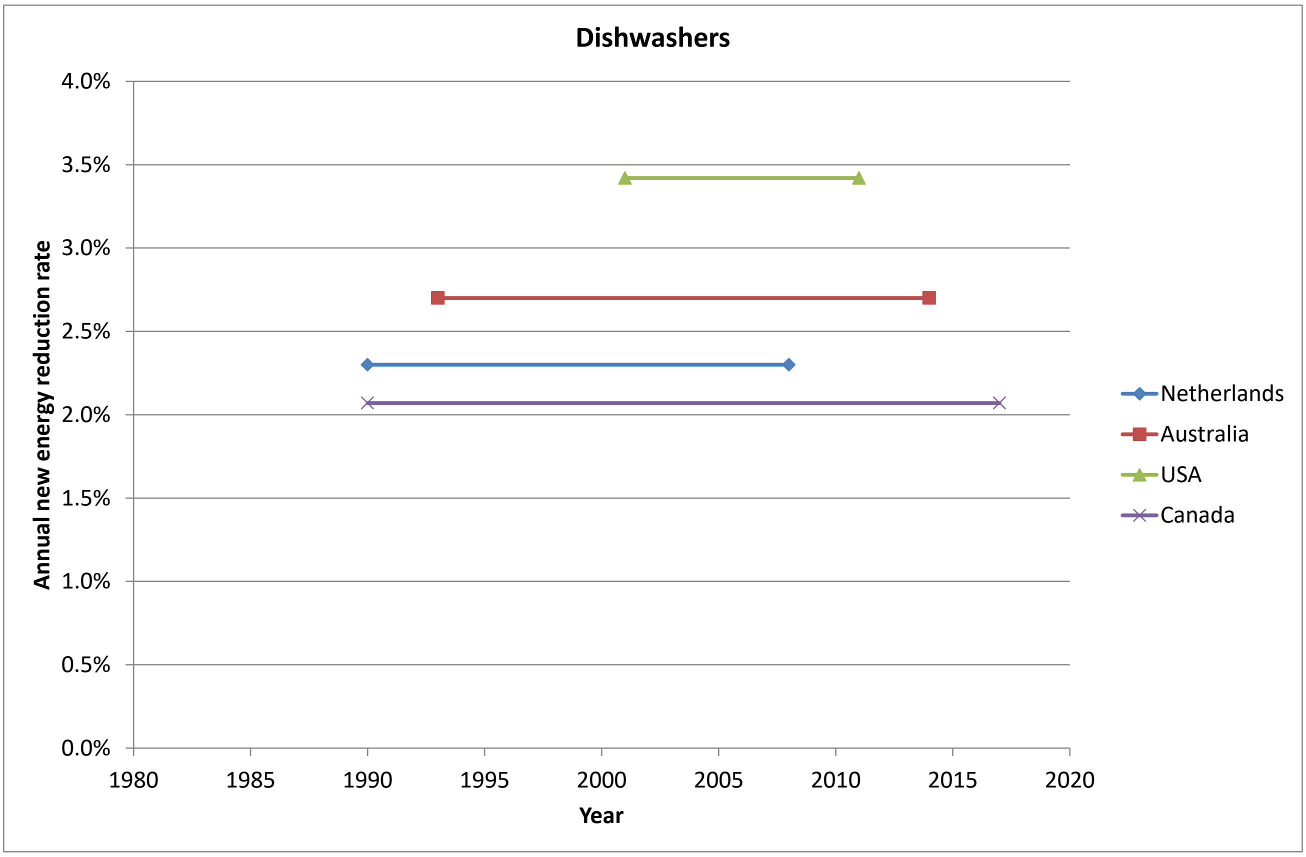

Figure 28: Annual historical reductions in energy consumption for new dishwashers in selected countries

Figure notes: Sources 18, 1041, 2602, 2611.

A summary of all average new data for dishwashers is shown in Table 26.

Table 26: Average rates of energy reduction for new dishwashers – historical and trends

Records	5
New min rate per annum	1.66%
New average rate per annum	2.43%
New max rate per annum	3.42%

A number of studies in the database projected future ex ante energy savings from a range of S&L programs, which are summarised in Table 27. This illustrates that there are still significant energy savings that could be achieved through new S&L programs.

Table 27: Projected average rates of energy reductions for the stock of dishwashers from new S&L measures – ex ante

Records	6
Stock min rate per annum	0.58%
Stock average rate per annum	1.05%
Stock max rate per annum	1.54%

Table notes: In addition to the above results, which cover only electricity, one US study estimated gas stock savings of 1.1% per annum from external hot water use (Study 2001).

None of the studies reviewed estimated greenhouse gas emission impacts from dishwasher S&L programs.

3.5.5.5 Clothes dryers – overview of all impacts

Clothes dryers are reasonably common in developed countries, with ownership remaining fairly steady. They are relatively rare in developing countries. Historically, the vast majority of clothes dryers in service have been a simple perforated drum with a resistance electric heater[22] and a fan that blows warm air through the clothes while they are tumbled in the drum. There are condensing types (which condense and drain water from the clothes down the drain or into an on-board container) or vented types, where moisture filled air from the dryer is expelled outdoors or into the room where the dryer operates. In theory, there are also static clothes drying cabinets, but these are rare and none are regulated. Another variant is the dryer is the control mechanism – typically timer controlled (the user selects the time) or auto-sensing, where the dryer terminates based on the measured moisture content of the clothes. A range of different technologies are used to sense the dryness of the load for auto-sensing controls. While it does appear that there are a range of different types available, in practical terms, the efficiency of vented and condensing dryer types is generally very similar (when powered by a resistive heater). While the inherent efficiency of timer and auto-sensing dryer types is the same, there is some data that shows that auto-sensing types will tend to save a small fraction of energy by avoiding over-drying during normal use.

Having stated this, there are some small improvements in efficiency of conventional resistive type dryers that have been achieved in response to energy labelling and moderate MEPS levels (reducing temperatures, increasing air flows, reversing drum direction of rotation). But these improvements tend to be not more than a 20% overall energy reduction from pre S&L designs, when little attention was paid to energy consumption. Most clothes dryer efficiency metrics use a permutation of energy per kg of moisture removed. While this is a reasonable approach, it does tend to have some size bias (if not corrected) and is also quite sensitive to initial moisture content, so this makes regional comparisons on efficiency a little difficult.

[22] There is a significant gas fired dryer market in North America and Europe, but none of the studies examined covered efficiency trends for these products.

There are two substantial factors that impact on dryer energy consumption and efficiency. These are the initial moisture content of the load (usually considered to be a function of the spin performance of the clothes washer) and the load size. Test procedures and regulations are always being adjusted to become more representative of these two factors, which tend to be regionally specific and partly dependant on cultural factors and local habits. Several field studies have shown that dryer loads in some regions are generally much smaller than rated capacity (Harrington 2017; Dymond & Baker 2017). Combination washer-dryers can appear slightly more efficient if they are able to perform a high-speed spin before the dryer operation, even if the washer function has not been used.

In the late 1990s, AEG in Germany developed a clothes dryer that was powered by a heat pump rather than a resistive heater. This had the potential to substantially reduce energy consumption of this appliance type. Field studies have shown that heat pump dryers, which are now readily available, can reduce in-use energy consumption by around 60%, even for smaller loads that are typical in normal use (Sustainability Victoria 2016). Through the 2000s, heat pump dryers were still very expensive and their market share was negligible. However, gradual increases in production volume lead to price falls, which in turn lead to increases in market share after 2010. Heat pump dryers are now quite cost effective for medium to heavy dryer users in many countries. Advances in technology have meant that there are now many producers that have heat pump dryers available, including major suppliers in Europe, US and Asia. There are also so-called hybrid products in the US that supplement the heat pump component with resistive heating on some programs. While this increases the speed of drying, it does reduce the efficiency significantly. While heat pump dryers offer a relatively low energy technology for mechanically drying clothes, the average capacity of these systems is quite large and at this stage, all are condensing type dryers. So the move to heat pump dryers is also driving an increase in average capacity. However, as noted before, field studies have shown that heat pump dryers save 60% of energy even when used with small part loads.

While heat pump dryers now hold a significant market share in Europe, Switzerland is the only country to have set MEPS levels such that only heat pump dryers are able to pass, which was implemented in January 2012 (minimum permitted Class A). This was upgraded to Class A+ in January 2015. This has of course resulted in a major improvement in dryer efficiency in Switzerland.

There are in fact few historical data sets that accurately track the efficiency of clothes dryers over time. Data from Australia and Canada show very little change in efficiency over the period 1992 to 2016 (both countries with less than 0.3% per annum sales weighted average), but heat pump shares during this period were very small. Europe has reported an overall improvement of new dryer energy of around 2.2% per annum from 2002 to 2015. Reanalysis of early data from the Netherlands (Study 20) showed no change in energy consumption of dryers from 1980 to 1995 when energy labelling began (Weiss et al. 2010).

Swiss data (Study 2409, REF157) provides an assessment of the change in stock efficiency over the period 2002 to 2019[23]. The stock of clothes dryers increased 101% from 2002 to 2019, but the energy consumption of the stock of dryers only increased by 30.3% over the same period. This has resulted in a 35.1% ***increase in energy efficiency of the installed stock***, or an improvement rate of 1.8% per annum over 17 years. This is very impressive for stock efficiency rate and means that the improvement in efficiency of new products sold is substantial. This is illustrated in Figure 29 and Figure 30.

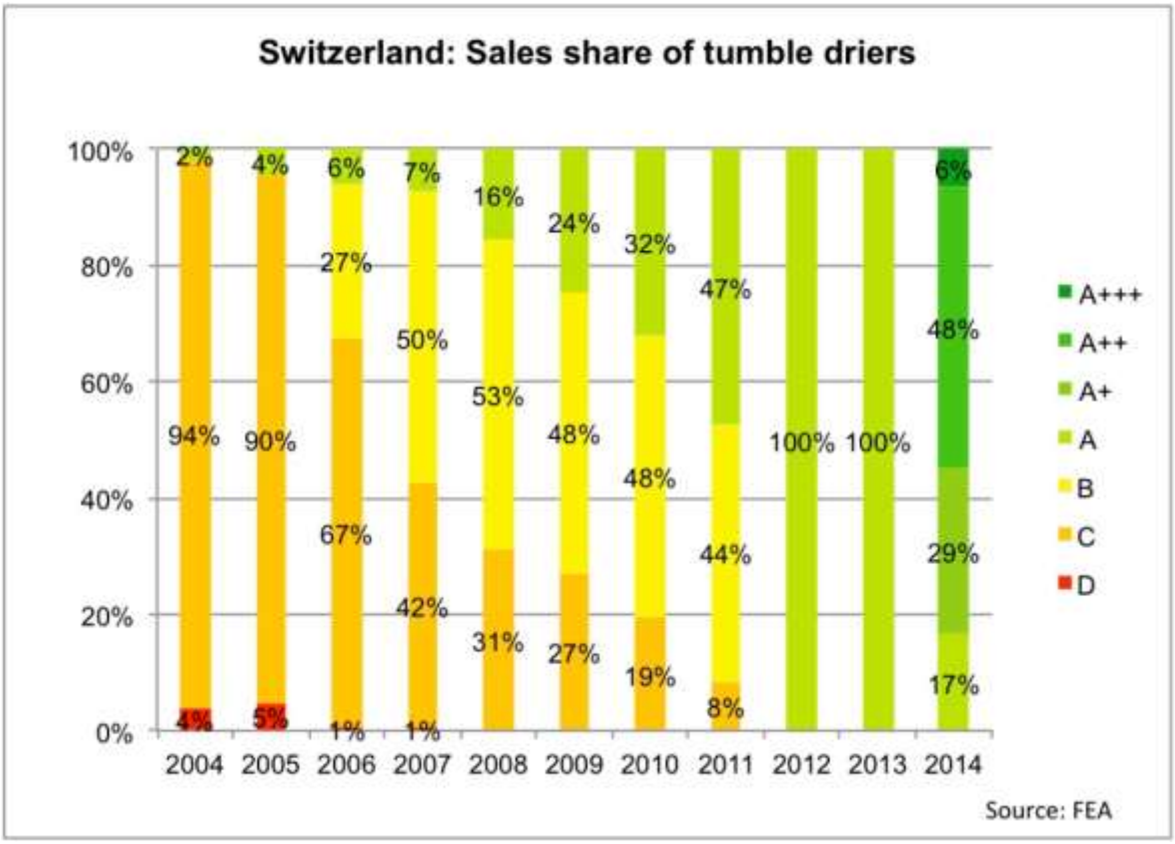

Figure 29: Evolution of sales share by efficiency class in the Swiss dryer market

Source: Figure 6 (Michel & Bush 2015), Study 1027.

[23] According to Michel & Bush (2015), the initial price of heat pump dryers was very high when they first seriously entered the market in around 2005. Heat pump dryers were targeted by public procurement and rebate programs by the city of Zurich (2004), by the utility of Zurich (2006) and other Swiss utilities (from 2007). Consequently the sales share of heat pump dryers was already close to 50% in 2011 before the new MEPS level came into effect.

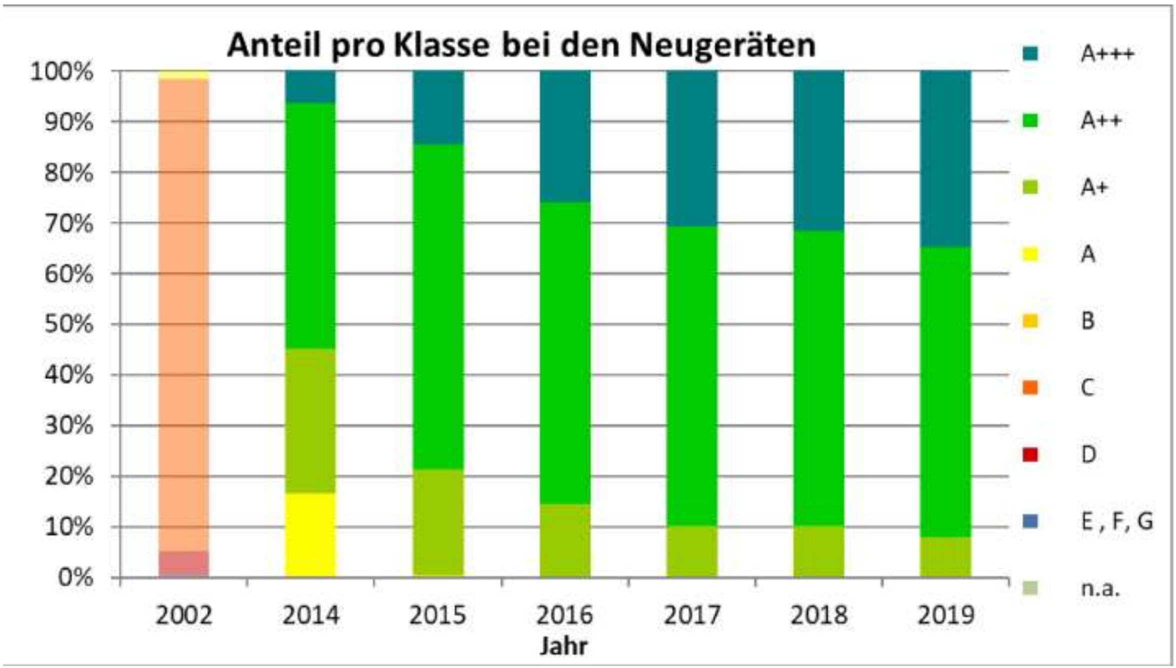

Figure 30: Recent changes in sales by efficiency class in the Swiss dryer market

Source: Page 23, Study 2408 (REF157).

A total of 24 records were extracted that recorded various dryer parameters. Many of these tracked energy reductions over time. A number of studies projected future ex ante energy savings from a range of S&L programs, which are summarised in Table 28. This illustrates that there are still significant energy savings that could be achieved through new S&L programs.

Table 28: Projected average rates of energy reductions for the stock of clothes dryers from new S&L measures – ex ante

Records	6
Stock min rate per annum	0.11%
Stock average rate per annum	0.88%
Stock max rate per annum	2.28%

Table notes: The high value was for Sweden (Study 2407, REF066) and appears to be much higher than Europe in general. The average stock rate improvement includes a large increase in the share of heat pump dryers over time.

None of the studies reviewed quantified emission reductions from clothes dryer S&L programs.

3.5.6 Televisions

3.5.6.1 Overview

The original technology for televisions was invented in the 1930s and used a cathode ray tube to project and electron stream onto a phosphorescent screen to create a picture. The main changes up to 2000 was the transition from black and white to colour (which varied by country, but from late 1950s to the 1970s). Screen sizes increased over this time and also remote controls became standard, but otherwise the basic technology only changed a little over that 70 odd years. In the early 2000s, flat screens for televisions came onto the market. Initially these were mostly either LCD screens with a fluorescent backlight, followed by plasma screens, where an image is created by individual plasma pixels embedded onto the flat screen. In 2000 there were virtually no S&L programs for televisions as their energy consumption was modest. Over the next 10 years there were improvements in manufacturing costs for flat panel technology and these quickly overtook the market. Some flat screen technologies, such as plasma, used vastly more power, with some models consuming as much as 500W or more. In response, many countries scrambled to introduce energy labelling and MEPS programs for televisions.

Over the years 2010 to around 2014, there were rapid improvements in television efficiency. But there were also increases in size that offset these gains to some extent. The overall trends in size and energy for televisions in Australia are illustrated in Figure 31 and Figure 32. Flat screen technologies were well suited to large scale manufacturing, so prices were able to fall as production volumes increased.

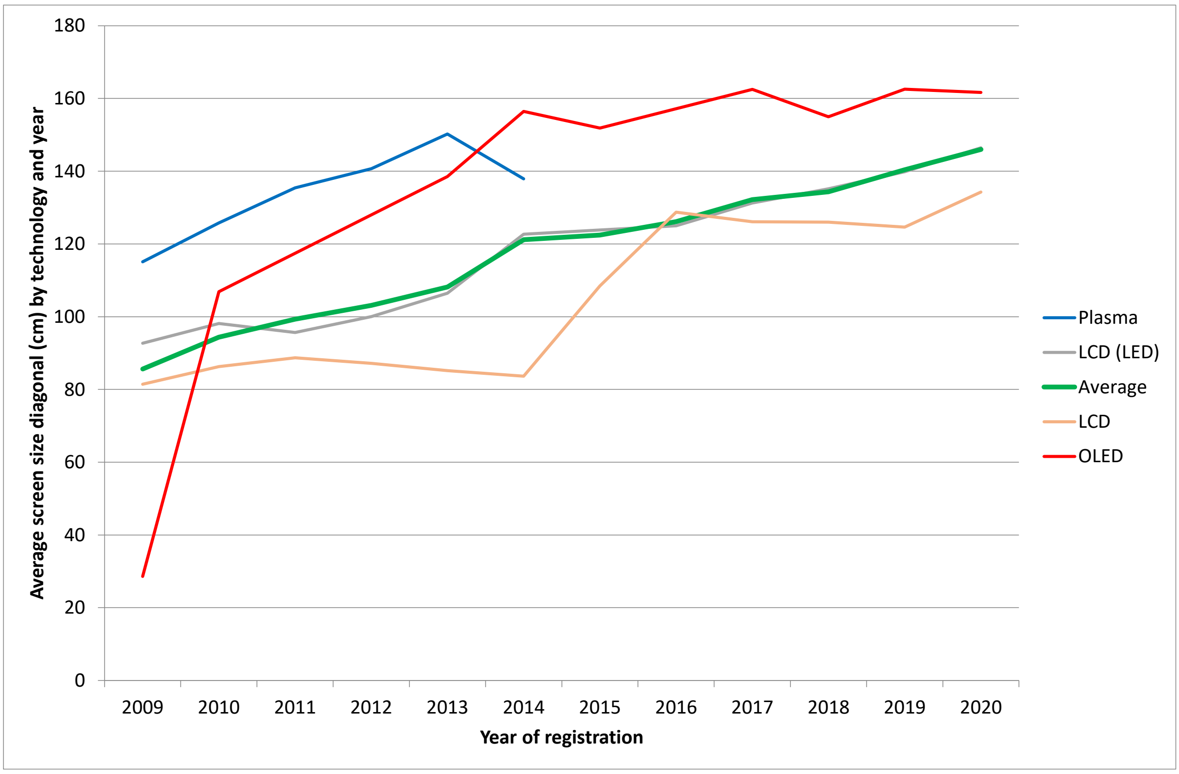

Figure 31: Trends in the size of new television registrations by technology type in Australia

Source: Figure 88 in (Strategy Policy Research 2019), updated by the author.

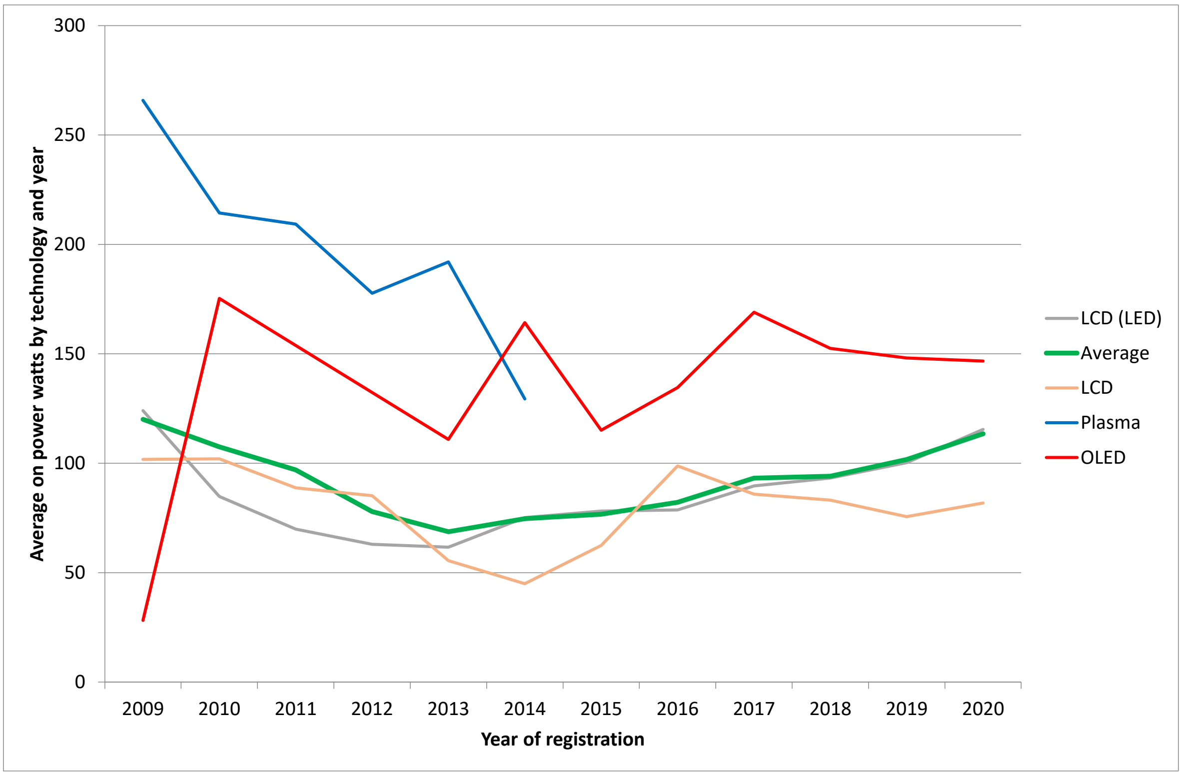

Figure 32: Trends in the on power of new television registrations by technology type in Australia

Source: Figure 89 in (Strategy Policy Research 2019), updated by the author.

While these data are sourced from Australia, they are reflective of many other countries around the world, because the televisions are now a global commodity and are traded widely. Key points to note are:

- An average television has increased in size by 50% (measured by the diagonal) from 2009 to 2020 for all technologies
- As area of flat screen television power is a function of screen area, this means that potentially there could have been a four-fold increase in power requirements (with a static efficiency)
- While plasma reduced its energy consumption substantially (while increasing its size), as a technology it was unable to compete with other technologies and fell out of the market by 2014
- Market share went from mostly LCD with fluorescent backlight in 2010 to mostly LCD with LED backlighting by 2014
- OLED were initially very small in size and now are very large in size
- Efficiency improvements have slowed since 2015, and since then increases in screen size have resulted in increases in average power (which is increasing at a slightly slower rate than screen area alone)

- OLED is presently slightly more energy intensive that LCD(LED) for the same screen size. Other high-definition screen technologies like 4k and 8k resolution are also having a negative energy impact as their market share increases.

These trends are broadly corroborated from data collected in Japan as shown in Figure 33.

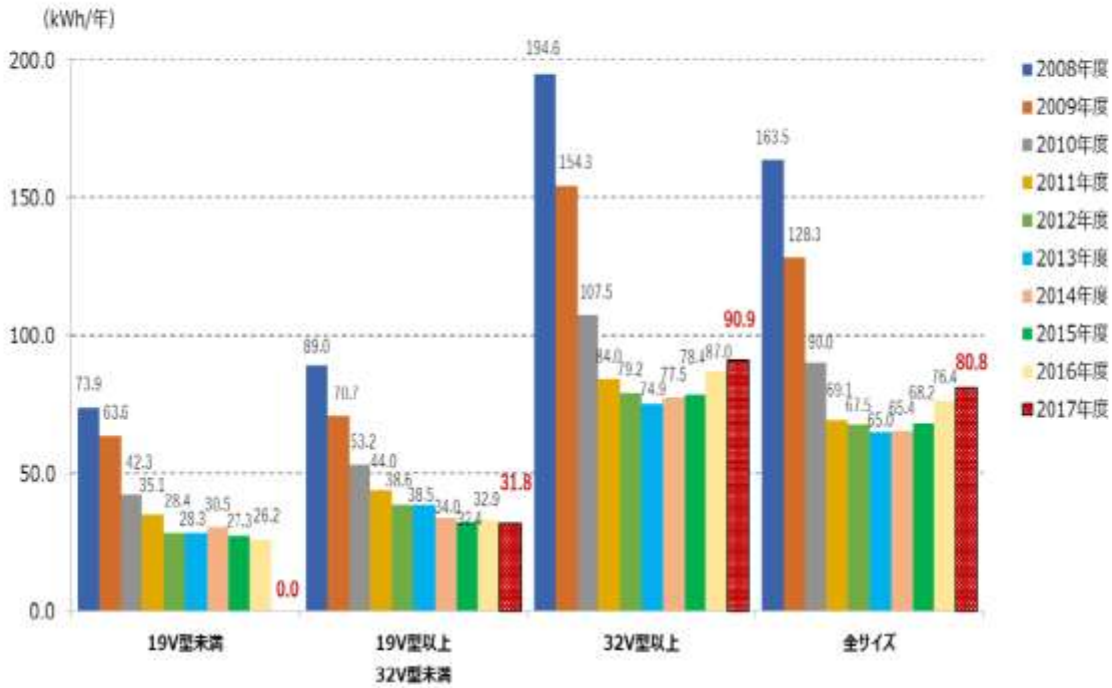

Figure 33: Changes in energy consumption by screen size in Japan 2008-2017

Figure notes: From the left the size ranges are <19", 19" to 32", greater than 32", and average of all televisions. Source Figure 3-11 Study 2210, REF278. This chart masks any sales share shift between sizes. An important point to note for this figure is that the improvement and then deterioration of energy consumption was well after the last Top Runner target, which was in 2008. Y axis in kWh per year energy consumption. Data is for the Japanese fiscal year (starts in April and ends in March).

While there are nominally 31 data records in the product analysis database for televisions, these cover all sort of periods around this technology change, which makes comparisons challenging. In broad terms, from 2009 to 2013 new televisions reduced their energy consumption by around 42% despite increases in screen size. Since 2013, energy has increased again and is now at a level that is comparable to 2009. It is evident that the size and energy service provided by today's television are substantially more sophisticated that those in 2010, but nonetheless, the energy consumption is still increasing.

It seems clear that S&L programs had a significant hand in forcing the energy efficiency improvements in televisions that were evident up to 2013. Quite a few countries had S&L programs for televisions, but attributing changes in global product development to any particular program or country is not really possible. At the height of the energy improvement phase, efficiency (defined as power per unit of area) was improving at a rate of 20% per annum for new products, which is extraordinary and far exceeds the rate of improvement of any other major appliance. It is tempting to claim much of this improvement as being due to the impact of S&L programs, but televisions in general and screen technologies in particular, are going through a rapid development and evolution phase, which is now resulting in an increase in energy consumption. This is despite the S&L programs that still remain in place in most countries. With such an initially fast improvement in efficiency in the early phases of regulation of televisions, it was hard to keep measures at stringent and effective levels. However, with screen sizes continuing to increase and energy consumption deteriorating per unit shipped, there has never been a more important time to revisit and upgrade S&L programs in an attempt to turn the tide on the current energy trends. Televisions are a product with large and growing stock numbers, so total energy consumption will also be growing faster if per unit energy consumption continues to deteriorate.

The reported historical changes in energy consumption of televisions are shown in Table 29. As noted above, these rates of change in energy vary wildly, depending on the time period included in the analysis, so this summary is only of minimal value.

Table 29: Average rates of energy improvement for new televisions – historical and trends

Records	15
New min rate per annum	-13.89%
New average rate per annum	2.41%
New max rate per annum	10.06%

Similarly, several studies projected stock energy savings, but all of these studies are dated 2016 or earlier so have not taken into account the rapid changes in size and technology that have occurred in recent years. The reported ex ante stock energy changes in energy consumption of televisions are shown in Table 30, but this summary is only of minimal value given the limitations of the data and the current changes.

Table 30: Projected average rates of energy reductions for the stock of television from new S&L measures – ex ante

Records	9
Stock min rate per annum	0.53%
Stock average rate per annum	1.84%
Stock max rate per annum	2.59%

Table notes: Source Studies 108, 2001, 2706, 2707.

3.5.7 Other products

As part of the data collection process, several other products were covered by the project data collection efforts. While some yielded useful data, some of these end uses present issues in terms of a traditional analysis of the impact of S&L programs. These are briefly discussed in the following sections.

3.5.7.1 Water heating

Water heating is a large energy user in the residential sector and is also significant in the commercial sector. However, water heating faces similar problems to lighting in that there are a wide range of technologies that can provide hot water, such as electric storage and instantaneous, gas storage and instantaneous, oil, heat pump and various types of solar thermal systems. The energy characteristics of all of these systems are very different, so most countries tackle water heater technologies one at a time and set separate S&L measures for each technology. For example, many countries set maximum heat loss standards for electric storage water heaters, which are worthwhile; however, heat loss typically only accounts for 10% to 30% of the total energy consumption. The only feasible way to reduce heat losses is to increase insulation thickness, which has other constraints (and still ignores the majority of energy consumption for this product). If a program tracks savings or efficiency improvements from this type of policy measure, they will necessary appear small (even negligible).

Some water heater types, especially solar thermal, and to a lesser extent heat pump types, are very sensitive to environmental operating conditions (such as incoming solar radiation and ambient conditions) and therefore performance can vary across regions, even within a single country. This makes even comparative labelling of these products complex.

The largest energy impacts occur when there is a technology change from say electric storage to heat pump or solar thermal. But as these products are usually regulated differently, substitutions that may occur due to information (like an integrated energy label) are not easy to track. Europe and North America, for example, have integrated energy labelling programs that allow consumers to compare energy (and possibly total operating costs) across technologies. But at this stage, cross technology standards that ban a certain technology from the market are relatively rare (for example, various countries have contemplated banning electric storage water heaters on an energy efficiency or energy consumption basis, but these are rarely successful). There are certainly restrictions on the installation of certain types of water heaters in some countries on the basis of efficiency or emissions (often for new homes), but prohibitions from sale are rare.

While there are some 36 records for water heating in the product analysis database, there are almost none that track the efficiency or energy of new products over time, largely because of the reasons outlined above. The SEAD study (Study 2001, REF138), developed ex ante stock savings estimates for seven countries covering a range of technologies and fuels. A summary of these results are shown in Table 31.

Table 31: Projected average rates of energy reductions for the stock of water heaters from new S&L measures – ex ante

Records	12
Stock min rate per annum	0.11%
Stock average rate per annum	0.89%
Stock max rate per annum	2.61%

Table notes: All records from (Study 2001) except for China (Study 2206). Higher rates were for South Africa for electric systems (heat pump) and for Mexico for gas systems.

A study for Europe (Study 2402) found that the stock of water heaters that use electricity is already improving by around 1.8% per annum by 2030 and for gas water heaters by a rate of 2.3% per annum as a result of the existing cross technology program under EcoDesign. The EU has a significant proportion of water heating from combi-boilers, which have achieved substantial energy efficiency improvements over the past 10 years. This change includes mapping of the substitution of water heater technologies over time (rather than just improvements within each technology).

3.5.7.2 Space heating

Space heating is also a large energy user in many countries in the residential and commercial sector. However, this is an end use that suffers from the same issues as water heating, in that a wide number of technologies are used for space heating and the mix is even more complex than water heaters. The other issue is that space heating (and space cooling) has substantial interactions with building shell performance and also with climate, so this makes setting up any sort of S&L program evaluation challenging. Nonetheless, there are very successful MEPS programs for specific product types such as gas boilers and furnaces. Again, these tend to be quite product specific and even climate specific to some extent. There is also a large overlap with air conditioners, most of which can provide a highly efficient space heating function in many climates.

There are nominally 46 records for space heating in the product analysis database, but almost none that track the efficiency or energy of new products over time. One study found that historical gas boiler new product efficiency improved by 0.54% per annum from 1983 to 2014 (Study 2612). There were some general data from Japan, but this was not specific to any technology.

The SEAD study (Study 2001, REF138), developed ex ante savings estimates for USA, Canada and the EU. Most records were in fact for different product sub-types in the USA. The average stock improvement rate for different electric furnaces was 1.93% per annum (8 records) but only 0.1% for gas and oil boilers. For Canada gas and oil boilers were found to have a stock improvement rate of 0.05% per annum for two types. For the EU it was found that the stock improvement rate for gas boilers was 0.24% per annum. In Japan, the improvements rates for gas and oil space heaters were very low, even across Top Runner target periods (new oil space heaters achieved a 0.9% per annum improvement over the Top Runner target years from 2000 to 2006) (REF036, Study 2215). New gas and oil space heaters only improved at a rate of 0.17% and 0.37% respectively over the period 2000 to 2016 (REF283, Study 2217).

Study 2402 for the EU found that the stock improvement rate was 0.73% per annum for electric space heating.

3.5.7.3 Transformers

For this study, transformers means those used by electricity distribution companies and typically operate at voltage of 6kV and above and have powers of 10kVA and above. There are nominally 26 records for transformers in the product analysis database, nearly all from two studies (Study 2001 and 2402). Both tracked the impact on stock energy consumption from new S&L programs (usually MEPS, but also related high efficiency programs). The SEAD study (2001) made stock energy impact estimates from the USA (1.6% per annum), the EU (1.31% per annum) and India (1.44% per annum). A study from China put ex ante impact at 0.02% per annum (Study 2602). The EU stock energy impacts from Study 2402 were 0.71% per annum to 2030.

3.6 Results for all main product groups

Table 32 show the rates and levels of energy improvement for the entire set of data entries in the S&L database for the four key product groups of: domestic cold appliances, non-ducted air conditioners (essentially room air conditioners), lamps and electric motors. For domestic cold, lamps and motors, the annual data tracks changes in energy consumption ignoring changes in size or capacity. For air conditioners, most data reported was in terms of efficiency, so only efficiency is reported in this section. Given that trends in air conditioner capacity are rarely reported, it is not clear whether these efficiency improvements will fully translate directly into energy reductions (they would if average capacity remained constant). Stock changes take into account changes in capacity (including for air conditioners) as well as changes in the stock of installed products. Moving from the third column to the sixth in the table shows the average, minimum and maximum values reported in the data set for:

- the annual new rate - the annual rate of energy improvement (reduction) over the policy period for newly sold products (energy efficiency for new air conditioners as noted above)
- the total change new – the total change in energy of new products over the policy period (energy efficiency for new air conditioners)
- the annual rate stock - the annual rate of energy improvement (reduction) over the policy period for the stock of installed equipment
- the total change stock – the total change in energy consumption of the stock of products over the policy period.

Table 32: Rates and levels of energy improvement for four major product groups

	Analysis period years New (stock)	Annual new rate (%)	Total change new (%)	Annual rate stock (%)	Total change stock (%)
Domestic cold appliances					
Average	14.1 (19.0)	2.3%	30.2%	1.0%	22.0%
Minimum	2 (2)	-0.2%	-1.9%	0.1%	1.6%
Maximum	40 (35)	8.2%	73.5%	1.9%	63.8%
Non-ducted air conditioners (1)					
Average	9.2 (17)	2.9%	27.4% (2)	0.6%	13.0%
Minimum	2 (1)	0.2%	1.4% (2)	0.1%	0.8%
Maximum	35 (30)	7.9%	132% (2)	2.1%	83.8%
Lamps					
Average	(19.8)	N/A	N/A	0.83%	21.6%
Minimum	(7)	N/A	N/A	0.03%	0.21%
Maximum	(31)	N/A	N/A	2.19%	68.6%
Electric motors					
Average	(16.5)	N/A	N/A	0.22%	3.7%
Minimum	(6)	N/A	N/A	0.03%	0.6%
Maximum	(21)	N/A	N/A	1.97%	34.0%

Table notes: (1) Annual rate of new improvement for air conditioners is efficiency, while the annual rate of stock improvement is energy. (2) Value of 132% is a total efficiency improvement over the period.

Note that the annual stock rate energy improvements (reductions) are the improvements which are attributable to the effect of the MEPS and labelling programs. This means that they should have taken account of and set aside any efficiency improvements that would have occurred without the policy measures coming into effect, including stock changes. Accordingly, they are not reporting simple improvements in product energy improvement. Overall trend data (without attribution) would ordinarily show higher annual rates of improvement than the values reported in the table for stock improvements because they will include the impact of autonomous energy efficiency improvement in addition to those attributed to the policy measures itself.

The results in Table 32 confirm that, for all of these products, MEPS and labelling policies are leading to faster energy efficiency improvements than would occur in the absence of such policy measures. For new domestic cold appliances (refrigerators, freezers and refrigerator-freezers) the average annual rate of energy reduction due to MEPS and labelling of 2.3%, while for non-ducted air conditioners the annual rate of efficiency improvement is 2.9%. This means that over a ten year period on average new domestic cold appliances will consume 18% less than they would have done without the policy measures and 33% less over 20 years. For air conditioners the corresponding savings in energy consumption are 22% and 40% of the BAU case (assuming constant capacity).

The rate of improvement of the energy consumption of the stock of products can vary at a different rate to that of new products. In the dataset, the average annual rate of improvement of the stock due to MEPS and labelling is 1.0% for domestic cold appliances, 0.6% for non-ducted air conditioners, 0.83% for lamps and 0.22% for electric motors. If sustained over 10 or 20 years these would lead to the following reductions in total stock energy consumption:

- Domestic cold appliances – 10% (10 years), 22% (20 years)
- Non-ducted AC – 6% (10 years), 13% (20 years)
- Lamps – 9% (10 years), 18% (20 years)
- Electric motors – 2.2% (10 years), 4.5% (20 years).

Direct comparison of stock data with the new product efficiency data is problematic because the parameters recorded are rarely the same – in most of the studies the efficiency is either reported for new products or (more commonly) for the stock of products, but not for both. Nonetheless, it is possible that these data vary as they do partly because:

- Average new savings, where reported, are for new products entering the market each year. Stock energy reductions are for the stock of all installed products. The latter takes into account increasing numbers of appliances and equipment in use over time (from household and population growth and increased ownership) so will necessarily appear smaller than changes in an average new product. If the new improvement rate was steady for more than the lifetime of the product and the stock of products installed was static, these two numbers would eventually converge. But improvement rates for new and the installed stock never remain static for any length of time in practice.
- Domestic cold appliances have been regulated for a long time and the efficiency improvements from new regulations are not leading to such significant step changes in efficiency as occurred in the past – therefore the new products are showing smaller rates of annual improvement than the stock of products due to the impact of the earlier rounds of regulations still working their way through the stock.
- For air conditioners, older regulations tended to only affect the full load efficiency where the scope for improvement was rather limited, whereas newer regulations are tending to address the part-load efficiency (typically through seasonal ratings), which has a higher technical scope for improvement – which could explain why the average rate of improvement of new products is higher than that recently observed in the stock.
- For lamps, the comparatively modest rate of average improvement in the stock efficiency may be explainable by the limited number of sources in the dataset (33 covering all parameters) and the challenge of attributing efficiency changes to MEPS and labelling policy impacts when a fundamental technology transition and substitution is underway (the move from incandescent and fluorescent lighting to solid state lighting). There is much discussion about what impacts should be attributed to S&L and it is quite possible that conservative assumptions are being made because many of the studies reported savings from specific lighting components rather than for lighting as an end use overall. There is no doubt that

actual overall energy improvements in lighting are running much faster than the limited number of evaluations compiled for this study has shown.

- For electric motors the seemingly modest annual efficiency improvement rate reflects the relatively limited scope of known technological options to improve motor efficiency compared to the other products and that, with one exception, the MEPS and labelling measures currently in place apply to the motor itself and not the motor and drive combination (which would unlock much greater technical savings potentials); however, motor energy use is so significant that even relatively modest percentage efficiency gains lead to very large savings.

Table 33 shows the equivalent data for all the other major product groupings in the database.

Table 33: Rates and levels of energy efficiency improvement for other major product groups

	Analysis period (years)	Annual new rate (%)	Total change new (%)	Annual rate stock (%)	Total change stock (%)
Central AC					
Ave	15.0	1.1%	13.6%	0.16%	2.7%
Min	12	1.1%	13.6%	0.1%	1.1%
Max	18	1.1%	13.6%	0.5%	9.2%
TVs					
Ave	16.9	3.0%	16.5%	1.8%	35.3%
Min	10	0.5%	4.5%	0.5%	11.2%
Max	20	6.7%	38.3%	2.6%	54.4%
Transformers					
Ave	13.8			1.2%	18.0%
Min				0.0%	0.3%
Max	20			2.2%	55.8%
Wet appliances					
Ave	14.5	2.5%	48.9%	1.0%	15.3%
Min	5	0.1%	1.1%	0.0%	0.2%
Max	20	6.4%	85.3%	3.0%	52.4%
Water heaters					
Ave	12.7			1.6%	17.5%
Min	2			0.1%	0.3%
Max	19			4.9%	43.4%
Space heaters					
Ave	13.1			1.2%	13.6%
Min	2			0.0%	0.4%
Max	20			3.2%	37.0%

	Analysis period (years)	Annual new rate (%)	Total change new (%)	Annual rate stock (%)	Total change stock (%)
Ventilation/fan					
Ave	14.4	3.4%	22.5%	1.0%	15.7%
Min	4	3.4%	22.5%	0.1%	2.2%
Max	19	3.4%	22.5%	2.0%	40.0%
Cleaning appliances					
Ave	22.5			1.3%	31.6%
Min	13			1.0%	18.2%
Max	34			2.6%	41.2%
Cooking appliances					
Ave	13.2	2.3%	24.4%	0.9%	13.6%
Min	2	1.4%	10.5%	0.0%	0.6%
Max	20	3.1%	45.0%	3.9%	64.5%
Chillers					
Ave	4.8			1.6%	32.6%
Min				1.6%	32.6%
Max	18			1.6%	32.6%
Commercial refrigeration					
Ave	16.0			1.5%	26.5%
Min	13			0.7%	11.9%
Max	18			3.7%	60.6%
Vending machines					
Ave	18.3	5.6%	36.2%	2.5%	55.8%
Min	18	-0.2%	-1.4%	1.5%	33.9%
Max	20	12.2%	58.3%	2.7%	61.3%
Computing					
Ave	15.1			1.2%	14.1%
Min				0.4%	7.3%
Max	18			3.6%	23.3%
Pumps					
Ave	16.0			1.6%	29.9%
Min	11			0.3%	4.3%
Max	19			3.3%	61.8%

	Analysis period (years)	Annual new rate (%)	Total change new (%)	Annual rate stock (%)	Total change stock (%)
Other electronics					
Ave	18.1	8.4%	51.4%	1.8%	37.6%
Min	6	4.7%	13.0%	0.2%	3.3%
Max	27	13.0%	98.2%	4.8%	80.6%
Miscellaneous					
Ave	13.5			0.3%	5.1%
Min	6			0.2%	1.0%
Max	21			0.4%	8.3%

Figure 34 shows how the annual rate of improvement in stock energy improvement (reduction) varies by main product grouping, while Figure 35 shows how the stock energy improvement (reduction) rates compare to the new product energy improvement rates for the same set of product groups. As would be expected for most product groupings, the new product energy improvement rate is higher than the stock energy improvement rate – which reflects that in most cases the impact of the policy measure takes time to work its way through the stock and within the database there are a number of new programs and somewhat less mature ones. In the sole case of TVs the stock energy is improving faster than the new energy improvement rate – this probably reflects the large impact of the technology shift towards solid state flat screen technology from 2010 to 2014 and the coincidence of this with past and new policy settings. The stock energy number also accounts for increases in the number of units in operation so will usually be smaller because of this factor. Figure 36 shows the typical total stock energy reductions that can be achieved by each product type, based on the data collected over a typical program analysis period (15 to 20 years). While the potential energy savings do vary by product type (due to differences in technical potential and other nuances regarding S&L implementation), the figure shows that energy reductions of 10% to 30% over moderate timeframes have been achieved by most countries. Ambitious targets are more likely to yield energy reductions that are closer to the maximum values.

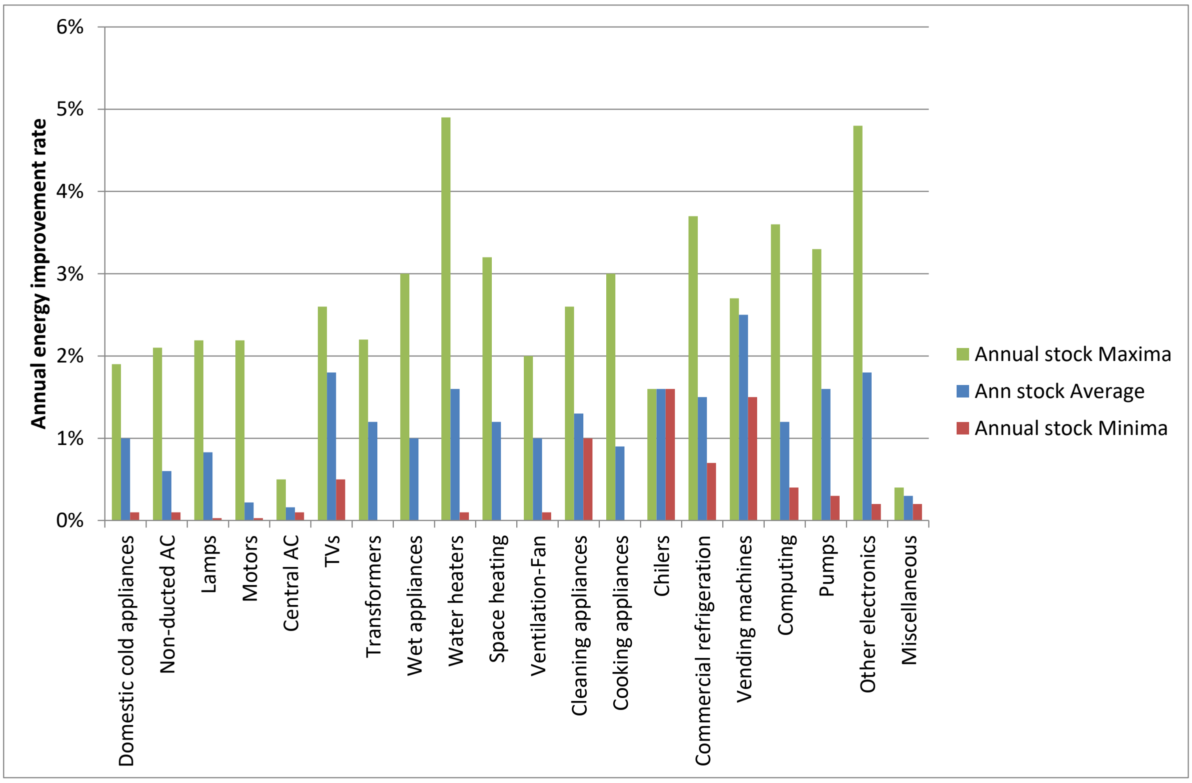

Figure 34: Annual rate of improvement in stock energy consumption by main product grouping

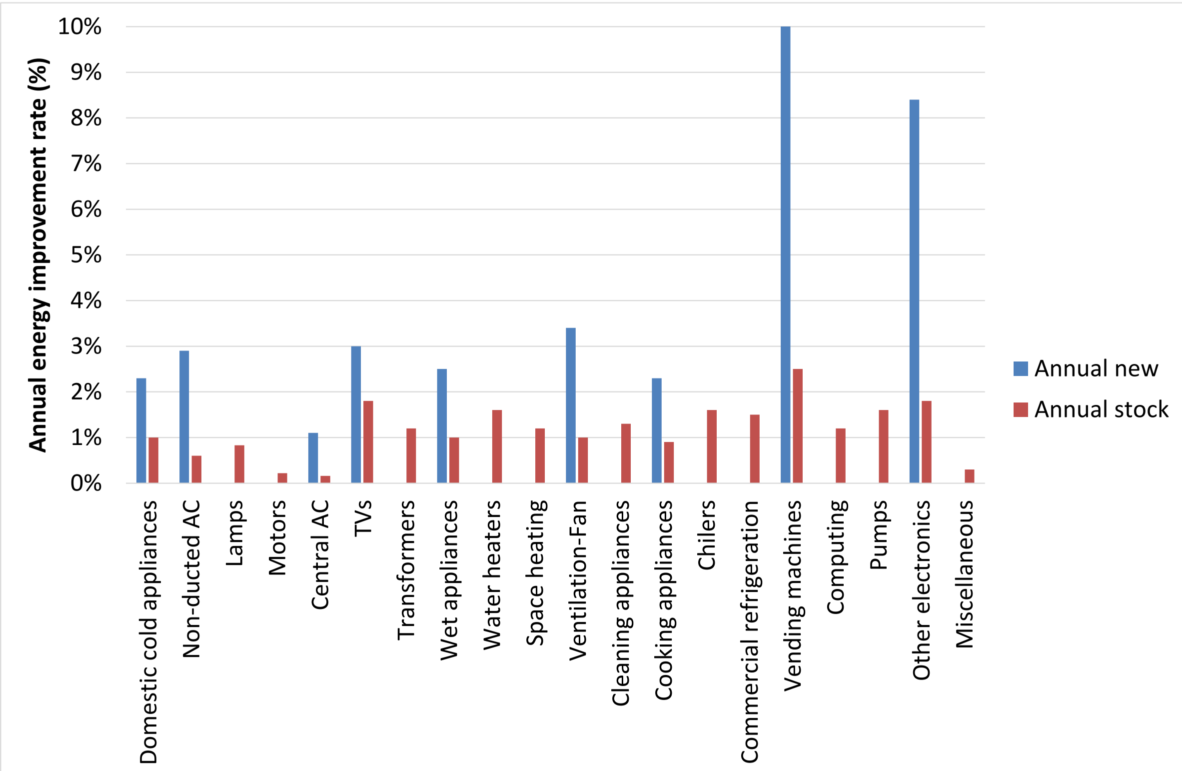

Figure 35: Annual rate of improvement in new product and stock energy consumption by main product grouping

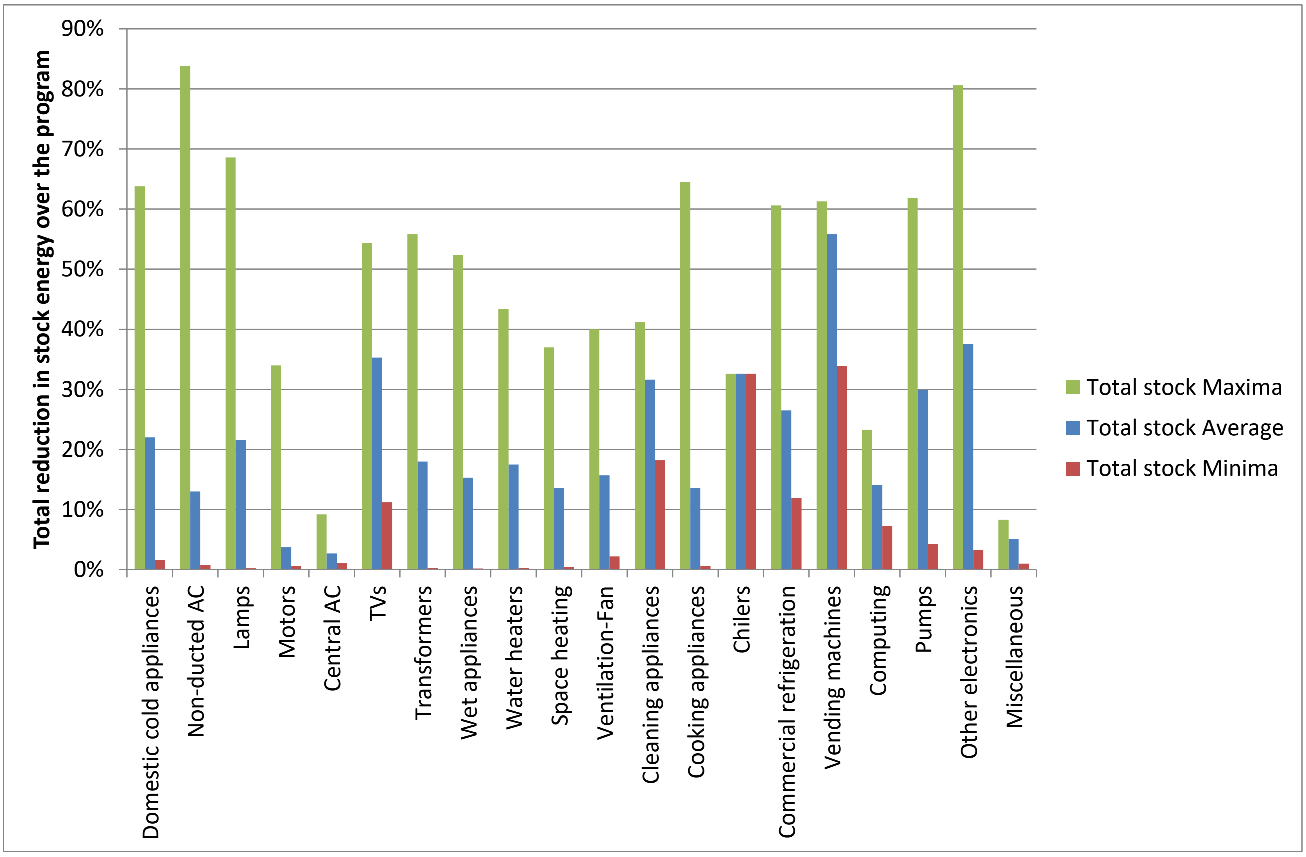

Figure 36: Total change in stock energy consumption by main product grouping over typical program duration

4 Achievements of S&L – costs and benefits

4.1 Overview

This section examines the evidence regarding the costs and benefits arising from S&L programs across many jurisdictions. While there are potential secondary benefits that accrue from energy efficiency (see next sections), this section focuses on two main areas. The first is reductions in energy purchase costs as a result of reduced energy consumption from S&L programs. If energy impacts can be accurately estimated and energy costs are known, then a clear benefit for the consumer can be estimated. The second component is the increase in costs associated with S&L programs. Typically, program costs (i.e. the costs to design and implement the program by regulatory bodies) are very small to negligible, and while many cost benefit studies explicitly include these in the overall assessments, they are not directly borne by consumers. The main costs included in cost benefit studies are increases in purchase costs associated with more efficient appliances and equipment. For an energy labelling and information type program, these costs are often small to negligible as normal market forces will be at play. Where costs for a stringent MEPS level are being estimated, there can be price impacts over a short period. This is a more complex area because making ex ante estimates of likely purchase cost increases are difficult due to the many unknowns. This issue is examined in detail in Section 4.3.

Most cost benefit analyses are focused on the decrease in direct energy costs and the increase on product purchase cost from the perspective of the consumer. There are of course other secondary benefits, such as reduced pollution as a result of reduced energy consumption (particulates, SOx and NOx, greenhouse gas emissions) as well as macroeconomic impacts from consumers having more disposable income from reduced energy bills. These larger scale impacts can be quantified when a total societal cost perspective is taken, but most cost benefit studies do not tend to include these factors in their core calculations (except for the shadow cost of greenhouse gas emissions, which are commonly included). Some of these broader issues are covered in later sections.

The other consideration is that cost benefit analyses are often (but not always) conducted by or for government bodies. Each government has its own requirements regarding what has to be included, time horizons and economic settings like discount rates. These factors vary somewhat by jurisdiction and the authors have not attempted to examine and compile these differences. Typically, most cost benefit analyses would look at total energy consumption costs (and emission costs if included) at forecast emission intensity rates and tariff escalation rates (in real terms, if any) and then determine a net present value at a specific discount rate. The same calculation is undertaken for BAU and the “with measures” case with increased equipment purchase costs. Discount rates are important as they indicate a time preference for money – higher discount rates greatly devalue future energy benefits from energy savings (making savings look less attractive) relative to capital and up-front costs. Governments tend to use moderate discount rates for S&L programs (typically in the range 3% to 7%) but this does vary by government. Given that S&L programs can be seen as investments in public good, there is a strong case for using discount rates at the lower end. Some countries use a discount rate of close to 0% for long term projects like building shell upgrades, but this may not always be appropriate for the range of appliances and equipment covered by the present study.

4.2 Impacts on end user energy costs

Section 3 sets out a wide range of evidence of energy impacts and stock energy reductions that arise from S&L programs. Such programs are now in place in more than 100 countries around the world and many of these programs have been running for as long as 40 years. As a result there is now a good deal of expertise, knowledge and skill with regard to program design and evaluation such that accurate estimates of future BAU and with policy measure energy consumption estimates can be developed for the medium term. Projections are more difficult for a newly regulated product because of lack of data and experience. But many products like domestic cold appliances and air conditioners have been re-regulated many times in many countries, so there is the ability to fine-tune future estimates based on past experience. This approach is common for well-established S&L programs. Organisations like the CLASP and United4Efficiency (U4E)[24] have a range of resources to help countries develop and upgrade their S&L programs such as the labelling and standards guidebook (CLASP 2005)(being updated in 2021), the CLASP policy impacts calculator[25], the CLASP S&L policy tool database[26] (CLASP 2021) and the and U4E's model regulations[27] for S&L programs.

In order to convert energy consumption[28] to energy costs, current and future energy tariffs need to be projected over the modelling period. Sometimes there is an assumption about whether future energy prices increase or decrease in real terms from today (escalation or de-escalation). This allows a future cost stream to be calculated for both the BAU and the "with S&L measures" case. These future energy cost streams are then turned into a net present value at the specified discount rate, giving total future costs for both BAU and the "with S&L measures" case.

Where a cost is assigned to avoided future greenhouse gas emissions from future energy reductions, then the emissions associated with the stock of BAU and the "with S&L measures" cases are also calculated. This requires a future emissions intensity profile to be projected for the relevant energy sources. A current and future shadow cost of emissions is then overlaid onto the emissions stream for both cases to generate a set future emissions costs stream. This is also then brought back to a net present value at the specified discount rate.

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[24] See https://www.clasp.ngo/ and https://united4efficiency.org/

[25] See https://www.clasp.ngo/tools/mepsy/ - this tool also includes a stock model.

[26] See https://clasp.ngo/policies

[27] See https://united4efficiency.org/resources/model-regulation-guidelines/

[28] To estimate total future energy impacts, a product energy stock model is usually deployed. This calculates the total energy consumption of the BAU case for the specified time horizon (typically 15 to 30 years). The stock model then also calculates the future energy profile for the "with S&L measures" case. See free CLASP tool that includes a stock model https://www.clasp.ngo/tools/mepsy/

Calculation of future energy costs is relatively straightforward if the energy projections are reasonable and accurate. In general terms, this is the least complex part of the cost benefit process.

4.3 Impacts on overall equipment purchase costs

4.3.1 Overview of purchase cost issues

The traditional view of energy policy experts is that, all other things being equal, if the efficiency of a particular product is forced-up (through MEPS) so that it is better than the average market offering, then the average price of that equipment type will increase in response. This is because the prevailing assessment of economists is that there is (or must be) a correlation between price and efficiency, which exists in a perfect market. While this can be true in real markets, there are a range of complex factors that can confound this simple concept.

There are many factors that affect the retail price of a product, which is what the consumer sees. These include:

- Product quality, style and appearance
- Brand name and reputation (including reliability)
- Advertising and market awareness
- Market competition
- The cost of manufacture
- Ancillary or secondary services
- Retail margins.

The impact of a more stringent MEPS level, for example, may have some impact on the cost of manufacture, but this is just one of many factors that affect market price. The starting point for most economists undertaking a cost benefit analysis is that they can establish a correlation between price and energy or price and efficiency.

There are other complexities to consider. Even where a relationship between price and energy can be established at a particular point in time, this may not be applicable into the future. There is a large body of evidence that shows that real prices have been declining fairly quickly for many decades while energy consumption has also been declining in parallel (Ellis et al. 2007; Weiss et al. 2010; Energy Efficient Strategies 2016). So any relationship between price and energy has to be considered within the bubble of ongoing price and energy reductions into the future. There is also strong evidence that new future stringent regulations can trigger innovation by manufacturers to meet any new requirements at a lower than expected cost. A few retrospective studies show that the expected price increases from MEPS increases did not occur at all (or were barely detectable) and one US study showed that both long term prices and life cycle costs decreased more rapidly under regulation than without (this is examined in a later section).

4.3.2 Relationship between price and energy use

While many analysts have attempted to establish a relationship between price and energy use over the years, often with very good datasets, the results often demonstrate that these two variables are usually weakly correlated.

A study from Sweden in 2014 illustrated the relationship between energy and price for a fairly narrowly defined size and type of refrigerator, as shown in Figure 37. While there is clearly some relationship between price and energy, the correlation coefficient is quite low (R^2 not stated) (more than a five-fold variation in price for a given energy consumption). Note the very narrowly defined product type, size range and timeframe.

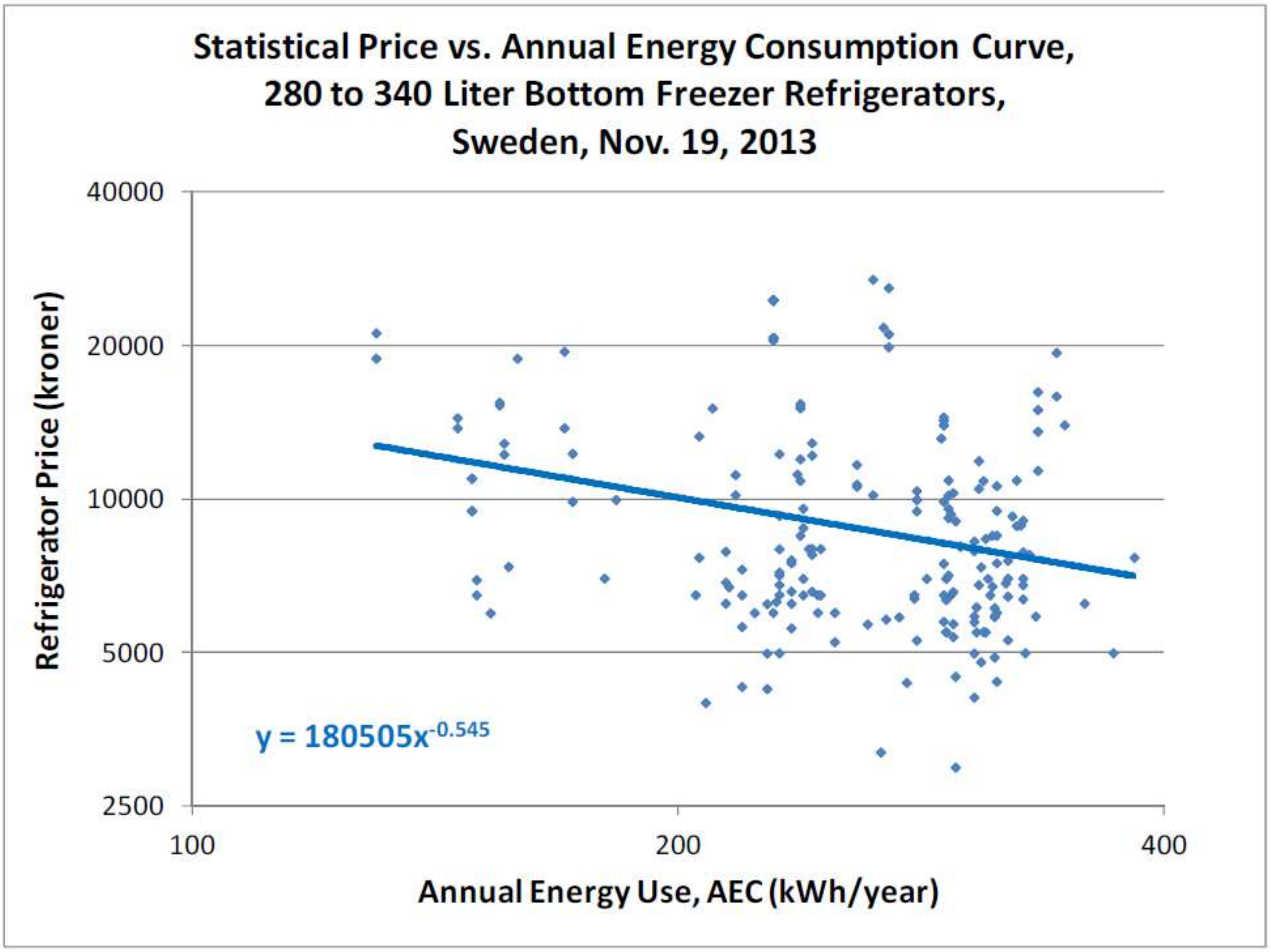

Figure 37: Illustration of the statistical determination of a price-efficiency curve based on real-time market data

Figure notes: logarithmic scale on both axes. Source Study 41.

A detailed analysis of the price and energy consumption of the refrigerator market in Australia was undertaken in 2016 based on 2013 sales data. This data set covered actual price paid and more than 95% of product sales in Australia in that year. The approach used was to ascertain a relationship between volume and energy and volume and price for each type of refrigerator defined in the standard (10 types overall). Then a function of standardised price and standardised energy use was developed. The standardised price determined whether each product was more or less expensive than an average product of that size. The standardised energy use determined whether each product used more or less energy than an average product of that size. A standardised price of less than 1.0 meant that it was cheaper than average for the size, while a standardised energy of less than 1.0 meant that it used less energy than average for the size. A regression of standardised energy versus standardised price was then conducted. The novel aspect to this analysis was that data points for the energy – price regression were weighted by sales of the model for the year. This meant that the resulting linear regression line was pulled much more towards models with higher sales than models with fewer sales. A sales weighted regression was also used to determine the functions of volume and price and volume and energy. The advantage of this approach is that it allows all sales records to be included. Models that sell for a very high price (typically custom or built-in models) but with few sales have only a small impact on the overall regression. The results are illustrated for the largest selling product type in Figure 38.

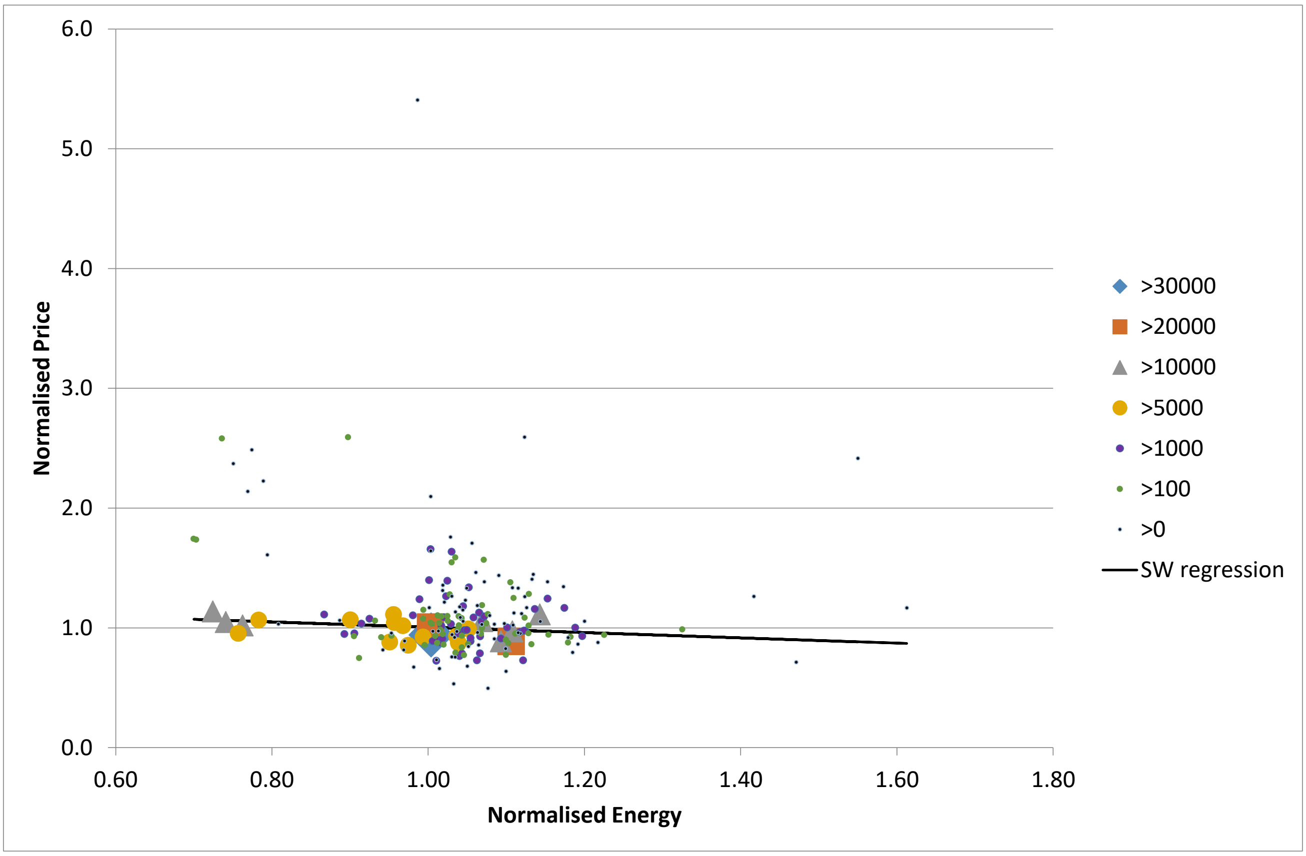

Figure 38: Sales Weighted Regression of Normalised Energy Versus Normalised Price for Group 5T, in Australia, 2013 sales

Figure notes: source Figure 65, Study 1041. Group 5T is a frost free refrigerator-freezer with a top mounted freezer. The size of each point reflects the sales in that year as shown in the legend. The sales weighted linear regression takes into account the sales of each data point in addition to its X and Y location. In this case, a 20% reduction in energy consumption (0.8 normalised energy) would, on average, be expected to result in a 4.4% increase in purchase price.

As can be seen in Figure 38, the resulting regression line sits tightly through all of the largest selling models, depicted with larger circles. An analysis of all 10 refrigerator types revealed interesting data about the relationship between price and energy for Australian refrigerators, as shown in Table 34

Table 34: Normalised Energy–Normalised Price Regressions by Domestic cold type in 2013, Australia

Group	Group Description	Energy-Price Slope	Intercept	R^2	Models	Comments
1	All refrigerator	-0.911	1.928	0.032	47	Negative slope, low R^2
2	Refrigerator with ice box	-0.288	1.291	0.041	80	Negative slope, low R^2
3	Refrigerator/short term freezer	-1.553	2.566	0.202	6	Too few models
4	Refrigerator-Freezer cyclic/manual	-2.199	2.647	0.078	6	Too few models
5T	Refrigerator-Freezer frost free (freezer@top)	-0.222	1.227	0.027	154	Negative slope, low R^2
5B	Refrigerator-Freezer frost free (freezer@bottom)	0.613	0.409	0.020	206	Positive slope, low R^2
5S	Refrigerator-Freezer frost free (side/side)	0.187	0.814	0.004	91	Positive slope, very low R^2
6C	Chest freezer	0.079	0.924	0.002	38	Positive slope, very low R^2
6U	Vertical freezer man defrost	-1.615	2.613	0.400	68	Negative slope

Table notes: Refrigerator group is defined in (AS/NZS4474. 1 2007). Source Table 9, Study 1041. A negative slope is expected for a regression of price versus energy use. A positive slope means more expensive products use more energy.

Even with comprehensive sales and price data for nearly all models on the market (representing more than 1 million products sold in 2013), the detailed analysis shows that the correlation between price and energy is very weak, at best. Three types of products had a positive slope, which is opposite to what is expected (i.e. more expensive products used more energy) – this is likely to be associated with additional features such as through the door ice and water and multi/split door configurations. If used in a regulatory assessment, this positive slope data would yield lower purchase costs from more stringent MEPS levels, resulting in negative costs of regulation at all stringency levels. Even where there were a substantial number of models in the data set and the regression slope was negative (as expected), the sales weighted regression correlation coefficient (R^2) was less than 0.05 for all types (except for Group 7), meaning, in simplistic terms, that energy explains less than 5% of the variation in price in the sample.

So determination of a realistic function of purchase cost versus energy consumption (or efficiency) based on sales data is non-trivial. Many larger economies undertake so called techno-economic energy engineering analysis of the costs of manufacturing to meet proposed future MEPS levels. This is common in the USA and in Europe, where significant resources are available to undertake these types of analysis. To get realistic estimates of base costs, a technical assessment of current technology in use has to be made (all components, design and construction and costs of manufacturing). This of course can only be done for some representative models on the market. The engineering assessment then proposes a range of technical changes to these standard product designs that should improve the energy consumption. For example, in the case of refrigerators, an engineering analysis would look at more efficient compressors, use of variable speed drives, improved insulation (better foaming, vacuum panels), improved controls and temperature balance, improved gaskets and seals and so forth. Each of the improvements should reduce the energy consumption by a defined amount, based on the typical market design. However, each technical change will have different costs and different energy impacts. So typically each change is assessed independently in order to determine their relative cost effectiveness. Changes are then added in sequence from the most cost effective to the least cost effective to generate a life cycle operating cost curve (noting that each impact is not additive – it depends on previous measures already adopted). The optimum combination of measures is then usually taken as the minimum life cycle cost e.g. see design option 8 in Table 35.

Table 35: Illustration of techno-economic analysis for a two-door direct cool refrigerator-freezer

Design Option	Energy consumed kWh/year	Energy saved kWh/year	Improve over last option %	Purchase Price USD $	Delta Purchase Price USD $	Manu-facturing cost USD $	Value of Electric-ity[1] USD $	Electricity Savings USD $	LCC USD $	Pay-back period years	Net Volume litres	Volume corrected LCC USD $	EEI
Base-case	747	0	0	430	0	188	90.2	0.0	1367	0	184	1367	128
1	645	101	14	440	288	189	78.0	-10.4	1249	3	184	1249	111
2	597	48	7	440	288	189	72.2	-16.3	1189	1.9	184	1189	102
3	547	50	7	452	403	199	66.2	-22.3	1139	2	184	1139	94
4	410	137	19	552	1306	230	49.6	-38.9	1066	3.7	184	1066	70
5	250[1]	160	22	541	1207	241	30.2	-58.2	854	2.3	175	882	44
6	204	46	6	541	1213	241	24.6	-63.8	797	2.1	173	829	36
7	169[2]	35	5	545	1243	243	20.3	-68.1	756	2	161	818	31
8	132	37	5	545	1247	243	15.9	-72.5	710	1.9	161	743	24
Design option with less certain impacts:													
9	111	21	3	1007	5447	426	13.4	-75.1	1146	8	161	1209	21

[1] The value of electricity is the annual operating cost

Source: Source: Protocols To Conduct Market And Impact Assessments (United for Efficiency 2021).

While this approach is technically sound, it is quite resource intensive and, in reality, only the largest and best resourced economies will be able to undertaken such an analysis. This is why it is critical that large economies take an active role in the development and implementation of progressive S&L programs, as it allows other countries to follow in their wake and adopt and adapt these program measures to their local conditions. Approaches that countries can take to adapt the findings of such techno-economic energy engineering analyses to help design their own S&L policy settings is discussed in the reference for Table 35.

4.3.3 Equipment price reductions in time

As noted previously, there is a large body of evidence that shows that long-term appliance purchase prices are generally declining in real terms while products are also becoming more efficient at the same time (Michel et al. 2015, 2017; Weiss et al. 2010).

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[29] fell by 21% over this period, or 2.3% per annum (Study 1026)[30]. 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) (Study 1026, 2406).

Average real washing machine prices across the EU 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) (Study 1026, 2406).

In Australia, the real price decline in new refrigerators, washing machines and dishwashers sold between 1993 and 2014 is shown in Table 36, alongside the corresponding reduction in the average energy consumption over the same period (Study 1041).

Table 36: Long term trends in average energy consumption and real purchase price in Australia for new whitegoods

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. Source: Study 1041.

US 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

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

[30] 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.

societal benefits. It suggests that some regulatory analyses approaches currently used do not accurately project future technical change in industries subject to regulation (Taylor, Spurlock & Yang 2015).

Australian refrigerator prices declined by between 1.8%-4.4%[31] per annum in real terms between 1993 to 2017, and this trend did not change around the introduction of MEPS in 2005, which resulted in a 25%-35% reduction in energy consumption (Study 10, Study 2702).

A study in Sweden also shows an upward trend in efficiency whilst product prices were falling (Study 42). Similar long-term declines in real product prices have been observed in reliable studies from the USA, Japan, UK (Ellis et al. 2007), Australia (Study 1041) and the EU (Study 43).

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 37) (Study 6)[32].

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 (Study 3).

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 washers in the USA in Figure 39.

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[31] The range in the declining rate of prices and energy consumption reflect different categories of refrigerators (Study 2702).

[32] 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.

Table 37: Comparison of predicted and actual price increases from US MEPS

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

Table notes: Source Study 6.

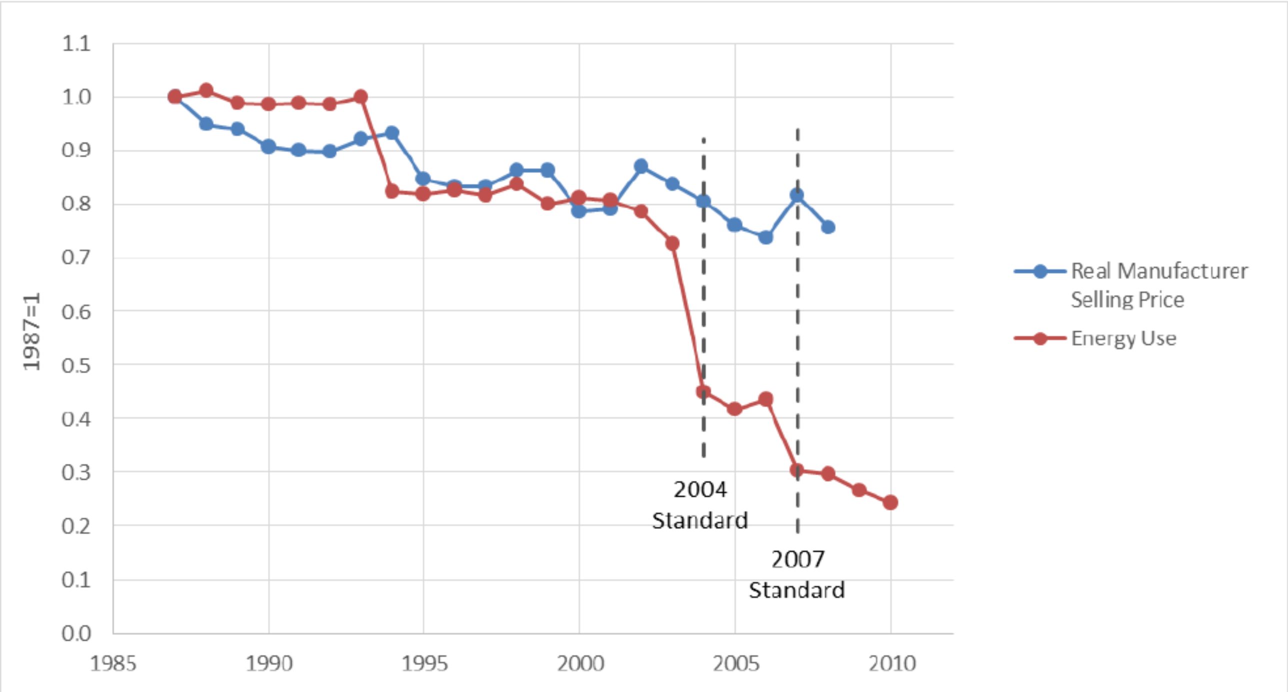

Figure 39: Price and energy trends for clothes washers in the USA

Figure notes: Source Study 6.

Similar data from Australia shows that real prices and energy use declined in parallel for 25 years as shown in Figure 40.

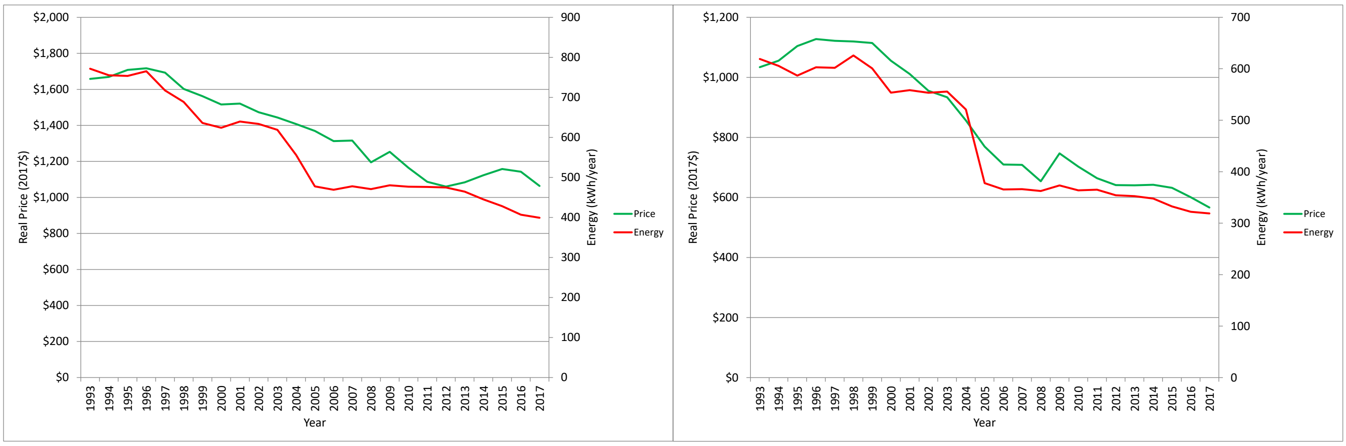

Figure 40: Long term changes in refrigerator energy and price (left) and freezer energy and price (right) in Australia

Figure notes: Source (E3 2017).

These findings indicate that it would be cost-effective for S&L 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[33] (as proposed for the USA) (Desroches 2013; US Department of Energy 2011). An environment of reducing appliance purchase costs and increasing energy costs will push the cost effectiveness threshold for energy efficiency to significantly higher levels.

For the present study, the Document Analysis Database holds some 55 records that illustrate cost reductions over time. Many of these records are already illustrated in the previous text, tables and figures. The price data for major product groups is summarised in the following tables.

[33] Learning curves (also called experience curves, which is a similar approach using slightly different parameters) is a technique that uses historical cumulative shipments (sales) of a product to more accurately characterise the historical real price trends in order to more accurately predict future real prices. The learning rate parameter “b” is used to calculate a so called “learning rate” for a product. For example, analysis for the US indicates that the learning rate for household refrigerators is 0.52, which suggests that the expected real price will fall by 52% for each doubling of cumulative shipments (US Department of Energy 2011). Depending on the base year, it can take some decades to double the cumulative shipments on an established product like a refrigerator. Numerous papers set out the rationale and technicalities of this approach when applied to S&L programs for appliances and equipment, which is widely considered as a best practice regulatory approach (Desroches 2012, 2013; Weiss et al. 2010).

Table 38: Long term historical price declines for domestic cold appliances

Records	15
New min rate per annum	0.68%
New average rate per annum	1.77%
New max rate per annum	5.30%

Table notes: All records were real cost decreases covering an average period of 22.4 years. Study 2603 (REF042) has been excluded as it contradicted other US data – this showed a price increase from 2003 to 2011, but the study was mainly examining quality issues.

There were only 3 records for air conditioners that covered price changes and all were from the USA between 1980 and 2010. The average annual decline in real cost was 2.2% per annum for these three records.

For electric motors there was no historical price trend data reported in the studies reviewed. For lighting the only reported value was for fluorescent lamp ballasts from 1995 to 2006 (3% real cost decrease per year). The EU analysis looks at total lifetime operating costs for lighting and this shows a 0.74% per annum cost decline for the stock for lamps in particular and a 0.33% per annum cost decline for the stock for lighting in general. There was some price data reported for wet products as set out in Table 39.

Table 39: Long term historical price declines for household wet appliances

Records	16
New min rate per annum	0.05%
New average rate per annum	2.29%
New max rate per annum	3.80%

Table notes: All records were real cost decreases covering an average period of 22 years. Study 2603 (REF042) has been excluded as it contradicted other US data – this showed a price increase from 2003 to 2011, but the study was mainly examining quality issues. Dryer prices fell at the average rate, clothes washers fell at 2.1% per annum and dishwashers fell at 2.5% per annum.

There were insufficient records in the Document Analysis Database to report meaningful price trends from the historical data for other products.

4.4 Overall net costs and benefits

The calculation of benefits (reduction in future energy costs, sometimes the value of reductions in greenhouse gas emissions[34] and calculation of net present value) is then undertaken as set out in the previous section. Also, the estimated equipment cost increases (noting all the attendant

[34] There is quite a variation across countries as to whether the reduction in future greenhouse gas emissions is included in the benefits calculated. This depends on the energy policy framework in each country. The benefits from emission reductions is a function of the energy savings, the emission intensity of the specific energy source and the projected emissions intensity of the energy source into the future (most important for electricity) as well as any direct cost or shadow cost of emissions. This future savings stream is then turned into a net present value using the relevant local discount rate.

difficulties and uncertainties associated with this aspect) as a net present value is also calculated. These calculations are undertaken for both the BAU case and the “with S&L measures” case. The difference between these two cases provides an estimate of net costs and net benefits for the S&L measure. Usually costs and benefits are summed for all years over a specified time horizon and a specified discount rate and converted to a net present value.

There are a number of ways that costs and benefits can be reported. Commonly both the net costs and net benefits (difference between BAU and “with measures”) are reported in absolute values. At this point of the calculation, many countries add in administrative and program costs to the overall cost equation. Some countries then report net overall benefits (total net benefits minus total net costs) to give a measure of absolute overall benefit from the S&L measure. However, this measure is still in local currency units, so is difficult to compare and depends on the number of products covered, which varies a lot by country. To allow meaningful comparisons across different countries and regions, it is most useful to turn these parameters in a more generic indicator of cost effectiveness. The most widely used indicator is the Benefit Cost Ratio (BCR) – total net benefits divided by total net costs. Where the BCR is over 1.0, then the program provides a net overall benefit. Where the BCR is less than 1.0, the overall costs exceed the overall benefit. Many countries require a minimum threshold of BCR for a program to be considered cost effective. While a useful generic measure, it provides no indication of the magnitude of the costs and benefits.

Many countries also undertake sensitivity analysis on the impact of different discount rates and also variations in the assumptions that go to make up overall costs and benefits. These are normal investigations, but these types of analyses have not been reported for this study.

Table 40 shows reported BCRs by economy. The reported data is the BCR value averaged across each set of products for which data is present in the database. With the exception of the EU, US and Australian data, these are not the BCR of the overall MEPS and labelling program as the data is not weighted by the value of the benefits and costs for each product assessed.

Table 40: Benefit Cost Ratios from S&L programs by economy

Economy	Benefit Cost Ratio averaged over all product groups	Notes on end years, products and discounting
Canada	5.1 (1)	Mix of 2030 and 2040, all regulated products
Australia	4.5	2030 – all regulated products
New Zealand	2.1(2)	2030 - just refrigerators
Fiji	2.6	2030, all regulated products
Samoa	9.4(4)	2030, all regulated products
Tonga	7.5(4)	2030, all regulated products
Vanuatu	12.6(4)	2030, all regulated products
Cook Islands	9.8(4)	2030, all regulated products
Kiribati	12.5(4)	2030, all regulated products
Japan	1.69	In 2020, 9 selected products(2)
EU	4.7	2030, all regulated products, not discounted
USA	5.3	2050, all regulated products

Table notes: This includes 31 products for Canada and these are shown in Figure 41. Note (1) The BCR for ceiling fan lights is excluded from this average BCR calculation because the value of 213 is so high while energy savings are small. Note (2) For New Zealand, the B/C Ratio appears low compared to other countries because, under NZ Treasury rules, they are obliged to report savings for S&L programs against the long run marginal cost of new electricity generation (8c per kWh). Note (3) Benefit cost ratio for Japan was calculated by the authors from data in REF285 (Study 2218) for 2020 data. For refrigerators and air conditioners, the benefit cost ratio was 3.0 – these two products make up 60% of benefits and 33% of costs. Note (4) For Pacific Island Nations, the benefits are high in these cases as energy savings reduce fuel required for diesel generators, which is the main source of power on many islands.

Figure 41 shows an example of how benefit cost ratios vary by product type from Canada.

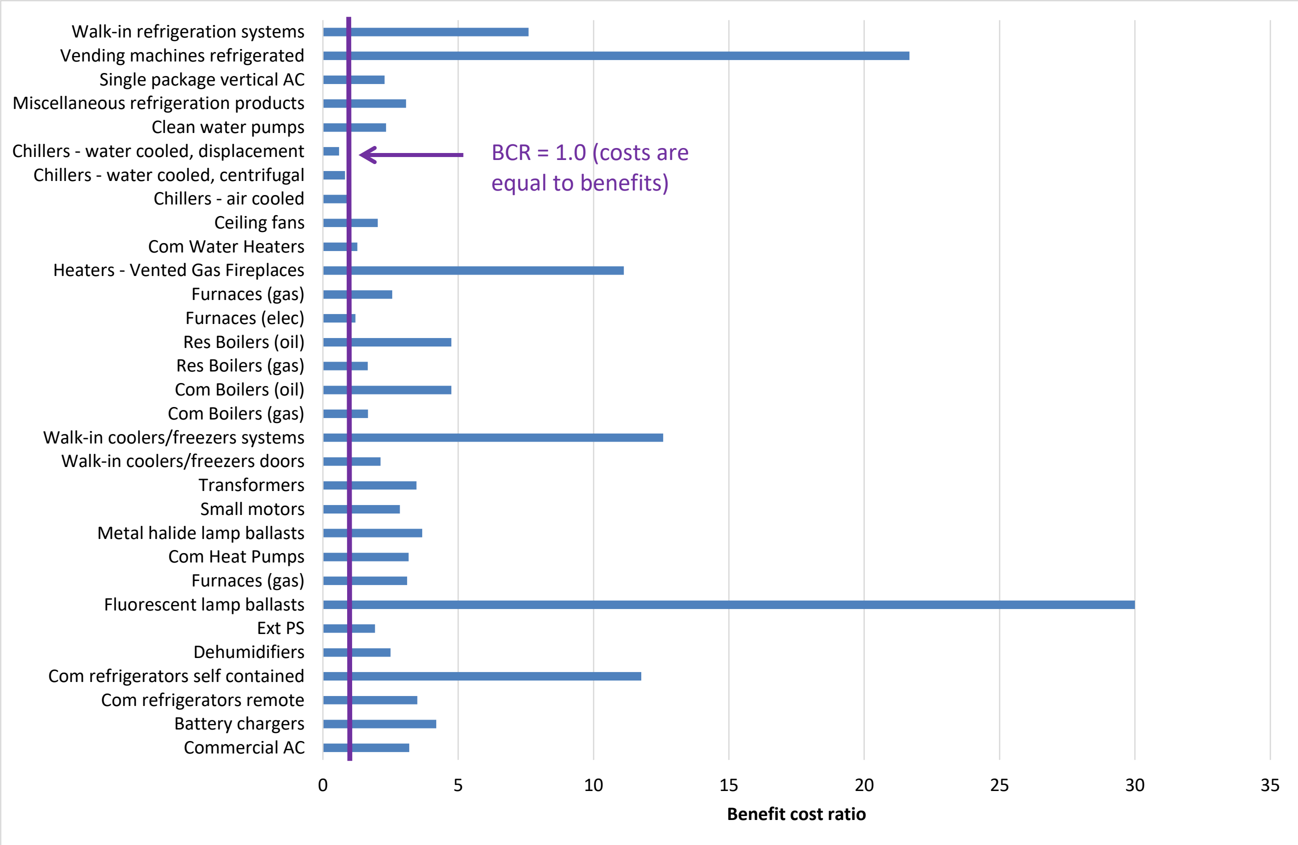

Figure 41. Benefit cost ratios from MEPS and labelling reported for products in Canada

Figure Notes: The BCR for ceiling fan lights is excluded from this graph, because the value of 213 if so high. Source Study 2613, made up of REF222, REF223 and REF224.

Data from Australia summarises the overall program net costs and benefits and benefit costs ratios as set out in Table 41.

Table 41: Summary of S&L program costs and benefits to 2030 in Australia

Category	Energy saved 2014-2020 PJ	NPV benefits AU$b	NPV costs AU$b	Benefit cost ratio
Existing S&L programs (35 elements)	1595	55.8	11.5	4.9
New programs to 2030 (18 elements)	324	8.0	2.6	3.1
All S&L programs	2021	66.0	14.8	4.5

Table notes: Existing program elements already in operation as of 2014. New program elements as being implemented from 2014 to 2030. Source (E3 2014).

More detailed data on benefit cost ratio for each of the new programs for the period from 2014 to 2030 is shown in Figure 42.

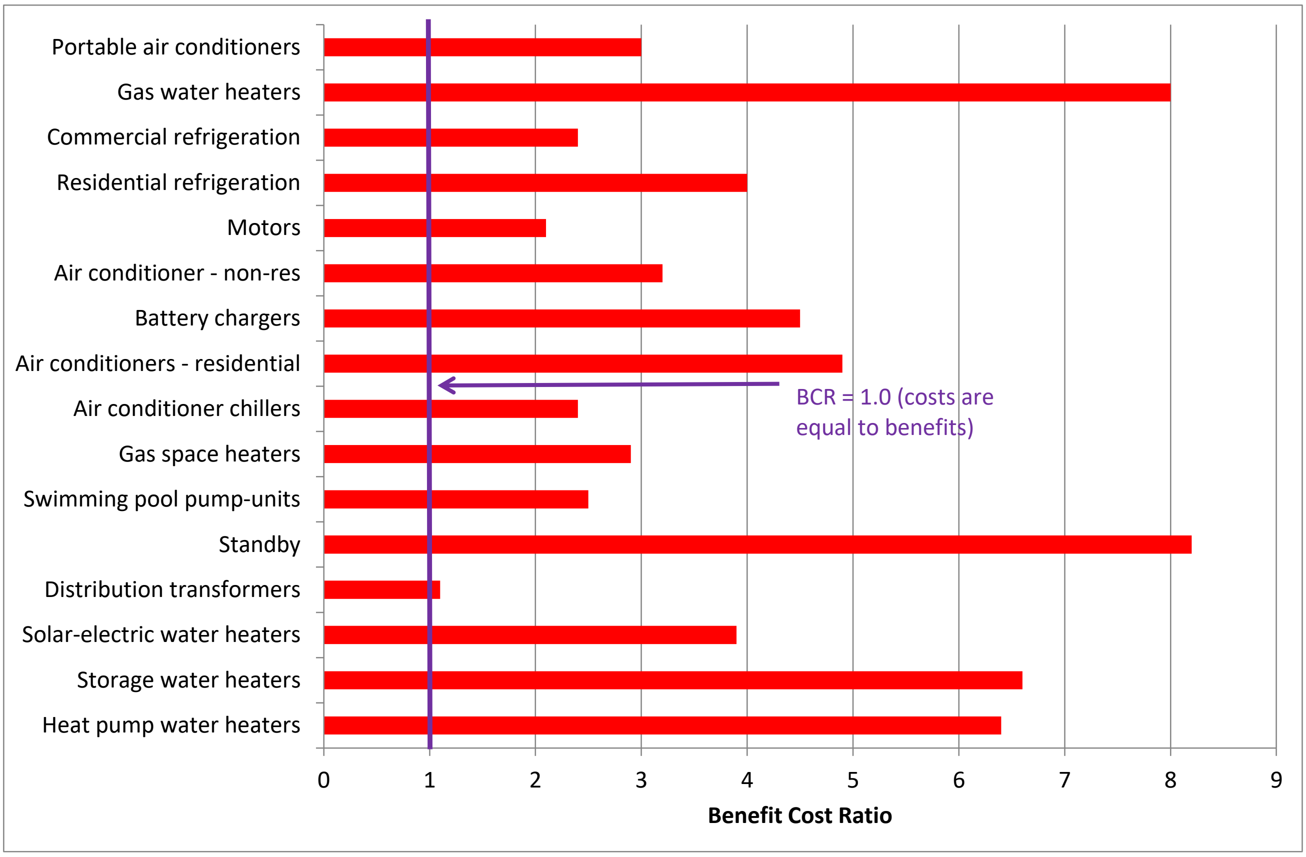

Figure 42: Benefit cost ratios for new S&L program measures to 2030, Australia

Figure notes: Source (E3 2014). Similar and more recent data available in (Collyer 2019).

As shown in Figure 43 for the USA, the net financial benefits to consumers from S&L programs already implemented are considerable.

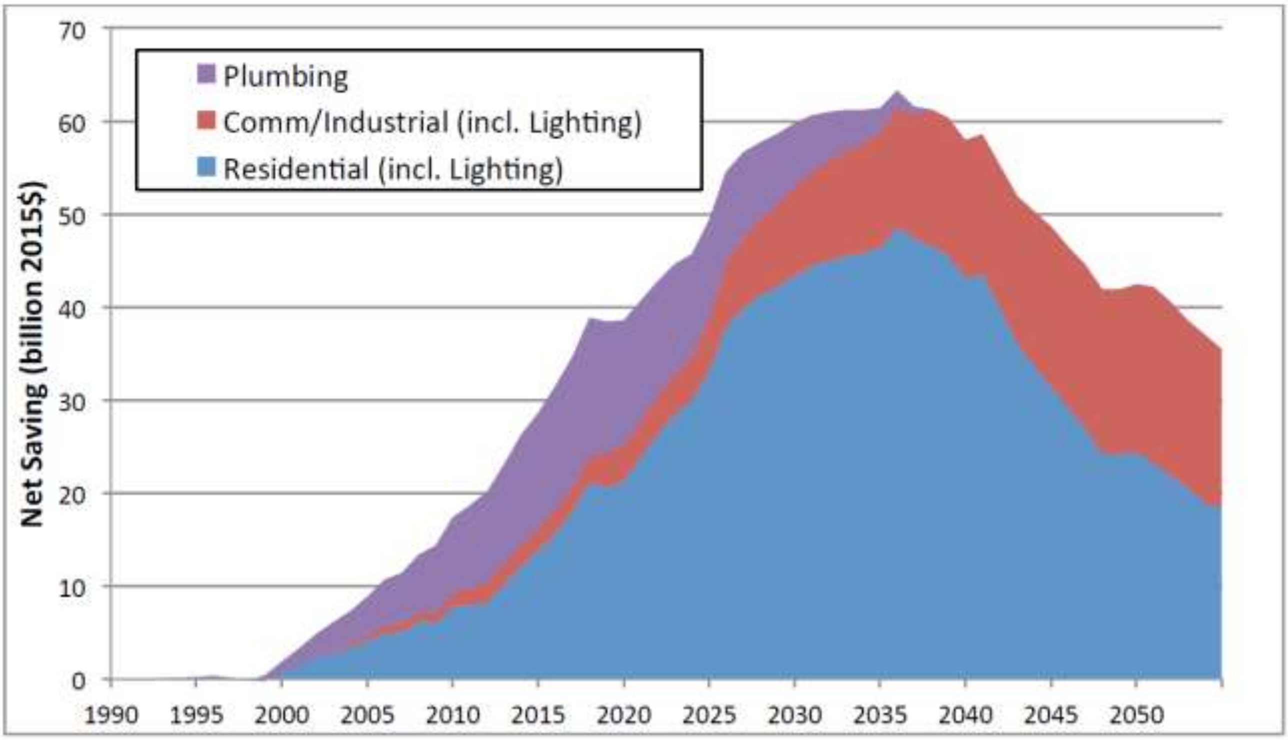

Figure 43: Annual undiscounted net consumer benefit by year for all MEPS by sector, USA

Figure notes: Source Figure 3, Study 2616, REF001.

In nearly all of the S&L programs reviewed, the national benefits outweighed the additional costs by at least 3 to 1[35], i.e. the net cost of energy savings was negative from a societal viewpoint. For example, in the United States, MEPS for all products had an estimated average BCR of about 5.3:1 out to 2050 (undiscounted)(REF001). In the UK, product policy (mainly European S&L legislation) in 2012 had a BCR of 3.8:1 (Department for Environment, Food and Rural Affairs (UK) 2015). The assumed discount rate does have some impact on the calculated BCR, especially over long periods. It is important to note that reported benefit-cost ratios are filtered to some extent as governments will rarely proceed with a program proposal that does not meet their minimum thresholds for viability.

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 (Study 112).

These finding supports the conclusion from the International Energy Agency that end-use efficiency measures offer the least cost pathway to CO_2 emissions reductions (see Figure 44) (Study 110).

[35] 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 (BCR) that exceeds 1.0 and/or if the sum of Net Present Value of costs and benefits from the measure is greater than zero.

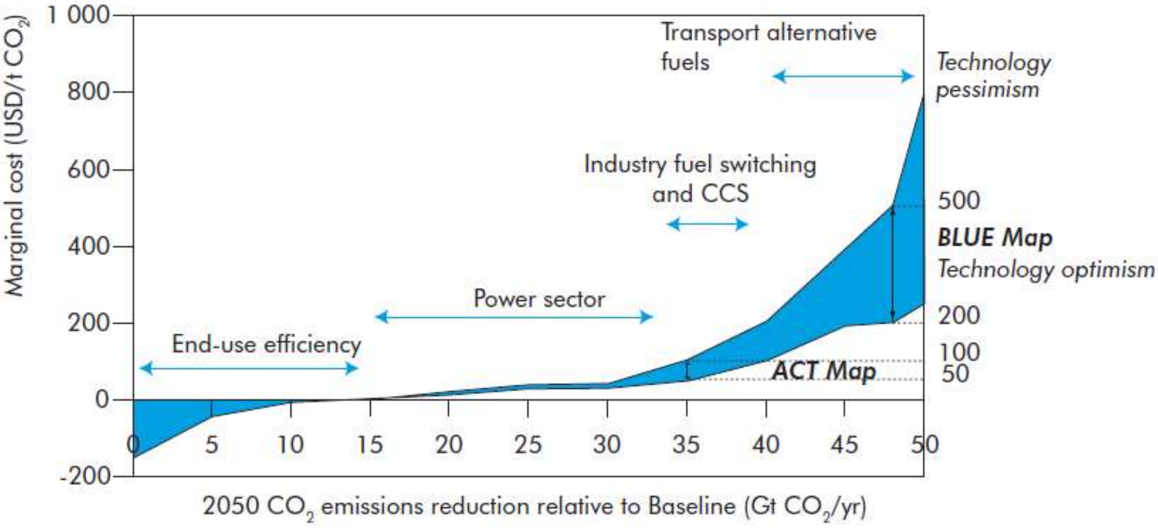

Figure 44: Marginal emission reduction costs for the global energy system, 2050 (IEA)

Figure notes: source Study 110.

It should be noted that cost-effectiveness of S&L measures are usually ensured by setting performance requirements at a level where the life cycle costs are minimised[36]. Since a large proportion of the costs associated with S&L programs relate to the expected changes in product purchase price, understanding the incremental cost of energy efficiency improvement is the key to accurately predicting the benefit to cost ratio and setting performance requirements.

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

5 Achievements of S&L – employment

5.1 Overview

A number of studies covered the issues of both employment and energy efficiency. However, while many of these studies were highly credible and used solid data, most were undertaken at a macroeconomic level and looked at the issue of energy efficiency in general, rather than employment impacts of S&L programs in particular. The main concepts set out in many of these studies were the generation of direct jobs (through the direct increase in products and services associated with a particular program measure) and indirect jobs (generated from flow on effects). Many of the studies looked at the labour inputs into building and renovations, which is quite labour intensive, and found that these types of energy efficiency measures generate far more jobs per million dollars of expenditure than, for example, a power station, which has low labour input. Most of the studies examined did not report quantitative data so data could not be extracted into the document analysis database.

Useful general references in the issue on employment are listed below Details are contained in Section 8):

- Study 7, Ryan, L. and N. Campbell, Spreading the Net: the Multiple Benefits of Energy Efficiency
- Study 1006, Puig, D., Farrell, T.C., Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe (COMBI)
- Study 1016, Cambridge Econometrics, Assessing the Employment and Social Impact of Energy Efficiency
- Study 1036, Gaffney, K., J. Vencil, L. Petraglia, and M. Rudman., It's all about the jobs! Stimulating employment and economic impacts from investments in energy efficiency and renewable energy
- REF081, Energy Efficiency Jobs in America
- REF082, How Does Energy Efficiency Create Jobs?
- REF083, BW Research, US Energy and Employment Report
- REF241, Green Energy Markets, Energy Efficiency Employment in Australia: An analysis of the current and potential jobs created by saving energy in Australia
- REF256, Dr William Blyth, Jamie Speirs, Dr Rob Gross, Low carbon jobs: the evidence for net job creation from policy support for energy efficiency and renewable energy.

The following section looks at employment creation data specific to S&L from two main studies.

5.2 Specific S&L data on employment

Table 42 shows information on estimated job creation as a result of equipment energy efficiency standards and labelling programs in the USA and EU. The EU figures are reported from the European Commission's official EcoDesign Impact Accounting study (Study 2402) and are based purely on an analysis of direct jobs e.g. jobs that are created due to the higher cost of more efficient equipment leading to additional investment and job creation in manufacturing, wholesale, retail and maintenance. The USA analysis is the findings from an Input/Output economic analysis conducted by the Appliance Standards Awareness Program and the American Council for an Energy Efficient Economy (REF133, Study 2605). The input/output analysis addresses both direct job creation (in manufacturing, wholesale, retail and maintenance) and the indirect jobs created from consumer expenditure in the wider economy that is made possible from net expenditure savings for consumers. The direct job creation is driven purely by the net increase in expenditure on equipment and in the case of the EU it is estimated that each ~€80k increment in annual expenditure on equipment results in the creation of a job in the manufacturing, wholesale, retail and maintenance value chain. For the US it is estimated that each increment in net consumer savings of between $188k and $225k will result in a job being created in the economy as a whole. These are quite different measures and they cannot be directly compared.

Table 42: Job creation estimates due to MEPS and labelling in the USA and EU

Economy	End-year	Jobs created (1000s) in that year	Type of jobs	Delta Acquisition Cost	Savings in Operating cost	Net savings	Units	Increase in acquisition cost per direct job created	Units	Increase in net savings per direct job created	Units
USA	2016	299	Direct and indirect	20.9	77	56.1	$bn			188	$k/job
USA	2030	553	Direct and indirect	22.1	146	124.2	$bn			225	$k/job
EU	2020	906	Direct only	72.4	134.1	61.7	€bn	80.0	€k/job		€k/job
EU	2030	1261	Direct only	102.0	250.2	148.2	€bn	80.8	€k/job		€k/job

Tables notes: Sources Study 2402 and 2605 with author analysis. US values are US dollars. See footnote[37] regarding multiple US data sources.

It can be difficult to generalise from these findings to draw lessons for other economies because of variations in the degree of a manufacturing presence, the cost of labour, and the degree to which expenditure in the economy at large will generate jobs. Some countries have no manufacturing presence for the types of products addressed in S&L programs and others have a greater presence than is the case for the USA or EU. However, even when there is no local manufacturing, then

[37] Data for the USA is from Study 2605 (REF133) and was prepared with the primary objective to examine employment issues. It is noted that the net savings reported in this study and those reported in Study 2616, REF001 do not apparently align. While there are a number of potential explanations, including the possibility that one reports constant $ values for a specific year and the other does not and that the set of MEPS programs covered may differ, the study team does not have access to the underlying assumptions and hence has not been able to resolve the cause of these apparent differences.

higher efficiency with higher costs[38] can drive up employment in those sectors, as supply chain revenues tend to be proportional to the value of goods. In the EU's case, the wholesale, retail, installation and maintenance jobs creation accounted for 30% of the total direct jobs creation impact. Furthermore, in all economies, there will be an indirect job creation effect (potentially a very significant one) from the net savings in costs (acquisition and operating costs) being spent in other economic areas that have higher labour intensity levels than the energy sector (which has one of the lowest levels). In the EU's case it has been estimated that this indirect job-creation effect is 3 to 5 times the direct one (Study 3).

REF241 found that energy efficiency is already a major employer in Australia. A minimum of around 59,000 people (0.5% of the total workforce) work in roles that directly affect homes' and businesses' energy efficiency (and possibly as many as 236,000 workers or 1.8%). This means that, at a minimum, more people are employed in roles that involve energy efficiency than any other part of the energy sector, including coal mining and electricity networks. The study estimates that implementing new energy efficiency improvements could create 120,411 job years of work. The majority of these would be related to building shell improvements, but around one third would be directly associated with appliances and equipment upgrades. Several white certificate schemes use labelling and standards frameworks to generate incentives for consumers to upgrade the efficiency of their existing appliances and equipment, which also generate employment.

While energy efficiency clearly has the potential to generate new employment opportunities, there are always challenges facing any such significant economic transition. Firstly, the skills required for energy efficiency jobs may be different to those available in the existing workforce, so training is likely to be required in some cases. Secondly, the location of energy efficiency jobs may require some elements of the workforce to relocate. And while not directly related to energy efficiency employment, communities that have historically relied on fossil fuel extraction and use may require economic and social support as the world moves towards a zero carbon future.

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[38] Section 4.3.2 showed that there is often a weak correlation between price and energy/efficiency.

6 Achievements of S&L – health impacts

The health benefits of S&L are not often assessed but there is emerging evidence that they could be very substantial and become a large part of the overall value proposition of these policy measures. The database contains five studies that have looked at the interactions between improving energy efficiency and health but none of these has been dedicated to energy efficiency standards and labelling. They have had a more general focus on how energy efficiency gains can improve health without considering the drivers for the efficiency improvements. The other studies listed (REF289 to REF291) looked at indoor air quality associated with the use of gas cooking and heating appliances, but the focus for these were more safety related rather than directly linked to S&L efficiency. Much of the work on health has been conducted in and focused on Europe and hence may not be directly transposable to other regions. Nonetheless the findings are significant. The main studies related to health issues are:

- REF050, Matthew Smith, Dr Andreas Hermelink, Maarten Cuijpers, Dr Edith Molenbroek, Dr Nesen Surmeli, Benefits of Ecodesign for EU households
- Study 1006, Puig, D., Farrell, T.C., Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe (COMBI)
- Study 1016, Cambridge Econometrics, Assessing the Employment and Social Impact of Energy Efficiency
- Study 1019, Christopher Russell, Brendon Baatz, Rachel Cluett, and Jennifer Amann, Recognizing the Value of Energy Efficiency's Multiple Benefits - Report IE1502
- Study 1038, Nora Mzavanadze, WP3 Air pollution: Literature review on avoided air pollution impacts of energy efficiency measures
- REF289, Len Ferrari, Frank Fleer, Ted Pender, Mark Tulau, Jacinda Houston, Anthony Myszka, Unflued Gas Appliances and Air Quality in Australian Homes: Technical Report No.9
- REF290, Department of Health and Ageing, The health effects of unflued gas heater use in Australia
- REF291, Brady Anne Seals, Andee Krasner, Health Effects from Gas Stove Pollution.

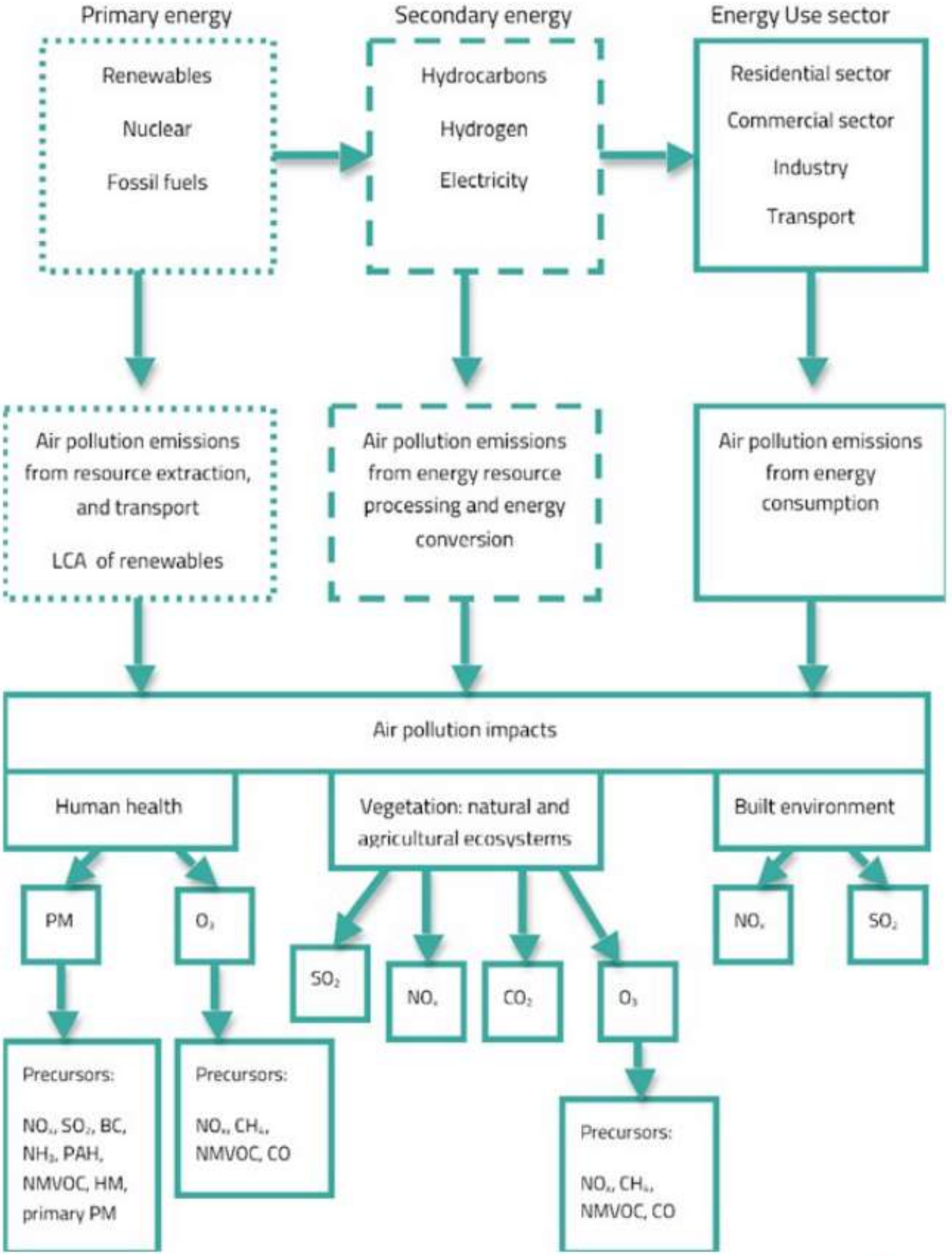
Reductions in air pollution are the main sources of health benefits from high efficiency equipment (see Figure 45) and these can arise from reducing direct emissions (i.e. emissions that are emitted directly by the equipment at the place of installation) but also by reducing indirect emissions due to the transformation of primary energy sources into secondary energy (most notably by the use of fossil fuels in the production of electricity). Direct emissions are a consequence of the combustion of fuels used for space and water heating and cooking in buildings and specifically arise from the combustion of gas, oil, coal and biomass. The main pollutants are particles while other air pollutants are VOC's (volatile organic compounds, in practice half-burned gases, part of OGC: Organic Gaseous Carbon), SO_2, NOx, and CO. Some of these are the most harmful substances when found to be PAH's (Poly-aromatic hydrocarbons – found in the OGC and particles), and dioxins. CO is not usually a problem in properly functioning installations and is usually addressed under safety requirements (this is usually not related to S&L efficiency requirements). Reduction in particles and OGC will also reduce VOC's and PAHs.

The EU Ecodesign Impact Accounting studies (study 2402) quantifies the avoided emissions due to the EU's Ecodesign MEPS and labelling policies. For the year 2030 they project that these policies will avoid the direct pollutant emissions shown in Table 43.

Table 43: Projected savings in direct airborne pollutant emissions in the EU due to Ecodesign and labelling policies

Pollutant	Avoided emissions in 2030 (kt/year)
NOx	333
NOx (SO_2 equiv)	233
CO	568
OGC	25
PM	43

Within these EU estimates, the reduction of nitrogen-oxides (NOx) emission, acidifying agent and ozone precursor (smog), is 149 kt SO_2 equivalent in the EU 2020 (ca. 1.3% of EU 2010 total NOx emissions). This arises from the EcoDesign emission limits set for heating boilers, water heaters, solid fuel boilers, local space heaters and air heating products. However, it is incomplete because of a lack of data necessary to quantify the NOx emissions for Solid Fuel Boilers and for a part of the Local Space Heaters product groups. The reduction of CO-emissions is estimated to be 189 kt/year in 2020 and 568 kt/year in 2030 which is reported to be 20% of the 2799 kt/year emissions from the same product groups in 2010. The reduction of OGC-emissions is 13 kt/year in 2020 and 25 kt/year in 2030, for which the latter is 11% of the 219 kt/year emissions from the same product groups in 2010. For comparison: in 2008 the total European NMVOC-emission (including the transport sector) was 12 500 kt/year. The reduction of PM-emissions is 13 kt/year in 2020 and 43 kt/year in 2030. The latter is 22% of the 193 kt/year of emissions from the same product groups 2010. For comparison: in 2008 the total European PM10-emission (including the transport sector) was 2750 kt/year (study 2402).



Scope of COMBI is marked under a straight line, dashed lines represent some aspects that fall under COMBI (mainly energy efficiency actions related to electricity), dotted lines represent elements that are outside the scope of COMBI. Abbreviations: NO_x – nitrogen oxides, SO_2 – sulphur dioxide, BC- black carbon, NH_3 – ammonia, PAH – polycyclic aromatic hydrocarbons, NMVOC – non-methane volatile organic compounds , HM – heavy metals, PM – particulate matter, CH_4 – methane, CO – carbon monoxide, CO_2 – carbon dioxide, O_3 – ozone. Source: based on Guerreiro et al., 2014; Wilkinson, Smith, Joffe, & Haines, 2007.

Figure 45: Visualisation of the various stages of the energy supply chain and air pollution

Figure notes: Source Study 1038

At least two approaches are used to assess the health benefits associated with reduced exposure of populations to pollutants. The first aims to assess the gain in healthy life years via the metric of disability-adjusted life years (DALY) due to better indoor air quality (this approach is used in the COMBI study (Study 1006). The second aims to take these direct health benefits and monetise their value so that they can be compared with other policy impacts on a common basis (JRC 2020[39]). The study team has not identified a study that directly assesses the DALY or monetised value of health benefits for S&L programs but a recent EU study by the European Commission's Joint Research Centre conducts a DALY analysis for energy savings in European buildings as a result of the energy efficiency policy measures triggered by Europe's Energy Performance of Buildings Directive and then applies a monetisation methodology to derive their value. Table 44 shows these findings wherein the value of the health benefits was just over 50% of the value of the energy savings. If these ratios were also to hold true for the impacts of the EU's Ecodesign and energy labelling programs, then this would amount to the monetised health benefits value shown in the same table.

Table 44: Projected value of health benefits from energy efficiency measures in Europe (actual estimates for the EPBD, speculative estimates for Ecodesign and labelling policies)

Parameter	Monetised value (€bn)
Ecodesign and labelling operating cost savings in 2030	250
Implied value of health benefits in 2030 due to Ecodesign and labelling	126
EPBD operating cost savings in 2020	175
Monetised value of EPBD health benefits due to energy savings in 2020	88
Monetised EPBD health benefits as a share of energy savings	50.3%

It should also be noted that very recently published research has found that fossil-fuel pollutants, and specifically particulate matter, could be having a much larger impact on human health than previously thought (Vohra et al. 2021; Burrows 2021). This research estimates that globally 18% of deaths are attributable to such pollution, roughly double the total previously ascribed to air pollution. While this research doesn't distinguish the origins of the pollution, much of which will be transport sector related, these findings suggest that there are much greater negative health impacts from particulate matter and fossil fuels than has previously been believed, which implies that previous health impact monetisation exercises may need to be revised.

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 (Study 1020).

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

[39] https://ec.europa.eu/jrc/en/publication/untapping-multiple-benefits-hidden-values-environmental-and-building-policies

stoves[40] 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 (REF211).

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 (Kuhn 2013; Sust et al. 2012). These types of health and well-being benefits are clearly of very high value, but are difficult to cost in monetary terms alone.

There is some evidence that more efficient indoor heating/cooling can improve indoor temperature conditions, which can have positive health impacts. But these types of studies usually focus on building shells rather than equipment and direct health impacts are difficult to disentangle from other socio-economic factors. A large scale New Zealand study found that health related benefits (health cost savings) from improved indoor temperatures associated with space heating energy efficiency improvements were around 10 times the energy related savings[41] (Preval et al. 2010).

There is now good evidence that some low income households are unable to adequately heat or cool their dwellings, mainly where energy bills make up a significant proportion of total household income (Australian Council of Social Services 2018). Where low income households have constraints on the level to which they can heat (due to poor or inefficient equipment and/or poor building shells), there can be negative health consequences from poor indoor environments (mould, increased infections). Naturally, where efficient equipment becomes available, some of the potential energy savings from the energy efficiency program may be taken 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 that will likely have other benefits such as improved health and well-being (Milne & Boardman 2000).

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[40] Almost all homes in China now have an improved cook stoves, with each estimated to save emissions by 1 to 3 tonnes of CO2e per year.

[41] Note: The measure related to installation of higher efficiency, clean heating sources. This reduced the cost of operation (and increased heating output) so allowed householders to heat their dwellings to a higher standard. While there were some energy savings, these were very modest due to the higher heating demand, which was encouraged as part of the program. The main benefits from the high efficiency heaters were health related benefits in terms of reduced respiratory related illness due to warmer indoor temperatures. This type of outcome can apply equally to energy efficiency programs targeted at improved building shell performance.

7 Achievements of S&L – innovation and other issues

7.1 Introduction

Many of the previous sections have shown evidence of innovation in the way that products are developed over time. The example of continuous improvements in energy efficiency and product performance while reducing real costs in parallel is a clear example of innovation.

One definition of innovation is: *Innovation is the creation, development and implementation of a new product, process or service, with the aim of improving efficiency, effectiveness or competitive advantage*[42]. The ability to improve efficiency and reduce costs at the same time is clearly one aspect of innovation. Much of the reduction in real costs of manufacturing comes from increased knowledge, skill, improved materials handling and better technology. Many studies have shown that the ability to reduce prices is strongly linked to cumulative production volumes: the more things that are made, the better at it we get (Desroches 2013, 2012; US Department of Energy 2011; Weiss et al. 2010).

The following documents provided general background on innovation and energy, but there was little data specific to S&L policies and programs:

- Study 1017, Steven Nadel, Neal Elliott, and Therese Langer, Energy Efficiency in the United States: 35 Years and Counting : Report E1502
- Study 1018, Casey J. Bell, James Barrett, and Matthew McNerney, Verifying Energy Efficiency Job Creation: Current Practices and Recommendations Report F1501
- REF190, Ari B. Reeves, Amit Khare, Yang Yu, How have energy efficiency standards and labeling policies affected product manufacturers?
- REF003, Girod, B., Stucki, T. & Woerter, M., How do policies for efficient energy use in the household sector induce energy-efficiency innovation? An evaluation of European countries
- REF212, Sibylle Braungardt, Edith Molenbroek, Matthew Smith, Rob Williams, Sophie Attali, Catriona McAlister, Impact of Ecodesign and Energy/Tyre Labelling on R&D and technological innovation
- REF242, Luke A. Stewart, The Impact of Regulation on Innovation in the United States: A Cross-Industry Literature Review.

7.2 Innovation background

At a high level, it is argued that regulation places a compliance burden on firms, which can cause them to divert time and money from innovative activities towards these compliance efforts. Assuming the business is not closed down by the burden of regulation, compliance efforts can be one of two types:

[42] Quote attributed to the New Zealand Government – see https://drkenhudson.com/best-way-define-innovation/

- *Circumventive innovation*, when the scope of the regulation is narrow and the resulting innovation allows the firms to escape the regulatory constraints (this broadly relevant with respect to circumvention of test methods, which is of course undesirable); or
- *Compliance innovation*, when the scope of the regulation is broad and the resulting product or process innovations remain within the scope of the regulation (REF242).

Innovation can be broadly broken down into incremental innovation (small improvements in methods and techniques to improve overall results) and radical innovation (where products or processes are completely displaced by new technologies or approaches). In general terms incremental innovation is less risky but radical innovation can produce larger rewards (and losses in some cases). Stewart argues that "regulations that are most effective at stimulating innovation will tend to require compliance innovation and, at the same time, will minimize the compliance burden (as well as) mitigate the risks of producing "dud" inventions" (Stewart 2010). Key findings are:

- Flexible regulations, including performance based standards, tend to aid both market and social innovation by maximizing the implementation leeway available to firms, allowing the market to dictate cost efficient and commercially viable solutions;
- Regulation that promotes more complete market information also aids both types of innovation (e.g. energy labelling);
- With social regulation, there is evidence that more stringent and disruptive regulation—when successful—tends to promote more radical innovation, whereas the moving target approach of gradually increasing stringency over time is more apt to result in incremental innovation.

Regulations set a necessary framework for compliance under most S&L programs. It would be fair to say that most of the time companies undertake a range of incremental innovations in order to improve the performance and efficiency of their products in the course of compliance. But occasionally radical innovation can lead to major paradigm shifts. Some examples of radical innovation are inverter driven compressors, vacuum insulation for refrigeration systems, flat screen televisions, LED lighting and heat pump clothes dryers. Where possible, specific data for S&L programs have been extracted from the reviewed studies and other reports in the following section.

7.3 Innovation examples for S&L programs

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*" (Taylor, Spurlock & Yang 2015).

When MEPS apply to all segments of the market and are performance based, rather than prescribing one particular design or technology over another or focusing on a specific piece of equipment, they help drive innovation (Study 1025, REF242). The fact that the regulatory process has been unsuccessful in predicting future efficiency costs is further evidence of innovation (Study 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 (Study 1023).

The introduction of LED lamps has seen rapid innovation in terms of price decreases and efficiency gains. Falling component costs, competitive pressure, and policy support for research and development, has led to LED prices falling by 28% to 44% per year as shown in Figure 46 (Study 1011). The competitive price and performance of LED lighting has already transformed the lighting market for most applications. An illustration of the rate of improved efficacy in the early laboratory research phases is shown in Figure 47. Commercial product efficacy is around 10 years behind the cutting edge laboratory results.

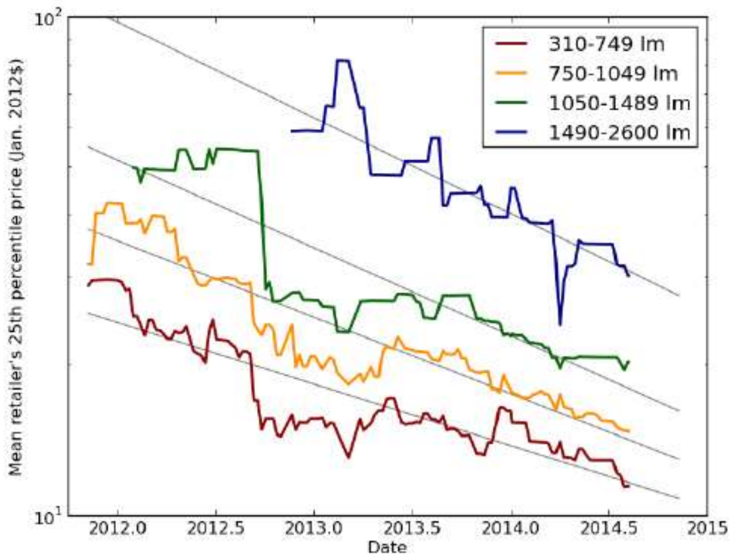

Figure 5. Trends in the mean retailer's 25th percentile price for LED A lamps, by lumen bin. Trends are shown on a semilog plot, so that exponential curves describe straight lines with slope equal to the exponential decline rate α.

Figure 46: Trends in price of LED A lamps by lumen bin

Figure 47: Advanced in LED efficacy from one manufacturer

Figure notes: Figures shown are for small research systems and are not applicable to commercial products. However, the best products in 2020 achieved around 200 lm/W, indicating a 10 year lead time from research and development to full commercialisation. Source (Kelly-Detwiler 2014).

Two country based S&L programs appear to be set up to drive ongoing innovation in the market. The first is the Top Runner program in Japan. Under this program, the government reviews the market efficiency for a specific product and identifies the most efficient product on the market (the “top runner”). The government then sets a target efficiency level that is equal (or comparable) to the “top runner” efficiency and a target date, usually over a period of 4 to 10 years, depending on the product. By the target date, the sales weighted average of all products shipped by each supplier has to meet or exceed the specified level. While on paper this is not a mandatory program, financial penalties for non-compliance, together with government naming and shaming of non-compliant companies, means that there is a very high level of compliance in practice. This type of policy effectively forcing all suppliers to adopt best available designs and technologies within a short time frame, so forces technological innovation. Analysis of data from Japan has shown that, in nearly all cases, efficiency targets are exceeded by the target date and tend to continue (if at a slower rate) for years after the target has been achieved (REF036, REF278 to REF284 inclusive). The long term effectiveness of this approach, of course, depends on how frequently targets are set. There is also an argument that suppliers will tend to reduce the performance of their most efficient models in the future for fear that this may end up setting the next Top Runner target. But there is little evidence of this effect in the available data as the most efficient models on the market continue to far exceed the Top Runner target efficiency levels, even for recent product updates. The Top Runner performance label and the unified energy conservation label also help counter any such effect. Some examples of the Top Runner achievement label are shown in Figure 48.

Figure 48: Top Runner compliance label showing level of compliance achievement

Figure notes: The white “e” on a green background indicates that the product exceeds the current Top Runner target and the % value shows the level of efficiency achievement relative to the Top Runner target. The orange “e” on a white background indicates that the product fails to meet the current Top Runner target and the % value shows the level of efficiency achievement. Note that these labels are used on all products except for those covered by the unified energy label (see Figure 17). Label source https://www.enecho.meti.go.jp/category/saving_and_new/saving/general/replacement/enelabel/

The second case of regulatory innovation is the integrated labelling and MEPS scheme in Korea. The energy label (shown to the left) is split into five grades or tiers (1-5), with tier 1 being the most efficient, while appliances below tier 5 are banned from sales (MEPS level). On average, tier 1 appliances have 30-40% energy savings compared to those in tier 5. This mandatory label and MEPS scheme applies to some 29 product types (REF196, Study 2214). The innovative aspect of this scheme is that the energy label and MEPS levels are regraded at frequent intervals (typically on a 5 year time frame) with the old tier 1 (most efficient) becoming the new tier 5 label grade (least efficient) and new MEPS level. Products that were graded at tier 2 to 5 under the old scale become banned under the revised MEPS levels. Industry understands the process and adapt and innovate to meet the continually updated efficiency regime. This is a good example of moving target regulation, which should strongly drive incremental innovation (Stewart 2010).

In some cases, the industry itself can drive innovation, and seek regulatory support to assist the uptake of the new technologies. Innovation saw the efficiency of circulation pumps[43] 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 as shown in Figure 49 (data shown is from 2015 and additional amendments were introduced in 2017 and 2019 but are not shown this figure).

[43] Used in hydronic 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.

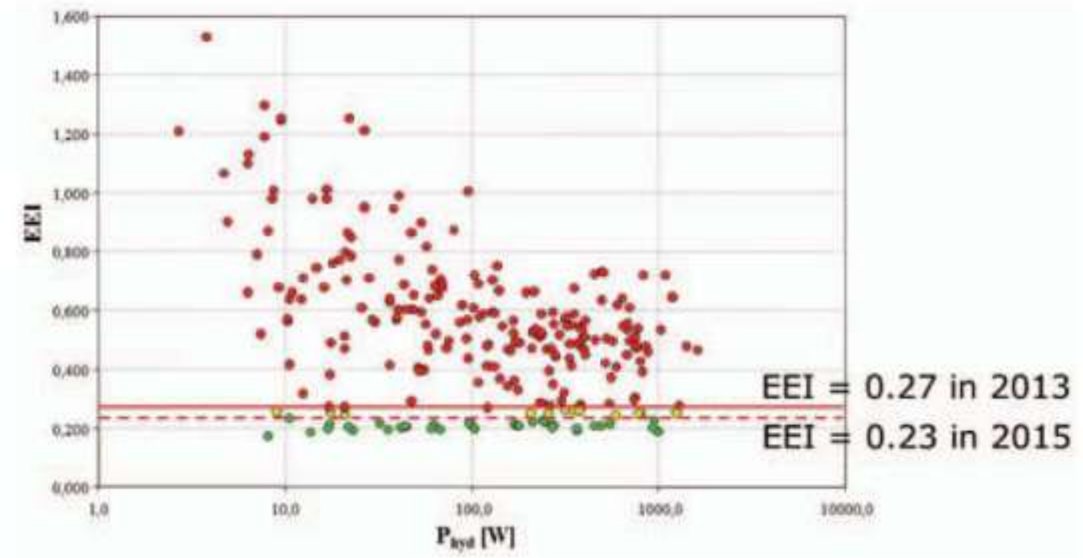

Figure 49: Circulators (from 2009 market) compared to requirements in to EC/641/2009

Figure 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. Source Studies 1002, 1033.

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 US analysis clearly shows that the decline in both the purchase price and the life cycle cost (purchase price plus lifetime energy) continues after the implementation of successive regulatory measures, and in most cases at a higher rate of decrease for both parameters as shown in Figure 50 (Study 43). This data suggests that MEPS often has little impact on purchase price. Cumulative shipments are an important determinant in long term price trends (this depends on the specific case, but for moderate MEPS and medium time frames, this appears to be true), but regulation is a more important driver of innovation, which results in more rapid reductions in life cycle costs (and in some cases purchase costs) than would happen in the absence of regulation.

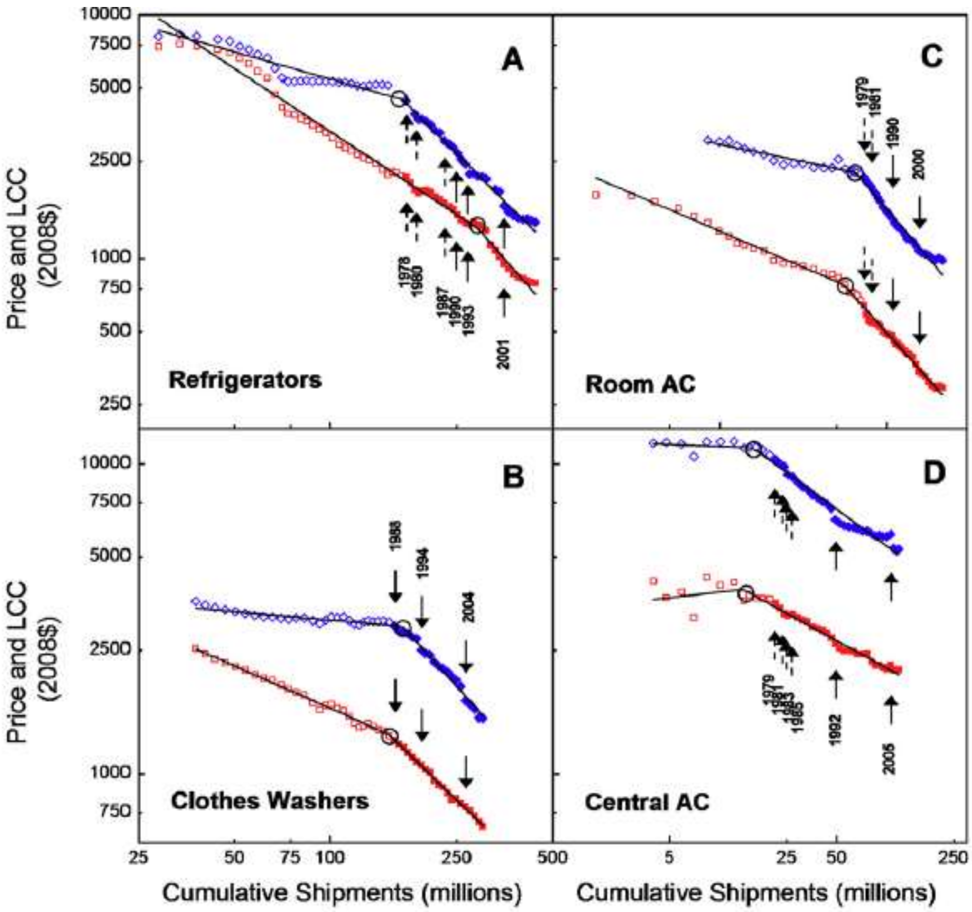

Figure 50: US federal MEPS purchase price (red) and life cycle cost (blue)

Figure notes: Source Study 43.

Figure 51 shows how the efficiency of refrigerators placed on the EU market evolved dramatically in response to the adoption of energy labels with defined efficiency classes; pre-labelling the efficiency of products is wholly randomly distributed whereas, just 3 years post labelling, almost all products on sale were designed to meet the class A, B or C efficiency threshold. Similar data is available for other countries with categorical labelling schemes. This shows that manufacturers value improved label ratings and focus effort and innovation to increment the performance of their products to the next label efficiency threshold at lowest possible cost.

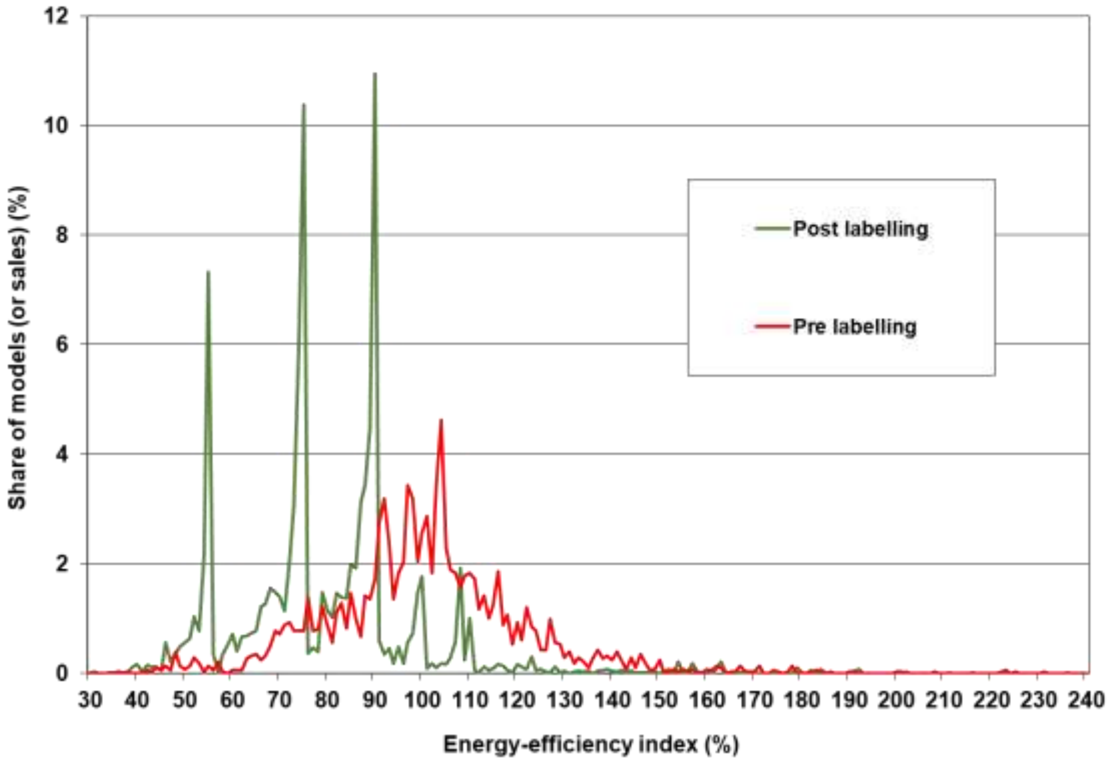

Figure 51: Distribution of refrigerator sales in the EU pre and post the introduction of energy labelling circa 1995

Source Study 35.

A celebrated illustration of how S&L has driven technology innovation is the case of energy labelling of clothes dryers in the EU. When the first study in support of regulations was released in 1995 it included a techno-economic energy engineering analysis that showed that it would be possible to double the efficiency of electric clothes dryers by including a heat pump. At that time no such products were on the market or even under consideration, however, the evidence led the highest (Class A) energy performance threshold to be set a level consistent with this technology solution. For many years there were no such products on the market; however, once the first such product was produced it was followed by a rapid increase in the number of clothes dryers using heat pumps and the incremental costs fell substantially, such that today heat pump dryers command a large part of the market in many countries. This transition was undoubtedly driven by policy drawing an aspirational performance level and inviting market actors to develop products that met it. Switzerland has now set a MEPS level that mandates heat pump dryers for new sales (Study 1034) so this technology went from hypothetical to mainstream in around 15 years.

The amendment of energy performance test metrics and their related efficiency metrics has also been an important driver of technology development and adoption for a variety of products. The move away from energy performance testing only at full capacity for air conditioners towards also testing and reporting performance at part loads has had a major impact on the adoption of variable cooling capacity compressors and related control technology. While the maximum full load performance of room air conditioners has increased steadily since the widespread adoption of S&L

programs, the part-load performance has improved much faster and this would not have occurred had the regulations not acknowledged and rewarded part-load performance. In a similar vein, countries which have adopted energy performance testing for refrigeration equipment at multiple ambient test temperatures have tended to witness a higher rate of adoption of variable capacity compressors than those that have relied on testing at a single ambient temperature. These test procedures force suppliers to optimise their products over a wider range of use, which will translate to more energy savings during normal use conditions.

As previously alluded to, it is sometimes difficult to be sure how much contribution S&L have made to the wider adoption of efficient technologies, especially when the motivation for a radical technology transition may have been driven by multiple factors, of which energy performance is only one. Televisions have undergone a technology revolution, moving from cathode ray tube technology to plasma, LCD and most recently LCD/LED and OLED technologies. While the move towards plasma technology was detrimental to energy efficiency, the move towards LCD followed by LED and OLED technology has been beneficial, albeit that it has also brought rebound consequences due to much higher image resolution and larger screen technology becoming more feasible and widely affordable. Figure 52 shows how the watts per unit screen area of new televisions have changed in the EU (as in most of the world).

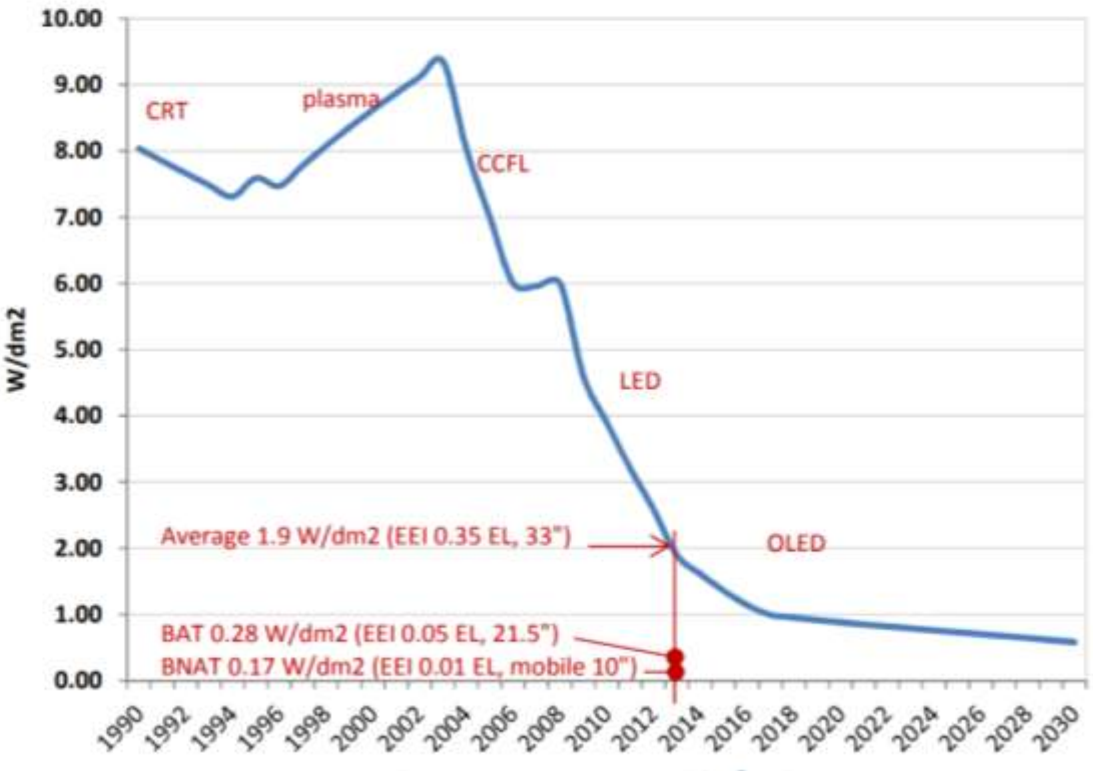

Figure 52: Evolution of the specific power demand of new TVs sold in the EU

Source (study 2402). This data is based on reported on mode power per unit of screen area. Historical efficiency metrics for televisions do not account for differences in screen luminance (this is only partially controlled), so part of this apparent improvement in efficiency is likely to be due to increasing dimness in the default picture mode.

S&L policies have helped to keep energy performance as a factor in consumer purchasing decisions and hence in the thinking of industrial product designers and thus have doubtlessly encouraged efforts to make screens more efficient while minimising auxiliary power demand. However, they have sometimes struggled to adapt as fast as TV technology has evolved and MEPS, in particular, have often become backstop, rather than technology forcing measures.

7.4 Other Co-Benefits

The primary benefits that flow from S&L programs primarily relate to efficiency improvements and savings in energy, but typically also include things like savings in operational costs and savings in greenhouse gas emissions (as covered in the preceding sub-sections). But there are a plethora of other 'co-benefits' that can also be delivered by such programs.

In the study, *Spreading the Net: the Multiple Benefits of Energy Efficiency*, Ryan and Campbell found that a range of co-benefits are routinely associated with the introduction of S&L programs (Ryan & Campbell 2012), as illustrated in Figure 53. Some of these have been flagged in previous sections. Most of these benefits relate to energy efficiency in general and it is hard to allocate specific benefits to S&L as one of many energy efficiency influences. Nonetheless, the benefits are real and will accrue.

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.

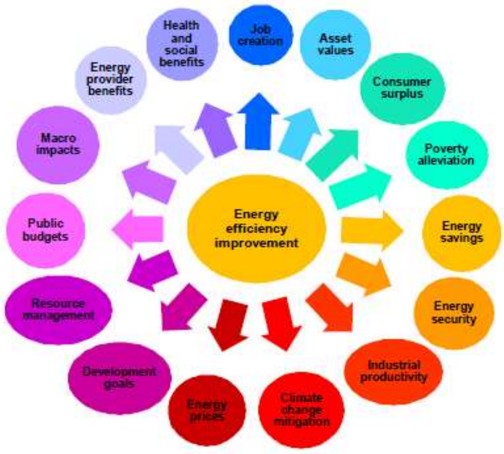

Figure 53: Range of co-benefits associated with S&L programs

Figure notes: Source - Figure 1 from Source Ryan & Campbell (2012).

Co-benefits can occur in areas totally unrelated to energy. For example, in the EU it has been shown that there is reduced water consumption of washing machines and dishwashers subject to the EU S&L program as a co-benefit from energy labelling, as set out previously. Similar benefits have been illustrated in other countries.

Typically, when estimating the benefits of a proposed S&L program, there are concerns that the expected savings may not be fully realised due to the fact that consumers may choose to take part of the potentially available savings in the form of a higher level of service, the so-called ‘rebound’ effect[44]. The important point for policy makers is that where some rebound is expected to reduce measured energy savings as delivered, the counterbalancing effect of the variety of co-benefits that

[44] More robust evaluation studies would however normally take the rebound effect into account when making estimates of expected energy savings. In these cases, the benefits that consumers enjoy from improved energy services also need to be considered (larger televisions, for example). It should also be understood that rebound is typically limited to only certain types of end uses such as space conditioning where use and level of service is somewhat discretionary as distinct from say a refrigerator which must remain in continuous operation to adequately preserve the contents within strict temperature limits.

typically flow from S&L programs should always be factored into the policy equation. As observed by Ryan and Campbell:

"*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*" (Ryan & Campbell 2012).

8 Studies and reports reviewed for the 2021 update

8.1 Index of studies included in the Document Analysis Database

Documents with quantitative data that could be used as part of the higher level meta-analysis for the 2021 update had key data extracted and entered into the Document Analysis Database. The Study number reflects the record identifier in the database. These are listed in order of Study number below. Around 40 reports from the 2015 and 2016 studies had data extracted and entered into the database. These earlier documents retained their original identifier number (1 to 112, or 1001 to 1041 as applicable). Around 70 new reports in 2021 had data extracted and entered into the database. New reports were allocated a database ID in the form 2XYY where X = region as follows:

- 0 International
- 1 Africa
- 2 Asia
- 3 Central/South America
- 4 Europe
- 5 Middle East
- 6 North America
- 7 Oceania.

YY was a sequential integer that reflected the order of entry into the database (random). In the database, where a study covered several countries, a separate record was created for each country.

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
6		Appliance Standards: Comparing Predicted and Observed Prices	Nadel S & deLaski A	ACEEE & ASAP	USA	2013	http://www.aceee.org/research-report/e13d
9		Evaluation of Energy Efficiency Policy Measures for Household Air Conditioners in Australia	Paul Ryan et al	EnergyConsult	Australia	2010	http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/Cooling/Air_Conditioners/201012b-aircon-evaluation-technical.pdf

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
10		Evaluation of Energy Efficiency Policy Measures for Household Refrigeration in Australia	Kevin Lane and Lloyd Harrington	Energy Efficient Strategies	Australia	2010	http://www.energyrating.gov.au/resources/program-publications/?viewPublicationID=2150
12		Incorporating Experience Curves in Appliance Standards Analysis	Desroches, L-BG, Karina; Chan, Peter; Greenblatt, Jeffery; Kantner, Colleen; Lekov, Alex; Meyers, Stephen; Rosenquist, Gregory; Van Buskirk, Robert; Yang, Hung-Chia;	Lawrence Berkeley National Laboratory	USA	2011	https://escholarship.org/uc/item/00q385jk#page-1
18		Analyzing price and efficiency dynamics of large appliances with the experience curve approach	Weiss M, Patel MK, Junginger M, Blok K	Energy Policy	Netherlands	2010	http://www.sciencedirect.com/science/article/pii/S0301421509007575
20		Evaluation of Fiji's Minimum Energy Performance Standards and Labelling Program	Robert Foster, Lloyd Harrington, and Jack Brown	Fiji Department of Energy	Fiji	2014	Personal communication
28		European TV market 2007-2013, Energy efficiency before and during the implementation of the Ecodesign and Energy Labelling regulations	Michel A, Attali S, Bush E	Topten International Services	EU-24	2014	http://www.topten.eu/uploads/File/European_TV_market_2007%E2%80%932013_July14.pdf
39		Energy Conservation Policies of Japan	Agency of Natural Resources and Energy Enegy Conservation and Renewable Energy Department	Agency of Natural Resources and Energy Enegy Conservation and Renewable Energy Department	Japan	2011	http://www.enecho.meti.go.jp/category/saving_and_new/saving/001/pdf/genjo_English.pdf
42		Recent and Historical Product Energy Efficiency and Life-cycle Cost Improvement in Swedish Appliance Markets	ENERVEE	ENERVEE	Sweden	2014	http://www.superefficient.org/en/Activities/Standards%20and%20Labels/~/media/Files/SL%20Project%20Reports/SEAD%20Data%20Access%20Report

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
47		Japanese Top Runner Approach for energy efficiency standards	Kimura, Osamu	Central Research Institute of Electric Power Industry	Japan	2010	Personal communication
80		The Impact of Refrigerator Standards on United States Households	James Mapp, and John H. Reed	IEPEC	USA	2013	http://www.iepec.org/conf-docs/conf-by-year/2013-Chicago/154.pdf
81		China's Practices on Evaluating the Energy Savings of Mandatory Energy Efficiency Standards	Li Pengcheng, Liu Meng, Chen Haihong, Li Yan	International Energy Program Evaluation Conference,	China	2012	http://www.iepec.org/conf-docs/papers/2012PapersTOC/papers/011.pdf
97		The Induced Innovation Hypothesis and Energy-Saving Technological Change	Newell R, Jaffe A & Stavin R	The Quartery Journal of Economics	USA	1999	http://www.rff.org/documents/RFF-DP-98-12-REV.pdf
103		Better Appliances: An Analysis of Performance, Features, and Price as Efficiency Has Improved	Mauer J, deLaski A, Nadel S, Fryer A & Young R	ACEEE & ASAP	USA	2013	http://www.appliance-standards.org/documents/reports/better-appliances-analysis-performance-features-and-price-efficiency-has-improved
106		Korea's Energy Standards and Labelling - Market Transformation	KEMCO	KEMCO	Korea	2011	Personal communication
108		Impacts of China's Current Appliance Standards and Labeling Program to 2020	David Fridley, Nathaniel Aden, Nan Zhou, Jiang Lin	LBNL	China	2007	https://china.lbl.gov/sites/all/files/lbl-62802-appliance-esl-2020march2007.pdf
1040		Evidence of Progress – Measurement of Impacts of Australia's S&L Program from 1990-2010	Danielle Lowenthal-Savy, Michael McNeil, Lloyd Harrington	EEDAL (Duke University, Lawrence Berkeley National Laboratory, Energy Efficient Strategies)	Australia	2013	https://ec.europa.eu/jrc/en/publication/books/proceedings-7th-international-conference-eedal-2013-energy-efficiency-domestic-appliances-and?search

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
1041		Whitegoods Efficiency Trends 1993-2014	Energy Efficient Strategies	Equipment Energy Efficiency Program (E3)	Australia	2016	http://www.energyrating.gov.au/document/whitegoods-efficiency-trends-1993-2014
2001	REF138	SEAD Member Economy Recent Achievements: Projected Savings from Energy Performance Standards since 2010	Michael A. McNeil, Virginie Letschert, Stephane de la Rue du Can, Puneeth Kalavase, Nicholas Bojda, Mo Zhou, Nicole Kearny, Ana María Carreño, Jenny Corry	LBNL/CLASP	Australia	2016	https://storage.googleapis.com/clasp-siteattachments/SEAD-Member-Economy-Recent-Achievements_FINAL.pdf
2002	REF266	Chinese policy leadership would cool global air conditioning impacts: Looking East	Amol Phadke, Nihar Shaha, Jiang Lin, Won Young Park,Yongsheng Zhang, Durwood Zaelke, Chao Ding, Nihan Karali	Energy Research and Social Science	General	2020	https://eta-publications.lbl.gov/sites/default/files/1-s2.0-s2214629620301468-main.pdf
2101	REF054	South Africa's Appliance Energy Efficiency Standards and Labeling Program: Impact Assessment	Stephane de la Rue du Can, Lethabo Thaba, Charlie Heaps, Resmun Moonsamy, Theo Covary, Michael McNeil	Department of Energy: Republic of South Africa	South Africa	2020	https://www.sanedi.org.za/img/Events/South%20Africa%20Appliance%20Energy%20Efficiency%20SL%20Impacts.%20Final%20February%202020.pdf
2102	REF073	Regulatory Impact Statement : The Energy (Appliance's Energy perfomance and Labeling) Regulations, 2016		Energy Regulatory Commission	Kenya	2016	Personal communication
2201	REF014	Impact of energy efficiency measures for the year 2018-19	Bureau of Energy Efficiency	Bureau of Energy Efficiency	India	2019	https://powermin.nic.in/sites/default/files/webform/notices/e-book_on_Impact_assessment_of_various_energy_efficiency_measures_taken_during_2018_19_0.pdf
2202	REF055	Market Analysis of China Energy Efficient Products (MACEEP)	Jayond Li, Steven Zeng, Hu Bo, Zheng Tan	CLASP	China	2016	https://storage.googleapis.com/clasp-siteattachments/02_2016_Market-Analysis-China-Energy-Efficient-Products_2013_FINAL.pdf

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
2203	REF071	Policy Measures and Impact on the market for the Room Air conditioners In India	Sameer Pandita, Kishore Kumar , Archana Walia, T.P Ashwin	EEDAL	India	2019	https://storage.googleapis.com/clasp-siteattachments/RAC-policies-and-market-transformation-in-India.pdf
2204	REF069	Evaluating the Impacts of Mandatory Policies and Labeling program for Appliances in India	Kishore Kumar, Sameer Pandita, Archana Walia	Energy Efficiency Asia Pacific Conference	India	2019	https://energy-evaluation.org/wp-content/uploads/2019/11/eeap2019-kishorekumar-paper.pdf
2205	REF169	Evaluating the Impact of Implementing Minimum Energy Performance Standards (MEPS) Appliance Regulation in Malaysia	Siti Fatihah Salleh, Mohd Eqwan Bin Mohd Rosian, Aishah Mohd Isa	International Journal of Environmental Technology and Management Vol.22 No.4/5	Malaysia	2019	https://www.inderscience.com/info/inarticle.php?artid=104752
2206	REF197	Prospective Evaluation of the Energy and CO2 Emissions Impact of China's 2010 – 2013 Efficiency Standards for Products	Nina Khanna, Nan Zhou, David Fridley and Michael McNeil	LBNL	China	2016	https://www.osti.gov/biblio/1345198
2207	REF245	Korea Energy Efficiency Policies: Korea's Energy Standards & Labeling. The Vision and Achievements of 22 years of Energy Efficiency Management Programs	KEMCO and MOTIE	KEMCO	Korea	2014	Personal communication
2208	REF265	The Identification and Rebound Effect Evaluation of Equipment Energy Efficiency Improvement Policy: A Case Study on Japan's Top Runner Policy	Dan Yu, Bart Dewancker, Fanyue Qian, The University of Kitakyushu	Journal Energies	Japan	2020	https://doi.org/10.3390/en13174397
2209	REF267	Improving the energy efficiency of room air conditioners in China: Costs and benefits	Nihan Karali, Nihar Shah, Won Young Park, Nina Khanna, Chao Ding, Jiang Lin, Nan Zhou	Energy Policy	China	2020	https://eta-publications.lbl.gov/sites/default/files/1-s2.0-s0306261919317106-main_1.pdf

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
2210	REF278	FY2019 Surveys on Measures to Improve Energy Supply and Demand Structure (Survey on Reviewing the Top Runner Program)(Japanese)	Mitsubishi Research Institute (MRI)	Ministry of Economy, Trade and Industry (METI)	Japan	2020	https://www.meti.go.jp/meti_lib/report/2019FY/000410.pdf
2211	REF279	FY2018 Surveys on Measures to Improve Energy Supply and Demand Structure (Survey on Reviewing the Top Runner Program)	Mitsubishi Research Institute (MRI)	Ministry of Economy, Trade and Industry (METI)	Japan	2019	https://www.meti.go.jp/meti_lib/report/H30FY/000730.pdf
2212	REF281	FY2019 Surveys on Measures to Improve Energy Supply and Demand Structure (Analysis of Current Status of Specific Energy Consuming Equipment)	Mitsubishi UFJ Research and Consulting	Ministry of Economy, Trade and Industry (METI)	Japan	2020	https://www.meti.go.jp/meti_lib/report/2019FY/000412.pdf
2213	REF284	FY2018 Progress Report on the Plan for Global Warming Countermeasures	Prime Minister's Office of Japan		Japan	2020	https://www.kantei.go.jp/jp/singi/ondanka/kaisai/dai41/siryou2.pdf
2301	REF177	AR - Pablo Paisan	Pablo Paisan	IRAM	Argentina	2020	
2302	REF118	Assessment of Brazil's Labeling Program for Air Conditioners	Climate Works and Projecto Kigali	CLASP	Brazil	2019	https://clasp.ngo/publications/assessment-of-brazils-labeling-program-for-air-conditioners
2303	REF193	MEPS & Etiquetas Recomendaciones para Chile y Experiencia internacional (MEPS & Labels, Recommendations for Chile and International experience)	Miquel Pitarch I Mocholí	U4E, GEF	Chile	2020	Personal communication
2304	REF286	Atlas da Eficiência Energética do Brasil	Jeferson Borghetti Soares et al	Ministry of Mines & Energy, Brazil	Brazil	2019	https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/atlas-da-eficiencia-energetica-brasil-2019
2305	REF287	RESULTADOS PROCEL 2018 ANO BASE 2017	Ana Lúcia dos Prazeres Costa	Electrobras	Brazil	2018	http://www.procelinfo.com.br/resultadosprocel2018/docs/Procel_rel_2018_web.pdf

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
2306	REF288	Estudo dos impactos energéticos dos Programas Brasileiros de Etiquetagem Energética: Estudo de caso em refrigeradores de uma porta, condicionadores de ar e motores elétricos	Rafael Balbino Cardoso	UNIVERSIDADE FEDERAL DE ITAJUBÁ	Brazil	2012	http://repositorio.unifei.edu.br/xmlui/bitstream/handle/123456789/1129/tese_cardoso_2012.pdf?sequence=1&isAllowed=y
2401	REF151	COOLPRODUCTS DON'T COST THE EARTH	Francisco Zuloaga, Jean-Pierre Schweitzer, Mauro Anastasio, Stéphane Arditi	EEB	European Union	2019	Personal communication
2402	REF126	Ecodesign Impact Accounting - STATUS REPORT: 2019 Excel Data set	Leo Wierda, René Kemna	VHK	European Union	2020	Personal communication
2405	REF022	EU Energy Label on Vacuum Cleaners: evaluation and market changes	Pierre Geismar, GfK Consumer Choices France	EEDAL	European Union	2015	http://iet.jrc.ec.europa.eu/energyefficiency/conference/eedal2015
2406	REF065	Monitoring the market based on sales data: Do 2015 white goods consume less energy than ten years ago?	Anette Michel, Sophie Attali, Therese Kreitz, Eric Bush	eceee building summer study	European Union	2017	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/8-monitoring-and-evaluation-building-confidence-and-enhancing-practices/monitoring-the-market-based-on-sales-data-do-2015-white-goods-
2407	REF066	Estimation tool for national effects of MEPS and labelling – version 2.0	Linn Stengård, Troels Fjordbak Larsen, Peter Bennich, Signe Friis Christensen,Kasper Schäfer Mogensen,	eceee building summer study	Sweden	2017	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/8-monitoring-and-evaluation-building-confidence-and-enhancing-practices/estimation-tool-for-national-effects-of-meps-and-labelling-version-20/
2408	REF122	Impact assessment of ecodesign and energy labeling of products (Effektvurdering af ecodesign og energimærkning af produkter)	BIG 2 GREAT and Viegand Maagøe	Danish Energy Agency	Denmark	2019	https://ens.dk/sites/ens.dk/files/Energikrav/effektvurdering_af_ecodesign_og_energimaerkning_2019.pdf

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
2409	REF157	Hoher Energieeffizienzgewinn bei den Elektrogeräten (High energy efficiency gains in electrical appliances)	Swiss Federal Office for Energy SFOE	BFE Switzerland	Switzerland	2020	https://www.bfe.admin.ch/bfe/de/home/news-und-medien/medienmitteilungen/mm-test.msg-id-81534.html
2601	REF002	Impacts Evaluation of Appliance Energy Efficiency Standards in Mexico since 2000	Michael McNeil, PhD., Lawrence Berkeley National Laboratory, Ana Maria Carreño, CLASP	IEPEC	Mexico	2015	https://www.iepec.org/wp-content/uploads/2015/papers/005.pdf
2602	REF030	Do Energy Efficiency Standards Improve Quality? Evidence from a Revealed Preference Approach	Sébastien Houde, Department of Agricultural and Resource Economics, University of Maryland, C. Anna Spurlock, LBNL	LBNL-182701	USA	2015	https://www.osti.gov/servlets/purl/1235446
2603	REF042	Do energy efficiency standards hurt consumers? Evidence from household appliance sales	Arlan Brucal and Michael J.Roberts	Journal of Environmental Economics and Management, Volume 96, Pages 88-107	USA	2019	https://www.sciencedirect.com/science/article/pii/S0095069617307647?via%3Dihub
2604	REF004	Energy-Saving States of America: How Every State: Benefits from National Appliance Standards	Andrew deLaski and Joanna Mauer	ASAP and ACEEE	USA	2017	https://appliance-standards.org/sites/default/files/Appliances%20standards%20white%20paper%202%202-14-17.pdf
2605	REF133	Jobs Created by Appliance Standards	Stickles et al	ASAP and ACEEE	USA	2018	https://www.aceee.org/research-report/a1802
2606	REF139	Análisis de la evolución del consumo eléctrico del sector residencial entre 1982 y 2018 e impactos de ahorro de energía por políticas públicas	Odón de Buen, Juan Ignacio Navarrete	CONUEE	Mexico	2019	Personal communication
2607	REF012	Energy Efficiency is a Renewable Resource	James E. McMahon	aceee summer study	USA	2011	https://www.aceee.org/files/proceedings/2012/data/papers/0193-000411.pdf

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
2608	REF105	2019 Annual Report, Voluntary Agreement for Ongoing Improvement to the Energy Efficiency of Set-Top Boxes	D+R International	Steering Committee	USA	2020	https://www.energyefficiency-va.ca/
2609	REF107	2019 Annual Report Canadian Energy Efficiency Voluntary Agreement for Set-Top Boxes	D+R International	Steering Committee	Canada	2019	https://www.energy-efficiency.us/
2610	REF189	Savings estimates for the United States Environmental Protection Agency ENERGY STAR voluntary product labeling program	Marla C Sanchez, Richard E Brown, Carrie Webber, Gregory K Homan	Energy Policy	USA	2008	https://www.sciencedirect.com/science/article/abs/pii/S0301421508001092
2611	REF225	Energy Consumption of Major Household Appliances Shipped in Canada, Trends for 1990-2017		Natural Resources Canada	Canada	2020	https://oee.nrcan.gc.ca/publications/statistics/aham/2017/
2612	REF201	Energy Efficiency Impact Report		ACEEE, ASE, Building council for sustainable energy	USA	2020	https://energyefficiencyimpact.org/
2613	REF222	A Cost-Benefit Analysis Details to support Proposed amendments to the Energy Efficiency Regulations, 2016 (Amendment 14)	Natural Resources Canada	Natural Resources Canada	Canada	2018	https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/regulatory-announcements/amendment-14-energy-efficiency-regulations/18437
2614	REF223	A Cost-Benefit Analysis Details to support Regulations Amending the Energy Efficiency Regulations, 2016 (Amendment 15)	Natural Resources Canada	Natural Resources Canada	Canada	2019	https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/forward-regulatory-plan-2019-2021/amendment-15-energy-efficiency-regulations/19384
2615	REF224	A Cost-Benefit Analysis Details to support Regulations Amending the Energy Efficiency Regulations, 2016 (Amendment 16)	Natural Resources Canada	Natural Resources Canada	Canada	2019	https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/forward-regulatory-plan-2019-2021/amendment-16-energy-efficiency-regulations/20812

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
2616	REF001	Energy and Economic Impacts of U.S. Federal Energy and Water Conservation Standards Adopted From 1987 Through 2015	Stephen Meyers, Alison Williams, Peter Chan, and Sarah Price	Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory	USA	2016	https://eta.lbl.gov/publications/energy-economic-impacts-us-federal-4
2701.1	REF048	Decision RIS: Household Refrigerators and Freezers	Equipment Energy Efficiency Committee	Australian and NZ Governments	Australia	2017	http://www.energyrating.gov.au/document/decision-ris-household-refrigerators-and-freezers-0
2701.2	REF048	Decision RIS: Household Refrigerators and Freezers	Equipment Energy Efficiency Committee	Australian and NZ Governments	New Zealand	2017	http://www.energyrating.gov.au/document/decision-ris-household-refrigerators-and-freezers-0
2702	REF250	Decision regulation impact statement: Swimming pool pumps	E3	Department of the Environment and Energy	Australia	2018	http://www.energyrating.gov.au/document/decision-ris-swimming-pool-pumps
2703	REF047	Impact of energy efficiency programs on electricity consumption in NSW and the ACT from 2000 to 2038	Energy Efficient Strategies et al	Transgrid	Australia	2020	Personal communication
2704	REF252	Decision regulation impact statement: Air conditioners	E3	Department of the Environment and Energy	Australia	2018	http://www.energyrating.gov.au/document/decision-ris-air-conditioners
2705.1	REF249	Decision RIS: Refrigerated display and storage cabinets	E3	Department of the Environment and Energy	Australia	2018	http://www.energyrating.gov.au/document/decision-ris-refrigerated-display-and-storage-cabinets-november
2705.2	REF249	Decision RIS: Refrigerated display and storage cabinets	E3	Department of the Environment and Energy	New Zealand	2018	http://www.energyrating.gov.au/document/decision-ris-refrigerated-display-and-storage-cabinets-november

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
2706	REF251	Decision Regulatory Impact Statement: Proposed Minimum Energy Performance Standards and Labelling for Televisions	E3	Department of the Environment, Water, Heritage and the Arts	Australia	2009	https://www.energyrating.gov.au/document/decision-regulatory-impact-statement-proposed-minimum-energy-performance-standards-and-labelling-televisions
2707.1	REF235	Energy Labelling and Minimum Energy Performance Standards for Appliances and Lighting: Impacts In Cook Islands, Fiji, Kiribati, Samoa, Tonga and Vanuatu	George Wilkenfeld and Associates	Pacific Community	Fiji	2016	http://prdrse4all.spc.int/sites/default/files/energy_labelling_and_minimum_energy_performance_standards_for_appliances_and_lighting-impacts_in_ci.fj_.ki_.sa_.to_.va_.pdf
2707.2	REF235	Energy Labelling and Minimum Energy Performance Standards for Appliances and Lighting: Impacts In Cook Islands, Fiji, Kiribati, Samoa, Tonga and Vanuatu	George Wilkenfeld and Associates	Pacific Community	Samoa	2016	http://prdrse4all.spc.int/sites/default/files/energy_labelling_and_minimum_energy_performance_standards_for_appliances_and_lighting-impacts_in_ci.fj_.ki_.sa_.to_.va_.pdf
2707.3	REF235	Energy Labelling and Minimum Energy Performance Standards for Appliances and Lighting: Impacts In Cook Islands, Fiji, Kiribati, Samoa, Tonga and Vanuatu	George Wilkenfeld and Associates	Pacific Community	Tonga	2016	http://prdrse4all.spc.int/sites/default/files/energy_labelling_and_minimum_energy_performance_standards_for_appliances_and_lighting-impacts_in_ci.fj_.ki_.sa_.to_.va_.pdf
2707.4	REF235	Energy Labelling and Minimum Energy Performance Standards for Appliances and Lighting: Impacts In Cook Islands, Fiji, Kiribati, Samoa, Tonga and Vanuatu	George Wilkenfeld and Associates	Pacific Community	Vanuatu	2016	http://prdrse4all.spc.int/sites/default/files/energy_labelling_and_minimum_energy_performance_standards_for_appliances_and_lighting-impacts_in_ci.fj_.ki_.sa_.to_.va_.pdf
2707.5	REF235	Energy Labelling and Minimum Energy Performance Standards for Appliances and Lighting: Impacts In Cook Islands, Fiji, Kiribati, Samoa, Tonga and Vanuatu	George Wilkenfeld and Associates	Pacific Community	Cook Islands	2016	http://prdrse4all.spc.int/sites/default/files/energy_labelling_and_minimum_energy_performance_standards_for_appliances_and_lighting-impacts_in_ci.fj_.ki_.sa_.to_.va_.pdf

Study ID	2021 Ref ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
2707.6	REF235	Energy Labelling and Minimum Energy Performance Standards for Appliances and Lighting: Impacts In Cook Islands, Fiji, Kiribati, Samoa, Tonga and Vanuatu	George Wilkenfeld and Associates	Pacific Community	Kiribati	2016	http://prdrse4all.spc.int/sites/default/files/energy_labelling_and_minimum_energy_performance_standards_for_appliances_and_lighting-impacts_in_ci.fj_.ki_.sa_.to_.va_.pdf

8.2 Index of all studies referred and reviewed for the 2021 update

Nearly 300 new reports were reviewed for this 2021 update of the Achievements of S&L report. These were allocated a master reference number (in the form REFXXX) as they were entered into the system, so the order is essentially random. These reports, along with their relevant details, are listed below in REF order. Many of these studies did not have suitable quantitative or qualitative data and so could not be used in this report. The Status/Study ID column indicates how the report was used (or not) as follows:

- Value of -1 indicates that the report has been assessed as having little information that can be used directly in the 2021 update
- Value of 0 indicates that the report has been assessed as likely to contain information of interest, but this cannot be extracted from the published material – in some cases inquiries with the authors are pending in order to access the underlying data
- Value of 0.5 indicates that the report has some qualitative data that this has been used in the 2021 update
- Value of 1 to 2790 is the Study number (see below) and indicates that the report has been subjected to quantitative analysis and that key data has been extracted and entered into the Document Analysis Database and used directly in the 2021 update (see Section 1.3).

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF001	2616	Energy and Economic Impacts of U.S. Federal Energy and Water Conservation Standards Adopted From 1987 Through 2015	Stephen Meyers, Alison Williams, Peter Chan, and Sarah Price Environmental Energy Technologies Division	LBNL	USA	2016	https://eta.lbl.gov/publications/energy-economic-impacts-us-federal-4
REF002	2601	Impacts Evaluation of Appliance Energy Efficiency Standards in Mexico since 2000	Michael McNeil, PhD., Lawrence Berkeley National Laboratory, Ana Maria Carreño, CLASP	IEPEC	Mexico	2015	http://www.iepec.org/?cat=18
REF003	0	How do policies for efficient energy use in the household sector induce energy-efficiency innovation? An evaluation of European countries	Girod, B., Stucki, T. & Woerter, M.	Energy Policy. 103: 223–237.		2017	https://www.sciencedirect.com/science/article/pii/S0301421516307182
REF004	2604	Energy-saving states of America: How every state Benefits from National Appppliance standards.	Andrew deLaski and Joanna Mauer	ASAP and ACEEE	USA	2017	https://appliance-standards.org/sites/default/files/Appliances%20standards%20white%20paper%202%202-14-17.pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF004	-1	Energy efficiency standards and innovation	Geoff Morrison	Environmental Research Letters	USA	2015	http://iopscience.iop.org/article/10.1088/1748-9326/10/1/011001
REF005	103	Better Appliances: An Analysis of Performance, Features, and Price as Efficiency Has Improved	Mauer J, deLaski A, Nadel S, Fryer A & Young R	ACEEE & ASAP	USA	2013	http://www.appliance-standards.org/documents/reports/better-appliances-analysis-performance-features-and-price-efficiency-has-improved
REF006	-1	Next Generation Standards: How the National Energy Efficiency Standards Program Can Continue to Drive Energy, Economic, and Environmental Benefits	Andrew deLaski, Joanna Mauer, Jennifer Amann,Michael McGaraghan, Bijit Kundu, Sameer Kwatra, James E. McMahon.	ASAP and ACEEE	USA	2016	https://www.aceee.org/sites/default/files/publications/researchreports/a1604.pdf
REF009	0	Appliance and Equipment efficiency Standards: A Money maker and a Job creater	Racheal Gold, Steven Nadel, John A. "Skip" Laitner and Andrew deLaski	ASAP and ACEEE	USA	2011	https://appliance-standards.org/sites/default/files/Appliance-and-Equipment-Efficiency-Standards-Money-Maker-Job-Creator.pdf
REF011	-1	Saving Energy and Money with Appliances and Equipment standards in the United states.		US Depertment of Energy	USA	2016	https://www.energy.gov/sites/prod/files/2016/02/f29/Appliance%20Standards%20Fact%20Sheet%20-%202-17-2016.pdf
REF012	2607	Energy Efficiency is a renewable Resource	James E McMahon	ACEEE summer study	USA	2012	https://www.aceee.org/files/proceedings/2012/data/papers/0193-000411.pdf
REF013	0	Achieved and potential Energy saving through Energy efficient procurement	K. Sydny Fujita and Margaret Taylor	Berkeley National Labaratory	USA	2012	https://eta-publications.lbl.gov/sites/default/files/achieved_and_potential_energy_savings_through_energy_efficient_procurement_lbnl-5737e.pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF014	2201	A Report on Impact of energy efficiency measures for the year 2018-19 India	BEE India	Bureau of Energy effieciency	India	2020	https://powermin.nic.in/sites/default/files/webform/notices/e-book_on_Impact_assessment_of_various_energy_efficiency_measures_taken_during_2018_19_0.pdf
REF016	-1	Ecodesign Impact Accounting OVERVIEW REPORT 2018	Leo Wierda, René Kemna, Sanne Aarts (VHK)	DG Energy	EU	2019	https://ec.europa.eu/energy/en/studies/ecodesign-impact-accounting-0
REF017	-1	Ecodesign Impact Accounting STATUS REPORT 2018	Leo Wierda, René Kemna (VHK)	DG Energy	EU	2019	https://ec.europa.eu/energy/en/studies/ecodesign-impact-accounting-0
REF018	0	Accelerating Energy Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies	Abhyankar, Nikit, Nihar Shah, Won Young Park, and Amol A. Phadke	Lawrence Berkeley National Laboratory	India, Japan, Korea	2017	https://eetd.lbl.gov/publications/accelerating-energy-efficiency-improv
REF022	2405	EU Energy Label on Vacuum Cleaners: evaluation and market changes	Pierre Geismar, GfK Consumer Choices France	EEDAL	EU	2015	http://iet.jrc.ec.europa.eu/energyefficiency/conference/eedal2015
REF023	0	The New South African Standards and Labelling Programme for Residential Appliances – A First-Hand Evaluation Case Study	Thomas Götz, Lena Tholen, Thomas Adisorn, Theodore Covary	IEPPEC	South Africa	2016	http://www.ieppec.org/session-17/
REF024	-1	Measuring the Impact of India's Standard and Labeling program	Neha Dhingra, Archana Walia, P. K. Mukherjee, CLASP	IEPPEC	India	2016	http://www.ieppec.org/session-17/
REF025	-1	Evaluating Behaviorally Motivated Policy: Experimental Evidence from the Lightbulb Market	Hunt Allcott and Dmitry Taubinsky	The American Economic Review, 105	USA	2015	https://www.aeaweb.org/articles?id=10.1257/aer.20131564
REF026	0	Economic Evaluation of Energy Efficiency Labelling in Domestic Appliances: the Spanish Market	Ibon Galarraga and Josu Lucas	Basque Centre for Climate Change	Spain	2013	https://www.bc3research.org/workingpapers/2013-08.html

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF027	-1	Retail Margins on Energy Efficient Appliances	Larry Dale, Hung-Chia Yang, Sydny Fujita	EEDAL	USA	2011	http://re.jrc.ec.europa.eu/energyefficiency/EEDAL/EEDAL11_Proceedings/17/167_Larry_Dale_standards_and_labels1.pdf
REF029	-1	Appliance Efficiency Standards and Price Discrimination	C. Anna Spurlock	LBNL	USA	2013	https://eaei.lbl.gov/group/energy-efficiency-standards
REF030	2602	Do Energy Efficiency Standards Improve Quality? Evidence from a Revealed Preference Approach	Sébastien Houde, Department of Agricultural and Resource Economics, University of Maryland, C. Anna Spurlock, LBNL	LBNL-182701	USA	2015	https://eaei.lbl.gov/group/energy-efficiency-standards
REF031	-1	Estimating Price Elasticity using Market-Level Appliance Data	K. Sydny Fujita, LBNL	LBNL	USA	2015	https://eaei.lbl.gov/group/energy-efficiency-standards
REF032	0	European Digital Signage Markets - GfK Monitoring of Energy Efficiency via Standards and Labels	Beate Diga, GfK	EEDAL	EU	2015	http://iet.jrc.ec.europa.eu/energyefficiency/conference/eedal2015
REF033	-1	Greenhouse and Energy Minimum Standards (GEMS) Review 2015 Report	David Kenington, Rachel Clarkson Databuild	Department of Industry and Science, On behalf of the E3 Committee	Australia	2015	http://www.energyrating.gov.au/news/gems-review-released
REF034	-1	Greenhouse and Energy Minimum Standards (GEMS) Review 2015 Appendices	David Kenington, Rachel Clarkson Databuild	Department of Industry and Science, On behalf of the E3 Committee	Australia	2015	http://www.energyrating.gov.au/news/gems-review-released

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF035	-1	The Nordic Ecodesign Effect Project, Estimating benefits of Nordic market surveillance of ecodesign and energy labelling	Lovisa Blomqvist and Troels Fjordbak Larsen	Nordic Council of Ministers. (Norden)	Nordic	2015	http://www.norden.org/en/theme/green-growth/the-prime-ministers-green-growth-projects/working-together-on-green-technology-norms-and-standards/nordsyn-surveillance-cooperation-for-green-products/publications/reports
REF036	-1	Top Runner Program Developing the World's Best Energy-Efficient Appliance and More	Agency for Natural Resource and Energy	Ministry of Economy Trade and Industry	Japan	2015	http://www.enecho.meti.go.jp/category/saving_and_new/saving/data/toprunner2015e.pdf
REF039	-1	International Review of Standards and Labeling Programs for Distribution Transformers	Virginie Letschert, Michael Scholand, Ana María Carreño	LBNL, CLASP, RIVER Consultores for US DOS LBNL-1005067		2016	https://publications.lbl.gov/islandora/object/ir%3A1005067
REF040	0	Effectiveness of Energy Efficiency Standards and Labeling Requirements: The Case of Air Conditioners in Japan, Thailand, China and India	Michikazu KOJIMA, Kensuke KUBO, Wakana KUSAKA, Mariko WATANABE		Japan, Thailand, China and India	2015	https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2600068
REF041	-1	Independent Review Of The Greenhouse And Energy Minimum Standards (GEMS) Act 2012, FINAL REPORT JUNE 2019	Ms Anna Collyer, a partner at law firm Allens	Australian Government	Australia	2019	http://www.energyrating.gov.au/review-gems-act
REF042	2603	Do energy efficiency standards hurt consumers? Evidence from household appliance sales	Arlan Brucal and Michael J.Roberts	Journal of Environmental Economics and Management, Volume 96, Pages 88-107	USA	2019	https://www.sciencedirect.com/science/article/pii/S0095069617307647?via%3Dihub

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF044	-1	First findings and recommendations Evaluation of the Energy Labelling Directive and specific aspects of the Ecodesign Directive	Ecofys et al	DG ENER ENER/C3 /2012-523	EU	2014	http://www.energylabelevaluation.eu/eu/documents/
REF046	-1	A powerful priority: How appliance standards can help meet U.S. climate goals and save consumers money	Joanna Mauer and Andrew deLaski	ACEEE/ASAP	USA	2020	https://www.aceee.org/sites/default/files/pdfs/a2001.pdf
REF047	2703	Impact of energy efficiency programs on electricity consumption in NSW and the ACT from 2000 to 2038	Energy Efficient Strategies et al	Transgrid	NSW Australia	2020	Personal communication
REF048	2701	Decision RIS: Household Refrigerators and Freezers	Equipment Energy Efficiency Committee	Aust & NZ Government	Australia	2017	https://www.energyrating.gov.au/document/decision-ris-household-refrigerators-and-freezers-0
REF048	2701	Decision RIS: Household Refrigerators and Freezers	Equipment Energy Efficiency Committee	Aust & NZ Government	New Zealand	2017	https://www.energyrating.gov.au/document/decision-ris-household-refrigerators-and-freezers-0
REF049	-1	Designing efficiency standards and labelling programs to accelerate long-term technological innovation	Robert Van Buskirk	eceee summer study		2015	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2015/7-appliances-product-policy-and-the-ict-supply-chain/designing-efficiency-standards-and-labelling-programs-to-accelerate-long-term-technological-innovation/
REF050	0	Benefits of Ecodesign for EU households	Matthew Smith, DrAndreas Hermelink, Maarten Cuijpers, Dr Edith Molenbroek,Dr Nesen Surmeli	Ecofys by order of: ANEC/BEUC	EU	2016	https://anec.eu/images/Publications/Final_report_Benefits_of_Ecodesign_for_EU_households.pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF051	0	The Energy efficiency Situation in Ghana	Samuel Gyamfi, Felix Amankwah Diawuo, Ebenezer Nyarko Kumi	University of Energy and Natural Resources	Ghana	2017	https://www.researchgate.net/publication/317391015_The_energy_efficiency_situation_in_Ghana
REF052	-1	A POLICY ANALYTICAL APPROACH OF ASSESSING ENERGY EFFICIENCY STANDARDS AND LABELING FOR APPLIANCES	Lei Zeng	Mälardalen University Press DissertationsNo. 177	China	2015	http://www.diva-portal.org/smash/get/diva2:800743/FULLTEXT02.pdf
REF053	-1	The Success story of the Ghana Refrigerator Efficiency Project Implemented by the Energy Commission	Kofi Agyarko		Ghana		http://www.energycom.gov.gh/files/The%20Success%20story%20of%20the%20Energy%20Efficient%20Refrigerator%20Project.pdf
REF054	2101	South Africa's Appliance Energy Efficiency Standards and Labeling Program: Impact Assessment	Stephane de la Rue du Can, Lethabo Thaba, Charlie Heaps, Resmun Moonsamy, Theo Covary, Michael McNeil,	Department of Energy: Republic of South Africa	South Africa	2020	https://www.sanedi.org.za/img/Events/South%20Africa%20Appliance%20Energy%20Efficiency%20SL%20Impacts.%20Final%20February%202020.pdf
REF055	2202	Market Analysis of China Energy Efficient Products (MACEEP)	Jayond Li, Steven Zeng, Hu Bo, Zheng Tan	Clasp	China	2016	https://storage.googleapis.com/clasp-siteattachments/02_2016_Market-Analysis-China-Energy-Efficient-Products_2013_FINAL.pdf
REF056	-1	Impacts of China's 2010 to 2013 Mandatory Product Energy Efficiency Standards: A Retrospective and Prospective Look	David Fridley, Nina Z. Khanna, Nan Zhou, Michael McNeil	aceee building summer study	China	2016	https://www.aceee.org/files/proceedings/2016/data/papers/5_131.pdf
REF057	-1	LED Revolution: How Real is the Phase-out of Legacy Lights in Canada?	Jake Fuller, Salil Gogte, Alice Herrera	aceee building summer study	Ontario, Canada	2018	https://www.aceee.org/files/proceedings/2018/index.html#/paper/event-data/p047

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF058	-1	Appliance Standards: Tactical Planning to Maximize Federal Savings and Legislative Priorities to Re-Enable State Leadership	Alex Chase and Ted Pope, Jonathan McHugh	aceee building summer study	California	2018	https://www.aceee.org/files/proceedings/2018/index.html#/paper/event-data/p140
REF059	0	Cost Benefit Analysis of technology-neutral regulations to introduce Minimum Energy perfomance standards for general lighting	Kay Walsh, Rowan Spazzoli, Talisa Du Bois, Samantha Filby, Chris Reeders	NOVA	South Africa	2019	https://www.savingenergy.org.za/wp-content/uploads/2019/10/MEPS-for-Lighting-in-SA-Final.pdf
REF060	-1	Do Voluntary Agreements for Appliance Efficiency Deliver?	Hans-Paul Siderius, Mirjam Harmelink, Frank Klinckenberg,	aceee building summer study	EU	2018	https://www.aceee.org/files/proceedings/2018/index.html#/paper/event-data/p165
REF061	0	Assessing the impact of the EU Ecodesign Directive on a member state level	Tobias Fleiter, Sibylle Braungardt, Wolfgang Eichhammer, Tariq Sohaib, Barbara Schlomann, Rainer Elsland, Lukas Krantzl, Martin Jakob,	eceee building summer study	EU	2015	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2015/8-monitoring-and-evaluation-building-confidence-and-enhancing-practices/assessing-the-impact-of-the-eu-ecodesign-directive-on-a-member-state-level/
REF062	-1	India's experience in implementing strategic schemes to enhance appliance energy efficiency & futuristic integrated policy approaches to adopt most efficient technologies	S. Sundaramoorthy, Dr.Archana Walia	eceee building summer study	India	2017	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/2-policy-governance-design-implementation-and-evaluation-challenges/indias-experience-in-implementing-strategic-schemes-to-enhance-appliance-energy-efficiency-futuristic-integrated-policy-approaches-to-adopt-most-efficient-technologies/

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF063	-1	Electricity consumption of cold appliances, washing machines, dish washers, tumble driers and air conditioners. On-site monitoring campaign in 100 households. Analysis of the evolution of the consumption over the last 20 years.	Muriel Dupret, Jean-Paul Zimmermann,	eceee building summer study	France	2017	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/7-appliances-products-lighting-and-ict/electricity-consumption-of-cold-appliances-washing-machines-dish-washers-tumble-driers-and-air-conditioners-on-site-monitoring-campaign-in-100-households-analysis-of-the-evolution-of-the-consumption-over-the-last-20-years/
REF064	0	Living up to the expectations? Monitoring the effects of ecodesign and energy labeling in Germany	Corinna Fischer, Uta Weiß, Yifaat Baron, Tilman Hesse, Ina Rüdenauer, Jürgen Sutter,, Britta Stratmann	eceee building summer study	Germany	2017	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/7-appliances-products-lighting-and-ict/living-up-to-the-expectations-monitoring-the-effects-of-ecodesign-and-energy-labeling-in-germany/
REF065	2406	Monitoring the market based on sales data: Do 2015 white goods consume less energy than ten years ago?	Anette Michel, Sophie Attali, Therese Kreitz, Eric Bush	eceee building summer study	EU	2017	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/8-monitoring-and-evaluation-building-confidence-and-enhancing-practices/monitoring-the-market-based-on-sales-data-do-2015-white-goods-consume-less-energy-than-ten-years-ago/

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF066	2407	Estimation tool for national effects of MEPS and labelling – version 2.0	Linn Stengård, Troels Fjordbak Larsen, Peter Bennich, Signe Friis Christensen,Kasper Schäfer Mogensen,	eceee building summer study	Sweden	2017	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/8-monitoring-and-evaluation-building-confidence-and-enhancing-practices/estimation-tool-for-national-effects-of-meps-and-labelling-version-20/
REF067	-1	Development of a Standards and Labeling Program for Air Compressors in India		Clasp and PWC	India	2020	https://storage.googleapis.com/clasp-siteattachments/Development-of-a-Standards-and-Labeling-Program-for-Air-Compressors-in-India.pdf
REF068	-1	Updating Energy Efficiency Research and Evaluation for continued Social-Environmental Relevence	Rafael Friedmann	Energy Evaluation	None	2019	https://energy-evaluation.org/wp-content/uploads/2019/11/eeap2019-raphaelfriedmann-paper.pdf
REF069	2204	Evaluating the Impacts of Mandatory Policies and Labeling program for Appliances in India	Kishore Kumar, Sameer Pandita, Archana Walia	Energy efficiency Asia Pacific Conference	India	2019	https://energy-evaluation.org/wp-content/uploads/2019/11/eeap2019-kishorekumar-paper.pdf
REF070	-1	Roadmap for Transforming India's Energy scenario through Appliance Energy efficiency Program	Kishore Kumar	Clasp	India	2018	https://pronto-core-cdn.prontomarketing.com/581/wp-content/uploads/sites/2/2018/06/Kishore-Kumar-Roadmap-for-Transforming-India%E2%80%99s-Energy-Scenario-through-Appliance-Energy-Efficiency-Program.pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF071	2203	Policy Measures and Impact on the market for the Room Air conditioners In india	Sameer Pandita, Kishore Kumar , Archana Walia, T.P Ashwin	EEDAL	India	2019	https://storage.googleapis.com/clasp-siteattachments/RAC-policies-and-market-transformation-in-India.pdf
REF073	2102	Regulatory Impact Statement : The Energy (Appliance's Energy perfomance and Labeling) Regulations, 2016		Energy Regulatory Commission	Kenya	2016	Personal communication
REF074	0	Consultancy Service for Detailed study on Impacts of Energy Perfomance Standards and Labels Implementation in Kenya	Kiremu Magambo	UNDP, Ministry of Industrialisation and Enterprise Development and SLP	Kenya	2014	Personal communication
REF075	-1	Fighting Climate Change one appliance at a time in six Pacific Island Countries	Linda Dethman, Monica Wabuke	Energy Evaluation	Pacific	2019	https://energy-evaluation.org/wp-content/uploads/2019/11/eeap2019-1.2-lindadethman-presentation.pdf , https://energy-evaluation.org/wp-content/uploads/2019/11/eeap2019-lindadethman-paper.pdf
REF076	-1	Evaluation of Compliance framework of labeling program in India	Neha Dhingra, Archana Walia, PK Mukherjee	Energy Evaluation	India	2017	https://energy-evaluation.org/wp-content/uploads/2019/06/2017-dhingra-paper.pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF077	-1	State of product energy efficiency in Europe – market insights from the new EU product registration database for energy labelling	Anton Berwald, Jana Rückschloss, K.-D. Lang, Karsten Schischke, Nils Nissen	eceee building summer study	Germany	2019	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2019/9-improving-energy-efficiency-in-ict-appliances-and-products/state-of-product-energy-efficiency-in-europe-market-insights-from-the-new-eu-product-registration-database-for-energy-labelling/
REF078	-1	The Impact of Federal Energy Efficiency Programs		aceee	USA	2018	https://www.aceee.org/sites/default/files/pdf/fact-sheet/impact-federal-ee-programs.pdf
REF080	-1	Modeling the Effects of Historical and Projected Energy Efficiency Incentives	Meera Fickling and Kevin Jarzomski	aceee building summer study	USA	2018	http://capabilities.itron.com/efg/2018/0194_0286_000488_ACEEE_2018_Final_ModelingEE.pdf
REF081	-1	Energy Efficiency Jobs in America		E2, E4thefuture	USA	2018	https://e4thefuture.org/wp-content/uploads/2019/09/Energy-Efficiency-Jobs-in-America-2019.pdf
REF082	-1	How Does Energy Efficiency Create Jobs?		aceee	USA		https://www.aceee.org/files/pdf/fact-sheet/ee-job-creation.pdf
REF083	-1	US Energy and Employment Report	BW Research	US DoE	USA		https://www.energy.gov/downloads/us-energy-and-employment-report
REF084	-1	Potential Impact of Lighting and Appliance Efficiency Standards on Peak Demand: The Case of Indonesia	Nihan Karali, Michael McNeil, Virginie Letschert and Stephane de la Rue du Can	EEDAL	Indonesia	2015	https://www.osti.gov/servlets/purl/1237333

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF085	0	Results of the European Code of Conduct for Broadband Equipment	Paolo Bertoldi, European Commission Joint Research Centre, Raffaele Bolla, University of Genova, Flavio Cucchietti, Telecom Italia, Andre Lejeune	EEDAL	EU	2015	https://publications.jrc.ec.europa.eu/repository/handle/JRC96177
REF086	-1	Using PAMS to estimate savings potential from increased energy efficiency – a case study	Ari Reeves and Ana Maria Carreño	EEDAL	Latin America and the Caribbean	2015	https://www.clasp.ngo/wp-content/uploads/2021/01/Using-PAMS-in-LAC-EEDAL-2015.pdf
REF088	-1	Energy Consumption and Energy Efficiency Trends in the EU-28 2000-2015	Bertoldi P., Diluiso F., Castellazzi L., Labanca N., Serrenho T.	JRC	EU	2018	https://publications.jrc.ec.europa.eu/repository/bitstream/JRC110326/efficiency_trends_2017__final_lr.pdf
REF089	0	Relationship between Appliance Prices and Energy-Efficiency Standards and Labeling Policies: Empirical Evidence from Residential Air Conditioners	Amol Phadke, Won Young Park, Nikit Abhyankar, Nihar Shah	EEDAL	Japan, Korea, EU, US, China and India	2017	Personal communication
REF090	-1	ABOUT ENERGY STAR® - 2018		US EPA	USA	2019	https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_Overview_of_Achievements_2018.pdf
REF091	0	BUENAS Methodology	Stephane de la Rue du Can	Berkeley Lab	South Africa	2018	https://www.savingenergy.org.za/wp-content/uploads/2018/11/Berkeley-Lab-BUENAS-Methodology.pdf
REF093	0	Harnessing appliance energy efficiency in South Africa: Policy gaps and recommendations to address actor-specific barriers	Lena Tholen, Thomas Götz, Theodore Covary, Stefan Thomas, Thomas Adisorn	EEDAL	South Africa	2015	https://bigee.net/media/filer_public/2015/11/03/eedal15_submission_102.pdf
REF094	-1	Shifting Consumers to efficient lighting-South Africa's lighting information Label	Theo Covary, Toni Blumeris, Xolile Mabusela	EEDAL	South Africa	2019	Personal communication

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REF095	-1	A success story for a social energy transition	Michael Geißler, Eva Marx, Natalie Preißler and Thomas Götz	EEDAL	Germany	2019	Personal communication
REF096	0	Forecasting Indonesia's electricity load through 2030 and peak demand reductions from appliance and lighting efficiency	Michael A. McNeil , Nihan Karali, Virginie Letschert	Energy for Sustainable Development 49 (2019) 65–7	Indonesia	2019	https://eta-publications.lbl.gov/sites/default/files/forecasting_indonesias_electricity_load.pdf
REF097	-1	Baseline Evaluation and Policy Implications for Air Conditioners in Indonesia	Virginie Letschert, Brian Gerke, Michael McNeil1 , Thomas Tu , Brian Dean, Edi Sartono3 , Jaya Rajasa and Chad Gallinat4	EEDAL	Indonesia	2017	https://eta-publications.lbl.gov/sites/default/files/eedal_conference_paper_baseline_evaluation_and_policy_implications_for_air_conditioners_in_indonesia_final.pdf
REF098	0	Cost-Benefit of Improving the Efficiency of Room Air Conditioners (Inverter and Fixed Speed) in India	Nihar Shah, Nikit Abhyankar, Won Young Park, Amol Phadke, Saurabh Diddi , Deepanshu Ahuja, P.K. Mukherjee, and Archana Walia	Lawrence Berkeley National Laboratory, Bureau of Energy Efficiency, Government of India and CLASP	India	2016	https://eta-publications.lbl.gov/sites/default/files/lbnl-1005787.pdf
REF099	0	Research for the formulation and implementation of energy efficiency standards in China	ZHU Peiwu	China Jiliang University	China	2017	Personal communication
REF100	-1	Progress of China Energy labelling Program		CEL center	China	2019	Personal communication
REF101	0	The implementation framework and process of China Energy label system	Peng Yanyan, Zhang Xin, Lin Ling, Xiz Yujuan	China National Institute of Standardization	China	2016	Personal communication

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REF102	0	Report of the Independent Inspector to the VA on CSTBs – 8th Reporting Period 2017-2018	Nesen Surmeli-Anac, Andreas Hermelink, David Kretschmer, Navigant	Technology Sectoral Governance INPO	EU	2020	http://cstb.eu/
REF103	-1	Independent Inspector Annual compliance report - final, reporting period 2019, Games console self-regulatory initiative	Jane Lee and Stephen Fernandes	Steering Committee for the self-regulatory initiative on energy efficiency of games consoles	EU	2020	https://efficientgaming.eu/docs/
REF104	-1	Imaging Equipment Voluntary AgreementAnnual Compliance Report of the Independent Inspector -Period 10 (1 January –31 December 2019	Dr Chris Robertson	EuroVAprintBrussels, Belgium	EU	2020	https://www.eurovaprint.eu/pages/compliance/
REF105	2608	2019 Annual Report, Voluntary Agreement for Ongoing Improvement to the Energy Efficiency of Set-Top Boxes	D+R International	Steering Committee	USA	2020	https://www.energy-efficiency.us/
REF106	-1	2019 Annual Report Voluntary Agreement for Ongoing Improvement to the Energy Efficiency of Small Network Equipment	D+R International	Steering Committee	USA	2020	https://www.energy-efficiency.us/
REF107	2609	2019 Annual Report Canadian Energy Efficiency Voluntary Agreement for Set-Top Boxes	D+R International	Steering Committee	Canada	2020	https://www.energyefficiency-va.ca/
REF108	0	How effective are EU minimum energy performance standards and energy labels for cold appliances?	Joachim Schleich, Antoine Durand, Heike Brugger	Energy Policy	EU	2020	https://doi.org/10.1016/j.enpol.2020.112069

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF109	-1	Awareness and Adoption of Energy Efficiency in Indian Homes - Insights from the India Residential Energy Survey (IRES) 2020	Shalu Agrawal, Sunil Mani, Dhruvak Aggarwal, Chetna Hareesh Kumar, Karthik Ganesan, and Abhishek Jain	Council on Energy, Environment and Water (CEEW)	India	2020	https://www.ceew.in/sites/default/files/CEEW-IRES-Awareness%20and-adoption-of-EE-in-Indian-homes-07Oct20.pdf
REF110	0	COP26 Product Efficiency, Call to Action, Doubling the energy efficiency of key products globally by 2030	Kevin Lane	IEA	Kenya	2020	Personal communication
REF111	-1	NSW Lighting Market Impact Evaluation:	Common Capital, Beletich Associates	NSW Government	NSW, Australia	2017	https://energy.nsw.gov.au/sites/default/files/2018-09/ESS-2017-18-Rule-change-consultation-paper-Appendix-B_0.pdf
REF112	0	South Africa: Energy Savings Estimates from New Standard and Labeling Program Policy Brief	Stephane de la Rue du Can, Michael A McNeil	LBNL	South Africa	2018	https://eta.lbl.gov/publications/south-africa-energy-savings-estimates
REF113	0	Assessment of the Japanese Energy Efficiency Standards Program	Jun Arakawa, Keigo Akimoto	Journal of Sustainable Development of Energy, Water and Environment Systems	Japan	2015	https://doi.org/10.13044/J.SDEWES.2015.03.0005
REF114	0	A systematic method for evaluating the effects of efficient lighting project in China	Fang Lv, Zhaoxia Wang, Yinan Li , Neng Zu	Energy efficiency journal	China	2015	https://link.springer.com/article/10.1007/s12053-015-9408-5
REF115	0	Analysing the impact of ENERGY STAR rebate policies in the US	Souvik Datta, Massimo Filippini	Energy efficiency journal	US	2015	https://link.springer.com/article/10.1007/s12053-015-9386-7
REF116	-1	The effects of energy efficiency and environmental labels on appliance choice in South Korea	Gicheol Jeong, Yeunjoong Kim	Energy efficiency journal	South Korea	2015	https://link.springer.com/article/10.1007/s12053-014-9307-1

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF117	0	Efficiency improvement opportunities for televisions in India: implications for market transformation programs	Won Young Park, Amol Phadke, Nihar Shar	Energy efficiency journal	India	2014	https://link.springer.com/article/10.1007/s12053-014-9255-9
REF118	2302	Assessment of Brazil's Labeling Program for Air Conditioners	Climate Works and Projecto Kigali	CLASP	Brazil	2019	https://clasp.ngo/publications/assessment-of-brazils-labeling-program-for-air-conditioners
REF119	0	Study of the energetic impacts of the Brazilian Energy Labeling Programs: Case study in single door refrigerators, air conditioners and electric motors.	Rafael Balbino CARDOSO	Thesis for UNIVERSIDADE FEDERAL DE ITAJUBÁ	Brazil	2012	https://repositorio.unifei.edu.br/xmlui/handle/123456789/1129
REF120	0	Impacts of the E3 program: Projected energy, cost and emission savings	E3	E3 (Equipment Energy Efficiency)	Australia	2014	https://www.energyrating.gov.au/sites/default/files/documents/Impacts-of-the-E3-Program.pdf
REF121	-1	Energy demand projections for appliances	Tim Mandel, Heike Brugger, Antoine Durand, Fraunhofer ISI, Emile Chappin, Delft University of Technology	Fraunhofer ISI	EU	2020	https://www.briskee-cheetah.eu/library-and-reports/scientific-working-paper-on-energy-demand-projections-for-appliances/
REF122	2408	Impact assessment of ecodesign and energy labeling of products (Effektvurdering af ecodesign og energimærkning af produkter)	BIG 2 GREAT and Viegand Maagøe	Danish Energy Agency	Denmark	2019	https://ens.dk/sites/ens.dk/files/Energikrav/effektvurdering_af_ecodesign_og_energimaerkning_2019.pdf
REF123	0.1	EU action on Ecodesign and Energy Labelling: important contribution to greater energy efficiency reduced by significant delays and non-compliance	EUROPEAN COURT OF AUDITORS	EUROPEAN COURT OF AUDITORS	EU	2020	https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=52828
REF124	0.5	ICT Impact study	René Kemna, Leo Wierda, William Li, Roy van den Boorn, Martijn van Elburg, Jan Viegand, Anson Wu	VHK	EU	2020	https://www.vhk.nl/downloads/Reports/2020/IA_report-ICT_study_final_2020_(CIRCABC).pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF125	0.5	Ecodesign Impact Accounting - STATUS REPORT: 2019	Leo Wierda, René Kemna	VHK	EU	2020	https://www.vhk.nl/research/eia.htm
REF126	2402	Ecodesign Impact Accounting - STATUS REPORT: 2019 Excel Data set	Leo Wierda, René Kemna	VHK	EU	2020	https://www.vhk.nl/downloads/Reports/EIA/EIA%20Printfile%20status%202019%20-%20VHK20201028.xlsx
REF127	0	COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT Accompanying the document COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people	European Commission	European Commission	EU	2020	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020SC0176
REF129	0.5	Benefits of the Appliance Standards and Labelling Programme - web pages	NA	Department of Mineral Resources and Energy (DMRE), RSA	South Africa	2020	https://www.savingenergy.org.za/asl/benefits/
REF130	0	Energy savings reports - web pages	NA	Department of Mineral Resources and Energy (DMRE), RSA	South Africa	2020	https://www.savingenergy.org.za/reports/
REF133	2605	Jobs Created by Appliance Standards	Brian Stickles, Joanna Mauer, Jim Barrett, Andrew deLaski	ASAP/ACEEE	USA	2018	https://appliance-standards.org/sites/default/files/Jobs_Report.pdf

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REF138	2001	SEAD Member Economy Recent Achievements: Projected Savings from Energy Performance Standards since 2010	Michael A. McNeil, Virginie Letschert, Stephane de la Rue du Can, Puneeth Kalavase, Nicholas Bojda, Mo Zhou, Nicole Kearny, Ana María Carreño, Jenny Corry	LBNL/CLASP	SEAD	2016	https://storage.googleapis.com/clasp-siteattachments/SEAD-Member-Economy-Recent-Achievements_FINAL.pdf
REF139	2606	Análisis de la evolución del consumo eléctrico del sector residencial entre 1982 y 2018 e impactos de ahorro de energía por políticas públicas	Odón de Buen, Juan Ignacio Navarrete	CONUEE/SENER	Mexico	2019	Personal communication
REF142		Effects of rescaling the EU energy label on household preferences for top-rated appliances	Corinne Faure, Marie-Charlotte Guetlein, Joachim Schleich	Fraunhofer ISI	EU	2020	https://www.isi.fraunhofer.de/content/dam/isi/dokumente/sustainability-innovation/2020/WP-11-2020_Effects%20of%20rescaling%20the%20EU%20energy%20label.pdf
REF143		Scientific working paper on energy demand projections for appliances	Tim Mandel, Heike Brugger, Antoine Durand, Emile Chappin	Fraunhofer ISI	EU	2020	https://www.briskee-cheetah.eu/library-and-reports/scientific-working-paper-on-energy-demand-projections-for-appliances/
REF144		Cheetah studies/papers	Fraunhofer ISI	Fraunhofer ISI	EU	2020	https://www.briskee-cheetah.eu/library/?f=&p=cheetah
REF145	0.5	Wissenschaftliche Untersuchung der Energieverbrauchsentwicklung und Maßnahmen zur Steigerung der produkt-bezogenen Energieeffizienz	OEKO Institut ~ 14 authors	OEKO Institut	Germany	2018	https://www.ifeu.de/wp-content/uploads/181206-Produktstudie_Endbericht_final_format.pdf
REF146	-1	Big EE - appliance reports for China (web pages)	Wuppertal et al	Wuppertal et al	China	2020	https://bigee.net/en/country/cn/appliances/
REF147	-1	Big EE - appliance reports for India (web pages)	Wuppertal et al	Wuppertal et al	India	2020	https://bigee.net/en/country/in/appliances/

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REF148	0	Nordcrawl 2	Kasper Mogensen, Troels Fjordbak, Lovisa Blomqvist	Nordic Council of Ministers	Scandinavia	2019	http://norden.diva-portal.org/smash/get/diva2:1312955/FULLTEXT01.pdf
REF149		IEPEC proceedings		IEPEC			https://www.iepec.org/?page_id=4715
REF150		IEPPEC energy evlaution resources		IEPPEC			https://energy-evaluation.org/resources/
REF151	2401	COOLPRODUCTS DON'T COST THE EARTH	Francisco Zuloaga, Jean-Pierre Schweitzer, Mauro Anastasio, Stéphane Arditi	EEB	EU	2019	https://mk0eeborgicuypctuf7e.kinstacdn.com/wp-content/uploads/2019/09/Coolproducts-report.pdf
REF152		ANTICSS project			EU	2020	https://www.anti-circumvention.eu/about-project/documents-and-deliverables
REF153	0.1	ANTICSS Project Deliverable D19a (D4.6): Impact Assessment of circumvention under EU Ecodesign and Energy labelling	Ina Rüdenauer (OEKO), Rainer Stamminger (UBONN), Christiane Pakula (UBONN), Kathrin Graulich (OEKO)	EU Horizon 2020 programme	EU	2020	https://www.anti-circumvention.eu/storage/app/media/D19a_ANTICSS_Circumvention_Impact_Assessment_final.pdf
REF154		Study to evaluate online compliance in the EU and provide suggestions and recommendations		CLASP	EU		https://clasp.ngo/rfps/study-to-evaluate-online-compliance-in-the-eu-and-provide-suggestions-and-recommendations
REF155	0.5	EEPLIANT2 Energy Efficiency Compliant Products 2	EEPliant project	EEPliant project	EU	2020	https://eepliant.eu/images/Documents/EEPLIANT2/EEPLIANT2-Laymans_Report.pdf
REF156	0	Job creation and energy savings through a transition to modern off-grid lighting	Evan Mills			2016	https://drive.google.com/file/d/0B1s8219SGDIjS1ZBa2NDZE5RZGc/view

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF157	2409	Hoher Energieeffizienzgewinn bei den Elektrogeräten (High energy efficiency gains in electrical appliances)	Swiss Federal Office for Energy SFOE	BFE Switzerland	Switzerland	2020	https://www.bfe.admin.ch/bfe/de/home/news-und-medien/medienmitteilungen/mm-test.msg-id-81534.html
REF158	-1	Topmotors Market Report Schweiz 2019	Swiss Federal Office for Energy SFOE	BFE Switzerland	Switzerland	2019	http://topmotors.ch/de/Market Report
REF159	-1	Schweizer Lichtmarkt 2019: Marktanteil von LED wächst weiter (Fact sheet: Swiss lighting market 2019)	Swiss Federal Office for Energy SFOE	BFE Switzerland	Switzerland	2020	https://www.bfe.admin.ch/bfe/de/home/news-und-medien/medienmitteilungen/mm-test.msg-id-81508.html
REF160	-1	REVIEW OF SOUTH AFRICA'S APPLIANCE ENERGY CLASSES AND IDENTIFICATION OF THE NEXT SET OF ELECTRICAL EQUIPMENT FOR INCLUSION IN THE NATIONAL STANDARDS AND LABELLING PROJECT: EXISTING MEPS	Urban Econ Development Economists | Energy Efficient Strategies | Kevin Lane Oxford	UNDP	South Africa		Personal communication
REF161	0	Enforcement of Energy Efficiency Legislative Instruments (1815, 1932 and 1958) at Ports of Entry (With Relevant Indicators/Statistics	Mr Edwin Kwasi Tamakloe, Mr. Hubert Nsor Zan	Energy commission	Ghana	2019	http://energycom.gov.gh/files/Enforcement%20of%20Energy%20Efficiency%20Legislative%20Instruments%20at%20the%20Ports%20of%20Entry.pdf
REF162	0	RISE 2020	World Bank	World Bank		2020	https://rise.worldbank.org/reports
REF163	-1	EU Code of Conduct on Energy Consumption of Broadband Equipment	Paolo Bertoldi	JRC	EU	2017	https://ec.europa.eu/jrc/en/publication/eu-code-conduct-energy-consumption-broadband-equipment-version-6
REF164	-1	Accelerating the Transition to More Energy Efficient Air Conditioners in Indonesia	Virginie Letschert, Sarah Price, Ambereen Shaffie1, Won Young Park, Nihan Karali, Nikit Abhyankar, Nihar Shah, Ari Pasek	LBNL	Indonesia	2020	https://eta-publications.lbl.gov/sites/default/files/lbnl_report_indonesia_acs_2020_rev_0.pdf

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REF165	-1	Indonesia Lighting Market Study and Policy Analysis	Clasp and PWC	Clasp	Indonesia	2020	https://storage.googleapis.com/clasp-siteattachments/Indonesia-Lighting-Market-Study-and-Policy-Analysis.pdf
REF166	-1	Indonesia Rice Cooker Market Study and Policy Analysis	Clasp and ipsos	Clasp	Indonesia	2020	https://storage.googleapis.com/clasp-siteattachments/Indonesia-Rice-Cooker-Market-Study-and-Policy-Analysis.pdf
REF167	-1	Indonesia Fan Market Study and Policy Analysis	Clasp and PWC	Clasp	Indonesia	2020	https://storage.googleapis.com/clasp-siteattachments/Indonesia-Fan-Market-Study-and-Policy-Analysis.pdf
REF168	-1	Indonesia Refrigerator Market Study and Policy Analysis	Clasp and eds	Clasp	Indonesia	2020	https://storage.googleapis.com/clasp-siteattachments/Indonesia-Refrigerator-Market-Study_FINAL.pdf
REF169	2205	Evaluating the Impact of Implementing Minimum Energy Performance Standards (MEPS) Appliance Regulation in Malaysia	Siti Fatihah Salleh, Mohd Eqwan Bin Mohd Rosian, Aishah Mohd Isa	International Journal of Environmental Technology and Management Vol.22 No.4/5	Malaysia	2019	https://www.inderscience.com/info/inarticle.php?artid=104752
REF172	-1	Analysis of the impact of energy efficiency labelling and potential changes on electricity demand reduction of white goods using a stock model: The case of Switzerland	S. Yilmaz, D. Majcen, M. Heidari, J. Mahmoodi, T. Brosch, M.K. Patel	Applied Energy Volume 239, 1 April 2019, Pages 117-132	Switzerland	2019	https://www.sciencedirect.com/science/article/abs/pii/S030626191930203X?via%3Dihub

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF173	-1	Cognitive reflection and the valuation of energy efficiency	Mark A.Andor, Manuel Frondel, Andreas Gerster, Stephan Sommer	Energy Economics Volume 84, Supplement 1, October 2019, 104527		2019	https://www.sciencedirect.com/science/article/pii/S0140988319303226?via%3Dihub
REF174	-1	Appliance energy labels and consumer heterogeneity: A latent class approach based on a discrete choice experiment in China	Donglan Zha, Guanglei Yang, Wenzhong Wang, Qunwei Wang, Dequn Zhou	Energy Economics Volume 90, August 2020, 104839	China	2020	https://www.sciencedirect.com/science/article/pii/S0140988320301791?via%3Dihub
REF175	0	The impact of EU's energy labeling policy: An econometric analysis of increased transparency in the market for cold appliances in Denmark	Casper Bjerregaard, Niels Framroze Møller	Energy Policy Volume 128, May 2019, Pages 891-899	Denmark	2019	https://www.sciencedirect.com/science/article/abs/pii/S0301421519300710?via%3Dihub
REF176	-1	Energy Cost Information and Consumer Decisions: Results from a Choice Experiment on Refrigerator Purchases in India	Manisha Jain, Anand B. Rao, Anand Patwardhan	Applied Energy 226:213-224	India	2018	https://www.iaee.org/energyjournal/article/3634
REF177	2301	AR - Pablo Paisan	Pablo Paisan	IRAM	Argentina	2020	Personal communication
REF178	-1	Reducing Energy Consumption and CO2 Emissions from Electric Motors in Pakistan Through Energy Efficiency Policy	Amna Shahab, Salman Zaffar and Stuart Jeffcott	CLASP	Pakistan	2020	https://storage.googleapis.com/clasp-siteattachments/CLASP-Pakistan-Motors-Report.pdf
REF179	-1	Vietnam Room Air Conditioner Market Assessment and Policy Options Analysis	Clasp and the Ecology and Environment Institute	CLASP	Vietnam	2019	https://storage.googleapis.com/clasp-siteattachments/2019-Vietnam-Room-Air-Conditioner-Market-Assessment-and-Policy-Options-Analysis.pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF180	-1	Department of Energy FY 2021 Congressional Budget Request (Volume 3 Part 1) Energy Efficiency and Renewable Energy	US Department of Energy	US DOE Department of Energy	USA	2020	https://www.energy.gov/cfo/downloads/fy-2021-budget-justification
REF181	0	2017 Report to Congress on the Benefits and Costs of Federal Regulations and Agency Compliance with the Unfunded Mandates Reform Act	Office of Management and Budget	OMB Office of Management and Budget	USA	2018	https://www.eenews.net/assets/2018/02/26/document_pm_01.pdf
REF182	-1	2017-12-04 Agency Information Collection Extension, With Changes; Submission for Office of Management and Budget review; comment request	US Department of Energy Energy Efficiency and Rewnewable Energy Office	USE DOE EERE	USA	2017	https://beta.regulations.gov/document/EERE-2017-BT-CRT-0054-0010
REF183	0	2016 Report to Congress on the Benefits and Costs of Federal Regulations and Agency Compliance with the Unfunded Mandates Reform Act	Office of Management and Budget	OMB Office of Management and Budget	USA	2016	https://obamawhitehouse.archives.gov/sites/default/files/omb/assets/legislative_reports/draft_2016_cost_benefit_report_12_14_2016_2.pdf
REF184	-1	Development and implementation of energy efficiency standards and labeling programs in China: Progress and challenges	Nan Zhou, Nina Zheng, David Fridley and John Romankiewicz	LBNL	China	2013	https://china.lbl.gov/publications/development-and-implementation-energy
REF185	-1	Who Pays for Energy Efficiency Standards?	C Fischer	RFF Resources for the Future	USA	2004	https://media.rff.org/archive/files/sharepoint/WorkImages/Download/RFF-DP-04-11.pdf
REF186	-1	Projected Regional Impacts of Appliance Efficiency Standards for the U.S. Residential Sector	Jonathan G Koomey, Susan A Mahler, Carrie A Webber, James E McMahon	Energy journal	USA	1999	https://www.sciencedirect.com/science/article/abs/pii/S0360544298000656
REF187	-1	Projected Regional Impacts of Appliance Efficiency Standards for the U.S. Residential Sector	Jonathan G Koomey, Susan A Mahler, Carrie A Webber, James E McMahon	LBNL	USA	1998	https://buildings.lbl.gov/publications/projected-regional-impacts-appliance

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF188	0	2015 Report to Congress on the Benefits and Costs of Federal Regulations and Agency Compliance with the Unfunded Mandates Reform Act	Office of Management and Budget	OMB Office of Management and Budget	USA	2015	https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/2015_cb/2015-cost-benefit-report.pdf
REF189	2610	Savings estimates for the United States Environmental Protection Agency ENERGY STAR voluntary product labeling program	Marla C Sanchez, Richard E Brown, Carrie Webber, Gregory K Homan	Energy Policy	USA	2008	https://www.sciencedirect.com/science/article/abs/pii/S0301421508001092
REF190	-1	How have energy efficiency standards and labeling policies affected product manufacturers?	Ari B. Reeves, Amit Khare, Yang Yu,	IEPPEC	India, Korea, Switzerland, and the United States.	2016	https://storage.googleapis.com/clasp-siteattachments/IEPPEC2016_Reeves_mfr-impacts_Final.pdf
REF191	-1	Ex post Impact Evaluations of Appliance Standards and Labeling Programs: A Global Review of Current Practices and Lessons Learned	Jennifer Corry Smith, Yang Yu, Ana Maria Carreño	IEPPEC	Australia, China, EU, Mexico, USA	2016	https://storage.googleapis.com/clasp-siteattachments/IEPPEC-Paper_Ex-post-impact-evaluations_Final.pdf
REF192	0	ACTUALIZACIÓN ESTÁNDAR MÍNIMO DE EFICIENCIA ENERGÉTICA PARA LÁMPARAS DE ILUMINACIÓN GENERAL (MINIMUM ENERGY EFFICIENCY STANDARD UPDATE FOR GENERAL LIGHTING LAMPS)	Ana María Ruz and Francisco Leiva	Ministerio de Energía - Fundación Chile	Chile	2019	Personal communication
REF193	2303	MEPS & Etiquetas Recomendaciones para Chile y Experiencia internacional (MEPS & Labels, Recommendations for Chile and International experience)	Miquel Pitarch I Mocholí	U4E, GEF	Chile	2020	Personal communication

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF194	-1	informe final de usos de la energia -DE LOS HOGARES CHILE (household energy use in Chile - results of survey of 3500)	Cristián Yáñez O., Adelqui Fissore SCh., Arturo Leiva G.	CORPORACIÓN DE DESARROLLO TECNOLÓGICO / IN-DATA	Chile	2018	Personal communication
REF195	-1	Results Procel 2020, base year 2019 (annual report)(Portugusese)		Procel Elecrtobras	Brazil	2020	Personal communication
REF196		Research on energy efficiency management development plan (Korean)	Lee Seongin·So Jinyoung	KOREA ENERGY ECONOMICS INSTITUTE	Korea	2018	Personal communication
REF197	2206	Prospective Evaluation of the Energy and CO2 Emissions Impact of China's 2010 – 2013 Efficiency Standards for Products	Nina Khanna, Nan Zhou, David Fridley and Michael McNeil	LBNL	China	2016	https://www.osti.gov/biblio/1345198
REF198		E3 Programme sales & efficiency data		EECA	NZ	2020	https://www.eeca.govt.nz/our-work/research/research-papers-and-guides/e3-programme-sales-and-efficiency-data/
REF199	-1	Public Health Benefits per kWh of Energy Efficiency and Renewable Energy in the United States: A Technical Report		US EPA	USA	2019	https://www.epa.gov/statelocalenergy/public-health-benefits-kwh-energy-efficiency-and-renewable-energy-united-states
REF200	-1	Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy: A Guide for State and Local Governments		US EPA	USA	2018	https://www.epa.gov/statelocalenergy/quantifying-multiple-benefits-energy-efficiency-and-renewable-energy-guide-state

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF201	2612	Energy Efficiency Impact Report		ACEEE, ASE, Building council for sustainable energy	USA	2020	https://energyefficiencyimpact.org/
REF201	0	Energy Efficiency Impact Report		ACEEE and ASE	USA	2020	https://energyefficiencyimpact.org/
REF202	0	Energy Efficiency in light of Global Trends in Durable Goods	Norbert Herzog, GFK	ECEEE/GFK	Europe	2019	file:///C:/Users/Lloyd/AppData/Local/Temp/9-283-19_Herzog_Presentation.pdf
REF203	-1	Evaluation of the National Framework for Energy Efficiency (NFEE) Evaluation Phase Two Report: Outcomes and Impacts	George Wilkenfeld	GWA, WSRS, EMET	Australia	2012	Personal communication
REF204	0	Market Assessment of Multi-split Air Conditioning Systems in the Chinese and Global Market	Nina Khanna, Chao Ding, Won Young Park, Nihar Shah, and Jiang Lin	Lawrence Berkeley National Laboratory	China	2019	https://eta-publications.lbl.gov/sites/default/files/lbnl_china_vrf_market_assessment_study_final_report_april2019.pdf
REF206	0	AMÉLIORER LA GOUVERNANCE DU SECTEUR DE L'ÉNERGIE RENOUVELABLE ET DE L'EFFICACITÉ ÉNERGÉTIQUE EN AFRIQUE DE L'OUEST (AGOSEREEAO) STRATEGIC REPORT ON THE:IMPLEMENTATION OF MINIMUM ENERGY PERFORMANCE STANDARDS APPROVED BY ECOWAS (MEPS) AND DEVELOPMENT OF NEW MEPS FOR CERTAIN ELECTRICAL APPLIANCES IN WEST AFRICA	Normand Michaud, Paul Waide, Antoine Durand	ECREEE	West Africa	2019	Personal communication

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF207	-1	Promoting Energy Efficiency in Residential and Public Sector in Nigeria		GEF and Energy Commission of Ngeria	Nigeria	2015	Personal communication
REF208	-1	Promoting Energy Efficiency in Residential and Public Sector in Nigeria		GEF	Nigeria	2014	Personal communication
REF209	0	Cost Benefit Analysis of technology-neutral regulations to introduce minimum energy perfomance standards for general lighting	Kay Walsh, Rowan Spazzoli, Talisa Du Bois, Samantha Filby, Chris Reeders	Ministry of resources and Energy South Africa, UNDP	South Africa	2019	https://www.savingenergy.org.za/wp-content/uploads/2019/10/MEPS-for-Lighting-in-SA-Final.pdf
REF211		China Energy Label 10th Aniversary	Chinese government	CNIS/Chinese Government	China	2015	Personal communication
REF212	0.1	Impact of Ecodesign and Energy/Tyre Labelling on R&D and technological innovation	Sibylle Braungardt, Edith Molenbroek, Matthew Smith, Rob Williams, Sophie Attali, Catriona McAlister	Fraunhofer, Triple E, Sea Green Tree, So Watt, Ecofys	EU	2014	https://ec.europa.eu/energy/sites/ener/files/documents/201405_ieel_product_innovation.pdf
REF213	0	ESTUDIO DE USOS FINALES Y CURVA DE OFERTA DE LA CONSERVACION DE LA ENERGÍA EN EL SECTOR RESIDENCIAL	Corporación de Desarrollo Tecnológico	Government of Chile	Chile	2010	https://united4efficiency.org/wp-content/uploads/2017/01/Usos-finales-y-curva-de-oferta-de-conservacion-energi%CC%81a-Sector-Residencial-2010-1.pdf
REF214		Country savings assessments (webpages)	U4E	U4E	All (bar OECD)	2021	https://united4efficiency.org/countries/country-assessments/
REF215	0	Efficiencia Energetica en America Latina Y El Caribe	Olade	Olade	Latin america and the Caribbean	2017	http://www.olade.org/publicaciones/eficiencia-energetica-en-america-latina-y-el-caribe-avances-y-oportunidades/

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF216	0.5	Infraestructura de la calidad para programas de eficiencia energética en América Latina y El Caribe	Olade	Olade	Latin america and the Caribbean	2019	http://www.olade.org/publicaciones/infraestructura-de-la-calidad-para-programas-de-eficiencia-energetica-en-america-latina-y-el-caribe/
REF217	-1	Reducing Energy Consumption and CO2 Emissions from Electric Motors in Pakistan Through Energy Efficiency Policy	Amna Shahab, Salman Zaffar and Stuart Jeffcott	CLASP	Pakistan	2020	https://storage.googleapis.com/clasp-siteattachments/CLASP-Pakistan-Motors-Report.pdf
REF218	-1	Philippines Room Air Conditioner Market Assessment and Policy Options Analysis		CLASP & Innogy	Philippines	2019	https://storage.googleapis.com/clasp-siteattachments/2019-Philippines-Room-Air-Conditioner-Market-Assessment-and-Policy-Options-Analysis.pdf
REF219	0	Improving the energy efficiency of room air conditioners in China: Costs and benefits	Nihan Karali, Nihar Shah, Won Young Park, Nina Khanna, Chao Ding, Jiang Lin, Nan Zhou	Applied Energy	China	2020	https://www.sciencedirect.com/science/article/pii/S0306261919317106
REF220	-1	Canada Energy Use Data Handbook 1990 to 2017	Natural Resources Canada	Natural Resources Canada	Canada	2019	https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/publications.cfm?attr=0
REF221	-1	Smarter Energy Use in Canada - report to the parliament under the Energy Efficiency Act 2018 - 2019	Natural Resources Canada	Natural Resources Canada	Canada	2020	https://www.nrcan.gc.ca/sites/nrcan/files/www/pdf/publications/emmc/2018-19-ReportToParliament-EEAct-EN.pdf
REF222	2613	A Cost-Benefit Analysis Details to support Proposed amendments to the Energy Efficiency Regulations, 2016 (Amendment 14)	Natural Resources Canada	Natural Resources Canada	Canada	2018	https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/regulatory-announcements/amendment-14-energy-efficiency-regulations/18437

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF223	2614	A Cost-Benefit Analysis Details to support Regulations Amending the Energy Efficiency Regulations, 2016 (Amendment 15)	Natural Resources Canada	Natural Resources Canada	Canada	2019	https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/forward-regulatory-plan-2019-2021/amendment-15-energy-efficiency-regulations/19384
REF224	2615	A Cost-Benefit Analysis Details to support Regulations Amending the Energy Efficiency Regulations, 2016 (Amendment 16)	Natural Resources Canada	Natural Resources Canada	Canada	2019	https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/forward-regulatory-plan-2019-2021/amendment-16-energy-efficiency-regulations/20812
REF225	2611	Energy Consumption of Major Household Appliances Shipped in Canada, Trends for 1990-2017	Natural Resources Canada	Natural Resources Canada	Canada	2020	https://oee.nrcan.gc.ca/publications/statistics/aham/2017/
REF226	-1	Energy Efficiency Residential and Small Commercial Applications Guidelines in the Pacific	The Pacific Power Association	The Pacific Power Association	Pacific	2019	http://www.seiapi.com/wp-content/uploads/2019/10/Energy-Efficiency-%E2%80%93-Residential-and-Small-Commercial-Applications-V1-Oct-2019_compressed.pdf
REF227	-1	Cost-benefit Analysis of Investment in Renewable Energy and Energy Efficiency in the Pacific	Thomas Jensen	UNDP	Pacific	2012	https://www.unescap.org/sites/default/files/14-Session2-Cost-benefit%20Analysis%20of%20Investment%20in%20Renewable%20Energy%20and.pdf
REF228	-1	The costs and benefits of introducing standards and labels for electrical appliances in Pacific Island countries	George Wilkenfeld	Secretariat of the Pacific Community	Pacific	2011	http://prdrse4all.spc.int/system/files/11pb_the_costs_and_benefits_of_introducing_standards_and_labels_for_electrical_appliances_in_pics.pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF229	-1	Situation Analysis and Feasability Study on the Impacts of Introducing and Appliance Labelling Programme in Samoa, Tonga and Vanuatu	International Institute for Energy Conservation - Asia	Secretariat of the Pacific Community	Samoa, Tonga and Vanuatu	2010	http://prdrse4all.spc.int/system/files/9823_tmpphp9jjy8r.pdf
REF230	-1	Electrical Appliance Energy Labelling and Minimum Energy Performance Standards for Pacific Island Nations: Baseline Study	George Wilkenfeld	Pacific Forum Secretariat	Pacific	1996	http://prdrse4all.spc.int/system/files/labeling_meps_pacificisland.pdf
REF231	-1	Energy Labelling and Minimum Energy Performance Standards for Appliances and Lighting in Fiji Expanding the Coverage of the Program to Additional Products	George Wilkenfeld	Pacific Forum Secretariat	Pacific	2014	https://www.reinfofiji.com.fj/wp-content/uploads/2017/11/06-15-MEPSL-Expansion-Final-Report.pdf
REF232	-1	FINAL The Costs and Benefits of Energy Labelling and Minimum Energy Performance Standards for Refrigerators and Freezers in Fiji	George Wilkenfeld	Australian Greenhouse Office	Fiji	2006	https://www.reinfofiji.com.fj/wp-content/uploads/2017/11/The-Costs-and-Benefits-of-Energy-Labelling-and-Minimum-Energy-Performance-Standards-for-Refrigerators-and-Freezers-in-Fiji.pdf
REF233	-1	Pacific Appliance Labelling and Standards Programme: Final Evaluation	Linda Dethman, Monica Wabuke, Allan Illingworth, Epeli Waqavonovono	Pacific Community	Pacific	2019	http://prdrse4all.spc.int/sites/default/files/final_pals_evaluation_report.pdf
REF234	-1	Appliance and Energy Labels and Standards - Pacific Appliance Labelling and Standards Programme	Pacific Appliance Labelling and Standards Programme	Pacific Community	Pacific	2018	http://prdrse4all.spc.int/sites/default/files/appliance_energy_labels_and_standards.pdf
REF235	2707	Energy Labelling and Minimum Energy Performance Standards for Appliances and Lighting: Impacts In Cook Islands, Fiji, Kiribati, Samoa, Tonga and Vanuatu	George Wilkenfeld	Pacific Community	Cook Islands, Fiji, Kiribati, Samoa, Tonga and Vanuatu	2016	http://prdrse4all.spc.int/sites/default/files/energy_labelling_and_minimum_energy_performance_standards_for_appliances_and_lighting-impacts_in_ci.fj_.ki_.sa_.to_.va_.pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF236	-1	Technical Analysis of Appliance Markets to Support the Pacific Appliance Labelling and Standards (PALS) Programme	International Institute for Energy Conservation - Asia	REEEP	Pacific	2012	https://www.reeep.org/sites/default/files/Technical%20Analysis%20of%20Appliance%20Markets%20to%20Support%20PALS%20Programme.pdf
REF237	-1	Evaluation Methodology for Energy Efficiency of Air Conditioners in Thailand	Malee Santikunaporn, Prapat Wangskarn & Channarong Asavatesanupap	WIT Transactions on Ecology and The Environment	Thailand	2017	https://www.witpress.com/Secure/elibrary/papers/ESUS17/ESUS17008FU1.pdf
REF238	-1	EGAT’s Experiences and Lessons Learned	Pitarn Chaichinda	Electricity Generating Authority of Thailand	Thailand	2014	http://www.thai-german-cooperation.info/download/20140327_03_EGAT_experiences.pdf
REF239	-1	Promoting Energy Efficiency in the Pacific (Phase 2)	International Institute for Energy Conservation - Asia	ADB	Pacific	2015	https://www.adb.org/sites/default/files/project-document/162145/44099-012-tacr-01.pdf
REF240	-1	Promoting Energy Efficiency in the Pacific (Phase I)	Econoler International	ADB	Pacific	2011	https://www.adb.org/sites/default/files/project-document/74740/42078-012-reg-tacr.pdf
REF241	0.1	Energy Efficiency Employment in Australia: An analysis of the current and potential jobs created by saving energy in Australia	Green Energy Markets	Energy Efficiency Council	Australia	2019	https://www.eec.org.au/policy-advocacy/projects/energy-efficiency-employment-in-australia
REF242	0.1	The Impact of Regulation on Innovation in the United States: A Cross-Industry Literature Review	Luke A. Stewart	Institute of Medicine Committee on Patient Safety and Health IT		2010	https://itif.org/files/2011-impact-regulation-innovation.pdf

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF243	-1	Lessons Learned Bringing LEDs to Market	4E Solid State Lighting Annex	4E Solid State Lighting Annex	Global	2017	https://ssl.iea-4e.org/files/otherfiles/0000/0106/Task_5_-_Lessons_Learned__Report_v9_final.pdf
REF244	-1	COMMUNICATION FROM THE COMMISSION Market assessment on mains-voltage lamps as required by Commission Regulation (EU) No 1194/2012, COM/2015/0443 final	European Commission	European Commission	EU	2015	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2015%3A443%3AFIN
REF245	2207	Korea Energy Efficiency Policies: Korea's Energy Standards & Labeling. The Vision and Achievements of 22 years of Energy Efficiency Management Programs	KEMCO and MOTIE	KEMCO	Korea	2014	Personal communication
REF246	-1	Energy Efficiency Indicators	IEA	IEA	Global	2020	https://www.iea.org/reports/energy-efficiency-indicators
REF247	-1	Sustainable Recovery	IEA	IEA	Global	2020	https://webstore.iea.org/download/direct/3008
REF248	-1	Energy Efficiency 2020	IEA	IEA	Global	2020	https://webstore.iea.org/download/direct/4259
REF249	2705	Decision RIS: Refrigerated display and storage cabinets	E3	Department of the Environment and Energy	Australia and NZ	2018	http://www.energyrating.gov.au/document/decision-ris-refrigerated-display-and-storage-cabinets-november
REF250	2702	Decision regulation impact statement: Swimming pool pumps	E3	Department of the Environment and Energy	Australia	2018	http://www.energyrating.gov.au/document/decision-ris-swimming-pool-pumps

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF251	2706	Decision Regulatory Impact Statement: Proposed Minimum Energy Performance Standards and Labelling for Televisions	E3	Department of the Environment, Water, Heritage and the Arts	Australia	2009	https://www.energyrating.gov.au/document/decision-regulatory-impact-statement-proposed-minimum-energy-performance-standards-and-labelling-televisions
REF252	2704	Decision regulation impact statement: Air conditioners	E3	Department of the Environment and Energy	Australia	2018	http://www.energyrating.gov.au/document/decision-ris-air-conditioners
REF253	-1	2013 - 2018 RETOS, LOGROS Y DESAFÍOS (Achievements and Challenges)	FIDE	FIDEICOMISO PARA EL AHORRODE ENERGÍA ELÉCTRICA	Mexico	2019	https://www.fide.org.mx/wp-content/uploads/book/FIDE-RETOS-LOGROS-DESAFIOS-2013-2018-OPT.PDF
REF254	-1	The Size of the U.S. Energy Efficiency Market: Generating a More Complete Picture	Karen Ehrhardt-Martinez and John A. “Skip” Laitner	ACEEE	USA	2008	https://www.aceee.org/sites/default/files/publications/researchreports/E083.pdf
REF255	-1	State Energy Efficient Appliance Rebate Program Program Plan Narrative – New Jersey	State of New Jersey	State of New Jersey	USA	2009	https://www.nj.gov/bpu/pdf/announcements/EEARP.pdf
REF256	-1	Low carbon jobs: the evidence for net job creation from policy support for energy efficiency and renewable energy	Dr William Blyth, Jamie Speirs, Dr Rob Gross	Imperial College London, British Institute for Energy Economics	Global	2014	http://www.biee.org/wpcms/wp-content/uploads/Speirs-Low-carbon-jobs-The-evidence-for-net-job-creation.pdf
REF257	-1	Beyond energy savings: The multiple benefits of energy efficiency Workshop	IEA	IEA	Global	2018	https://www.iea.org/events/beyond-energy-savings-the-multiple-benefits-of-energy-efficiency

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REF258	-1	Multiple Benefits of Energy Efficiency: From "hidden fuel" to "first fuel" (website)	IEA	IEA	Global	2021	https://www.iea.org/reports/multiple-benefits-of-energy-efficiency
REF259	-1	Kigali Cooling Efficiency Program (website)		K-CEP	Global	2021	https://www.k-cep.org/
REF261	-1	Impact assessment for the standard and labeling program in India	Tanmay Tathagat, Prasoon Kumar	Clasp	India	2011	Personal communication
REF262	-1	Atlas of Energy Efficiency Brazil 2020	Empresa de Pesquisa Energética	Empresa de Pesquisa Energética	Brazil	2021	https://www.epe.gov.br/sites-en/publicacoes-dados-abertos/publicacoes/Paginas/Atlas-of-Energy-Efficiency-in-Brazil-2020-Indicators-Report.aspx
REF263	-1	Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe (COMBI) - Final quantification report	Johannes Thema, Jana Rasch	Wuppertal	Global	2018	https://combi-project.eu/wp-content/uploads/D2.7_COMBI_quantification_report.pdf
REF264	-1	Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe (COMBI) - Final COMBI conference, 17 May 2018, Brussels		Wuppertal	Global	2018	https://combi-project.eu/downloads/final-conference/
REF265	2208	The Identification and Rebound Effect Evaluation of Equipment Energy Efficiency Improvement Policy: A Case Study on Japan's Top Runner Policy	Dan Yu, Bart Dewancker, Fanyue Qian The University of Kitakyushu	Energies	Japan	2020	https://doi.org/10.3390/en13174397
REF266	2002	Chinese policy leadership would cool global air conditioning impacts: Looking East	Amol Phadke, Nihar Shaha, Jiang Lin, Won Young Park,Yongsheng Zhang, Durwood Zaelke, Chao Ding, Nihan Karali	Energy Research and Social Science	China, global	2020	https://eta-publications.lbl.gov/sites/default/files/1-s2.0-s2214629620301468-main.pdf

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REF267	2209	Improving the energy efficiency of room air conditioners in China: Costs and benefits	Nihan Karali, Nihar Shah, Won Young Park, Nina Khanna, Chao Ding, Jiang Lin, Nan Zhou	Applied Energy	China	2020	https://eta-publications.lbl.gov/sites/default/files/1-s2.0-s0306261919317106-main_1.pdf
REF268	-1	Lost in translation: Overcoming divergent seasonal performance metrics to strengthen air conditioner energy-efficiency policies	Won Young Park, Nihar Shah, Jun Young Choi, Hee Jeong Kang, Dae Hoon Kim, Amol Phadke	Energy for Sustainable Development	Many	2020	https://eta-publications.lbl.gov/sites/default/files/1-s2.0-s0973082619313560-main.pdf
REF269	-1	An examination of losses in energy savings after the Japanese Top Runner Program?	Nozomu Inoue, Shigeru Matsumoto Aoyama Gakuin University	Energy Policy		2019	https://doi.org/10.1016/j.enpol.2018.09.040
REF270	-1	Assessment of commercially available energy-efficient room air conditioners including models with low global warming potential (GWP) refrigerants	Won Young Park, Nihar Shah, Brian Gerke	LBNL	China, Europe, India, Japan, South Korea, US	2017	https://eta-publications.lbl.gov/sites/default/files/assessment_of_racs_lbnl-_2001047.pdf
REF271	-1	Assessments of Japanese Energy Efficiency Policy Measures in Residential Sector	Jun ARAKAWA, Keigo AKIMOTO The University of Tokyo	Journal of the Japan Institute of Energy	Japan	2013	https://www.jstage.jst.go.jp/article/jie/93/4/93_333/_pdf
REF272	-1	International Comparison of Energy Efficiency Criteria and Test Procedures in Standards and Labeling Programs for Computer Monitors and Commercial Gas Stoves	Nina Khanna, Nan Zhou, David Fridley, John Romankiewicz	LBNL	China	2013	https://eta-publications.lbl.gov/sites/default/files/pc_gas_stove.pdf
REF273	-1	International Comparative Analysis of Appliance Efficiency Standards & Labeling Programs: Implications for China	Nan Zhou, Nina Zheng, David Fridley, John Romankiewicz	LBNL	Global	2012	https://eta-publications.lbl.gov/sites/default/files/lbl-5742e-appliance-standard-comparisonjune-2012.pdf
REF274	0.1	Check-Testing of Manufacturer Self Reported Labeling Data & Compliance with MEPS	Nan Zhou, Nina Zheng, David Fridley, Ruohong Wang, Christine Egan	LBNL	China	2008	https://eta-publications.lbl.gov/sites/default/files/lbl-247e-check-testing-mepsmarch-2008.pdf

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REF275	0.1	Refrigerator Energy Labelling and MEPS Compliance in the Australian Market	Energy Efficient Strategies	E3	Australia	2010	https://www.energyrating.gov.au/document/report-refrigerator-energy-labelling-and-meps-compliance-australian-market
REF276	-1	Supplement to the Air Conditioners Policy Guide: Accelerating the global adoption of energy-efficient and climate-friendly air conditioners - Model Regulation Guidelines	Won Young Park, Nihar Shah, Brian Holuj, Noah Horowitz, Alex Hillbrand	UNEP U4E	Global	2019	https://eta.lbl.gov/publications/model-regulation-guidelines-energy
REF277	-1	The Top Runner Program in Japan - its effectiveness and implications for the EU	Naoko Tojo, Izumi Tanaka	Swedish Environmental Protection Agency	Japan	2005	https://www.naturvardsverket.se/Documents/publikationer/620-5515-1.pdf
REF278	2210	FY2019 Surveys on Measures to Improve Energy Supply and Demand Structure (Survey on Reviewing the Top Runner Program)(Japanese)	Mitsubishi Research Institute (MRI)	METI	Japan	2020	https://www.meti.go.jp/meti_lib/report/2019FY/000410.pdf
REF279	2211	FY2018 Surveys on Measures to Improve Energy Supply and Demand Structure (Survey on Reviewing the Top Runner Program)(Japanese)	Mitsubishi Research Institute (MRI)	METI	Japan	2019	https://www.meti.go.jp/meti_lib/report/H30FY/000730.pdf
REF280	-1	The Role of Standards: The Japanese Top Runner Program for End-Use Efficiency	Osamu Kimura	Central Research Institute of Electric Power Industry, Cambridge University Press	Japan	2013	https://doi.org/10.1017/CBO9781139150880.023

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF281	2212	FY2019 Surveys on Measures to Improve Energy Supply and Demand Structure (Analysis of Current Status of Specific Energy Consuming Equipment)(Japanese)	MURC	Mitsubishi UFJ Research and Consulting (MURC)	Japan	2020	https://www.meti.go.jp/meti_lib/report/2019FY/000412.pdf
REF282	0.5	FY2018 Surveys on Measures to Improve Energy Supply and Demand Structure (Analysis of Current Status of Specific Energy Consuming Equipment)(Japanese)	MURC	Mitsubishi UFJ Research and Consulting (MURC)	Japan	2019	https://www.meti.go.jp/meti_lib/report/H30FY/010729.pdf
REF283	0.5	FY2017 Surveys for Energy Efficiency Policy Planning (Analysis of Current Status of Specific Energy Consuming Equipment)(Japanese)	MRI	MRI Research Associates	Japan	2018	https://www.meti.go.jp/meti_lib/report/H29FY/000537.pdf
REF284	2213	FY2018 Progress Report on the Plan for Global Warming Countermeasures (Japanese)	Prime Minister's Office of Japan	Prime Minister's Office of Japan	Japan	2020	https://www.kantei.go.jp/jp/singi/ondanka/kaisai/dai41/siryou2.pdf
REF285	0.5	Cost-benefit Analysis and Quantitative Policy Evaluation of the Top Runner Program in Regulating the Efficiency Standards of Home Appliances under the Energy Conservation Law (Japanese)	RIETI	Research Institute of Economy, Trade and Industry (RIETI)	Japan	2013	https://www.rieti.go.jp/jp/publications/summary/06040001.html
REF286	2304	Atlas da Eficiência Energética do Brasil	Jeferson Borghetti Soares et al	Ministry of Mines & Energy, Brazil	Brazil	2019	https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/atlas-da-eficiencia-energetica-brasil-2019
REF286	-1	Energy and Economic Impacts of U.S. Federal Energy and Water Conservation Standards Adopted From 1987 Through 2014	Stephen Meyers, Alison Williams, Peter Chan, and Sarah Price Environmental Energy Technologies Division	LBNL	USA	2015	https://eta.lbl.gov/publications/energy-economic-impacts-us-federal-3

2021 Ref ID	Status/ Study ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
REF287	2305	RESULTADOS PROCEL 2018 ANO BASE 2017	Ana Lúcia dos Prazeres Costa	Electrobas	Brazil	2018	http://www.procelinfo.com.br/resultadosprocel2018/docs/Procel_rel_2018_web.pdf
REF288	2306	Estudo dos impactos energéticos dos Programas Brasileiros de Etiquetagem Energética: Estudo de caso em refrigeradores de uma porta, condicionadores de ar e motores elétricos	Rafael Balbino Cardoso	UNIVERSIDADE FEDERAL DE ITAJUBÁ	Brazil	2012	http://repositorio.unifei.edu.br/xmlui/bitstream/handle/123456789/1129/tese_cardoso_2012.pdf?sequence=1&isAllowed=y
REF289	0.1	Unflued Gas Appliances and Air Quality in Australian Homes: Technical Report No. 9	Len Ferrari, Frank Fleer, Ted Pender, Mark Tulau, Jacinda Houston, Anthony Myszka	Department of the Environment and Heritage	Australia	2004	Personal communication
REF290	0.1	The health effects of unflued gas heater use in Australia		Department of Health and Ageing	Australia	2007	https://vgls.sdp.sirsidynix.net.au/client/search/asset/1291947
REF291	0.1	Health Effects from Gas Stove Pollution	Brady Anne Seals, Andee Krasner	Rocky Mountains Institute and others	USA	2020	https://rmi.org/insight/gas-stoves-pollution-health

8.3 Index of all studies reviewed for the 2015 and 2016 reports

The studies that were collected and analysed for the first Achievements of S&L report in 2015 (International Energy Agency 4E 2015) are listed in numerical order. These reports are numbered as Study 1 to Study 112. The studies that were collected and analysed for the 2016 update (International Energy Agency 4E 2016) are also listed in numerical order. These reports are numbered as Study 1001 to Study 1041.

2015/16 ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
1	Greening Whitegoods: A report into the energy efficiency trends of whitegoods in Australia from 1993 to 2009	Energy Efficient Strategies	E3	Australia	2010	http://www.energyrating.gov.au/program-publications/?viewPublicationID=2149
2	Assessment of building energy-saving policies and programs in China during the 11th Five-Year Plan.	Zhou, N., M.A. McNeil, M. Levine.	LBNL	China	2011	http://eetd.lbl.gov/node/49532
3	Ecodesign Impact Accounting - Part 1 – Status Nov. 2013.	Rene Kemna	VHK Consulting	EU	2014	https://ec.europa.eu/energy/sites/ener/files/documents/2014_06_ecodesign_impact_accounting_part1.pdf
4	Energy and Economic Impacts of U.S. Federal Energy and Water Conservation Standards Adopted From 1987 Through 2012	S. Meyers, A. Williams and P. Chan	LBNL	USA	2013	
5	Energy and Economic Impacts of U.S. Federal Energy and Water Conservation Standards Adopted From 1987 Through 2013	S. Meyers, A. Williams and P. Chan	LBNL	USA	2014	https://escholarship.org/uc/item/4sn784n0
6	Appliance Standards: Comparing Predicted and Observed Prices	Nadel S & deLaski A	ACEEE & ASAP	USA	2013	http://www.aceee.org/research-report/e13d
7	Spreading the Net: the Multiple Benefits of Energy Efficiency	Ryan, L. and N. Campbell	IEA	International	2012	http://www.iea.org/publications/insights/ee_improvements.pdf
8	Retrospective evaluation of appliance price trends	Dale L; Antinori, C; McNeil, M, McMahon, JE; Fujita, KS	Energy Policy	USA	2009	https://publications.lbl.gov/islandora/object/ir%3A154748
9	Evaluation of Energy Efficiency Policy Measures for Household Air Conditioners in Australia	Paul Ryan et al	EnergyConsult	Australia	2010	http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/Cooling/Air_Conditioners/201012b-aircon-evaluation-technical.pdf

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10	Evaluation of Energy Efficiency Policy Measures for Household Refrigeration in Australia	Kevin Lane and Lloyd Harrington	Energy Efficient Strategies	Australia	2010	http://www.energyrating.gov.au/resources/program-publications/?viewPublicationID=2150
11	Equipment Energy Efficiency Committee Decision Regulatory Impact Statement - Household Refrigerators and Freezers	Energy Efficient Strategies	E3	Australia and New Zealand	2008	http://www.energyrating.gov.au/program-publications/200804-2/
12	Incorporating Experience Curves in Appliance Standards Analysis	Desroches, L-BG, Karina; Chan, Peter; Greenblatt, Jeffery; Kantner, Colleen; Lekov, Alex; Meyers, Stephen; Rosenquist, Gregory; Van Buskirk, Robert; Yang, Hung-Chia;	University of California	USA	2011	https://escholarship.org/uc/item/00q385jk#page-1
13	Do energy efficient appliances cost more?	Ellis M, Jollands N, Harrington L & Meier A	Various	International	2007	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2007/Panel_6/6.025
14	Retrospective Examination of Demand-Side Energy Efficiency Policies.	Gillingham, K; Newell, RG; Palmer, K - Resources of the Future	Resources for the Future	USA	2004	http://www.rff.org/Documents/RFF-DP-04-19rev.pdf
16	An examination of the effectiveness of the EU minimum standard on cold appliances: the British case	Schiellerup, P	University of Oxford	UK	2002	
17	Using the Experience Curve Approach for Appliance Price Forecasting	US DOE	US DOE	USA	2011	https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/experience_curve_appliance_price_forecasting_3-16-11.pdf
18	Analyzing price and efficiency dynamics of large appliances with the experience curve approach	Weiss, MP, Martin K.; Junginger, Martin; Blok, Kornelis	Energy Policy		2010	http://www.sciencedirect.com/science/article/pii/S0301421509007575
19	A review of experience curve analyses for energy demand technologies	Weiss M, Junginger M, Patel MK & Blok K	Technological Forecasting and Social Change	The Netherlands	2010	http://www.sciencedirect.com/science/article/pii/S0040162509001668
20	Evaluation of Fiji's Minimum Energy Performance Standards and Labelling Program (MEPSL)	Energy Efficient Strategies P/L	Fiji Department of Energy	Fiji	2015	Personal communication

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21	Strategy for Energy Efficiency Policy in the Electricity Sector in Central America and Dominican Republic	BUN-CA	BUN-CA	Costa Rica/Central America	2015	http://www.bun-ca.org/index.php?option=com_content&view=article&id=86&Itemid=92
22	Lifting the label: evaluating the real impact of energy labelling in Vietnam	Charles Michaelis, Kevin Lane, Melanie Slade, Dang Hai Dung	International Energy Policy & Programme Evaluation Conference	Vietnam	2014	http://www.iepec.org/conf-docs/papers/2014/Charles%20Michaelis.pdf
25	PILESLAMP - Claimed Energy Saving, Cost Savings and Emissions Reductions and Associated Methodology	UNDP/GEF/NRDC Collaboration	UNDP/GEF/NRDC Collaboration	China	2014	Personal communication
27	10 Things you didn't know about energy efficient products (European Commission newsletter)	European Commission	European Commission	Europe	2015	https://ec.europa.eu/energy/en/energy_newsletter/newsletter-january-2015-0
28	European TV market 2007-2013, Energy efficiency before and during the implementation of the Ecodesign and Energy Labelling regulations	Michel A, Attali S, Bush E	Topten International Services	EU	2014	http://www.topten.eu/uploads/File/European_TV_market_2007%E2%80%932013_July14.pdf
29	International Review of Frameworks for Impact Evaluation of Appliance Standards, Labeling, and Incentives	Nan Zhou, John Romankiewicz, Edward Vine, Nina Khanna, and David Fridley	LBNL		2012	http://china.lbl.gov/sites/all/files/lbl-6003e-sli-evaluation-dec-2012.pdf
30	Do S&L programmes deserve a 'robust evaluation' label?	John Fawcett	Databuild	General	2014	http://www.iepec.org/conf-docs/papers/2014/John%20Fawcett.pdf
32	Cool labels: The first three years of the European Energy Label	John Winward, Pernille Schiellerup, Brenda Boardman	ECI, University of Oxford	EU	1998	http://www.eci.ox.ac.uk/research/energy/downloads/coollabels.pdf
33	DECADE Domestic equipment and carbon dioxide emissions: Transforming the UK cold market	Brenda Boardman, Kevin Lane, Mark Hinnells, Nick Banks, Geoff Milne, Andrew Goodwin, Tina Fawcett	ECI, University of Oxford	UK	1997	Personal communication

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34	Evaluating the impact of energy labelling and MEPS – a retrospective look at the case of refrigerators in the UK and Australia	Kevin Lane, Lloyd Harrington, Paul Ryan	UK Market Transformation Programme, EES, EnergyConsult		2007	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2007/Panel_4/4.292/paper
35	Monitoring of energy efficiency trends of European domestic refrigeration appliances	Waide, Paul	ADEME for EC SAVE	EU	1999	Personal communication
39	Energy Conservation Policies of Japan	Agency of Natural Resources and Energy Enegy Conservation and Renewable Energy Department	Agency of Natural Resources and Energy Enegy Conservation and Renewable Energy Department	Japan	2011	http://www.enecho.meti.go.jp/category/saving_and_new/saving/001/pdf/genjo_English.pdf
42	Recent and Historical Product Energy Efficiency (EE) and Life-cycle Cost Improvement in Swedish Appliance Markets	ENERVEE	ENERVEE	Sweden (plus some comparative data from other EU countries)	2014	http://www.superefficient.org/en/Activities/Standards%20and%20Labels/~/media/Files/SL%20Project%20Reports/SEAD%20Data%20Access%20Report/Sweden%20EE%20Policy%20Analysis%20Report%2020140120_final.pdf
43	A retrospective investigation of energy efficiency standards: policies may have accelerated long term declines in appliance costs	Van Buskirk RD, Kantner CLS, Gerke BF, Chu S	Environmental Research Letters	USA , EU	2014	http://iopscience.iop.org/1748-9326/9/11/114010
44	Impact of Ecodesign and Energy/Tyre Labelling on R&D and Technological Innovation	Braungardt et al	Europe	EU	2014	https://ec.europa.eu/energy/sites/ener/files/documents/201405_ieel_product_innovation.pdf
46	Assessment of the Impacts of Standards and Labelling Programs in Mexico (four products)	Sanchez I, Pulido H, McNeil M, Turiel I, della Cava M	INSTITUTO DE INVESTIGACIONES ELÉCTRICAS + LBL	Mexico	2007	https://escholarship.org/content/qt0qz4b7qk/qt0qz4b7qk_noSplash_880f11813e0e81ed7c3fcce072e96281.pdf

2015/16 ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
47	Japanese Top Runner Approach for energy efficiency standards	Kimura, Osamu	Central Research Institute of Electric Power Industry	Japan	2010	Personal communication
48	Top-Runner Program - its effectiveness and implications for emerging and developing countries	Katayama H	The Energy Conservation Centre	Japan	2008	http://eneken.ieej.or.jp/data/pdf/1651.pdf
50	Gamified Energy Efficiency Programs	Grossberg F, Wolfson M, Mazur-Stommen S, Farley K & Nadel S	ACEEE	USA	2015	http://aceee.org/research-report/b1501
51	Background report I: Literature review - Evaluation of the Energy Labelling Directive and specific aspect of the Ecodesign Directive	Edith Molenbroek, Heleen Groenenberg, Maarten Cuijpers, Luis Janeiro, Matthew Smith, Nesen Surmeli, Paul Waide, Sophie Attali, Corinna Fischer, Juraj Krivošik, Paula Fonseca, Bruno Santos, João Fong\	Ecofys	EU	2013	http://www.energylabelevaluation.eu/tmce/Background_document_I_-_Literature_report.pdf
52	Background report II: Survey results - Evaluation of the Energy Labelling Directive and specific aspects of the Ecodesign Directive	Author	Ecofys	EU	2012	https://ec.europa.eu/energy/sites/ener/files/documents/Background_document_II_-_Survey_results.pdf
53	Background document IV: comments first findings report	Author	Ecofys	EU	2012	http://www.energylabelevaluation.eu/tmce/Background_document_IV_-_first_findings_comments.pdf
56	Evaluation of the Ecodesign Directive (2009/125/EC) - Final Report	Author	CSES	EU	2012	Personal communication
58	Economic benefits of the EU Ecodesign Directive - Improving European economies	Edith Molenbroek, Maarten Cuijpers, Kornelis Blok	Ecofys	EU	2012	http://www.ecofys.com/files/files/ecofys_2012_economic_benefits_ecodesign.pdf

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60	Final technical report - Evaluation of the Energy Labelling Directive and specific aspects of the Ecodesign Directive	Edith Molenbroek, Mathew Smith, Heleen Groenenberg, Paul Waide, Sophie Atali, Corinna Fischer, Juraj Krivošik, Paula Fonseca, Bruno Santos, João Fong	Organisation	European Union	2014	http://www.energylabelevaluation.eu/tmce/Final_technical_report-Evaluation_ELD_ED_June_2014.pdf
61	Task 3 Report: Outlook on the estimated GHG Emissions Reductions - revised and updated final report	W. Irrek et al	Okopol, Wuppertal	EU	2010	http://ec.europa.eu/clima/policies/effort/docs/impact_ggas_en.pdf
63	Impacts of the EU's Ecodesign and Energy/Tyre labelling legislation on third jurisdictions	Paul Waide Luis Janeiro, Nesen Surmeli, Ann Gardiner, Jeremy Tait, Paula Fonseca, João Fong, Nuno Quaresma, Chris Evans	Organisation	European Union	2014	http://www.ecofys.com/files/files/ec-2014-impacts-ecodesign-energy-labelling-on-third-jurisdictions.pdf
64	Energy efficiency status report 2012: electricity consumption and efficiency trends in the EU-27	Paulo Bertoldi, Bettina Hirl, Nicola Labance	JRC	EU-27	2012	http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/energy-efficiency-status-report-2012.pdf
65	Eco-design legislation	EC	EC	EU	2015	https://ec.europa.eu/energy/sites/ener/files/documents/list_of_ecodesign_measures.pdf
66	Energy Labelling legislation of household appliances	EC	EC	EU	2015	https://ec.europa.eu/energy/sites/ener/files/documents/list_of_enegy_labelling_measures.pdf
67	Study on the impact of the energy label – and potential changes to it – on consumer understanding and on purchase decisions	Author	Organisation	EU	2014	https://ec.europa.eu/energy/sites/ener/files/documents/Impact%20of%20energy%20labels%20on%20consumer%20behaviour.pdf
68	Some Results and Propositions from a French Experiment with Energy Labelling	Colombier M & Menanteau P	ICE & IEPE	France	1997	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/1997/Panel_2/p2_5
69	Cold Labelling - the UK Experience of Energy Labels	Boardman B	University of Oxford	United Kingdom	1997	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/1997/Panel_2/p2_14

2015/16 ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
70	An examination of the effectiveness of the EU minimum standard on cold appliances: the British case	Schiellerup P	Environmental Change Institute	United Kingdom	2001	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2001/Panel_1/p1_3
71	Analysis of energy efficiency standards for Japanese appliances	Nagata Y	CRIEPI	Japan	2001	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2001/Panel_1/p1_5
72	Labelling of electrical appliances - An evaluation of the Energy Labelling Ordinance in Germany and resulting recommendations for energy efficiency policy	Schlomann B, Eichhammer W, Gruber E & Stockle F	Fraunhofer & GfK	Germany	2001	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2001/Panel_1/p1_12
73	Assessing the market transformation for domestic appliances resulting from European Union policies	Bertoldi P, Waide P & Lebot B	European Commission	Europe	2001	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2001/Panel_4/p4_24
74	Findings of the Cold II SAVE study to revise cold appliance energy labelling and standards in the EU	Waide P	PW Consulting	Europe	2001	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2001/Panel_5/p5_16
75	Appliance and equipment efficiency standards in the US: Accomplishments, next steps and lessons learned	Nadel S	ACEEE	USA	2003	https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2003/Panel_1/1045nadel/
76	New challenges of Japanese energy efficiency program by Top Runner approach	Muakoshi C, Nakagami H, Tsuruda M & Edamura N	Jyukankyo Research Institute	Japan	2005	http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2005c/Panel_4/4066murakoshi
77	Market analysis of China energy efficient products	Bo H, Li J, Zheng T & Zeng L	Top10 & CLASP	China	2011	http://proceedings.eceee.org/visabstrakt.php?event=3&doc=6-186-13
78	Energy efficiency and minimum standards: a market analysis of recent changes in appliance energy efficiency standards in the US	Spurlock C & Dale L	LBNL	USA	2011	http://proceedings.eceee.org/visabstrakt.php?event=3&doc=6-187-13
79	Modelling the dynamics of appliance price-efficiency distributions	Van Buskirk R	LBNL	International	2011	http://proceedings.eceee.org/visabstrakt.php?event=3&doc=6-289-13
80	The Impact of Refrigerator Standards on United States Households	James Mapp, Madison, WI and John H. Reed	IEPEC	USA	2013	http://www.iepec.org/conf-docs/conf-by-year/2013-Chicago/154.pdf
81	China's Practices on Evaluating the Energy Savings of Mandatory Energy Efficiency Standards	Li Pengcheng, Liu Meng, Chen Haihong, Li Yan	International Energy Program Evaluation Conference,	China	2012	http://www.iepec.org/conf-docs/papers/2012PapersTOC/papers/011.pdf

2015/16 ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
82	Estimation Tool for National Effects of MEPS and Energy Labeling	Troels Fjordbak Larsen, Karolina Petersson, Rikke Næraa	IT Energy, Swedish Energy Agency, Danish Energy Agency	Sweden, Denmark	2012	http://www.iepec.org/conf-docs/papers/2012PapersTOC/papers/010.pdf
83	Evaluation of a Lighting Market Transformation Program in Austrailia - Outcomes and Attributions	George Wilkenfeld	GWA	Australia	2012	http://www.iepec.org/conf-docs/papers/2012PapersTOC/papers/072.pdf
84	The Best Value for americas Energy Dollar: A National review of the cost of utility energy efficiency programs	Maggie Molina	ACEEE Paper	USA	2014	https://www.aceee.org/research-report/u1402
85	The $20 Billion Bonanza: Best Practice Electric Utility Energy Efficiency programs and their Benefits to the South-West	Howard Gellar et al	South West Energy Project	USA	2012	https://azsolarcenter.org/images/PDF/Library1/sweep-20b-bonanza.pdf
86	Impacts of U.S. Appliance Standards to Date	James E. McMahon Peter Chan Stuart Chaitkin	LBL	USA	2000	http://ees.lbl.gov/sites/all/files/impacts_of_us_appliance_standards_to_date_lbnl-45825.pdf
87	Estimating Sales and Market Share from Sales Rank Data for Consumer Appliances	Touzani S & Van Buskirk R	LBNL	USA	2015	https://eaei.lbl.gov/publications/estimating-sales-and-sales-market-sha
88	Observed energy savings from appliance efficiency standards	Meier A	LBNL	Various	1997	http://www.sciencedirect.com/science/article/pii/S0378778896010213
89	Estimate of Cost-Effective Potential for Minimum Efficiency Performance Standards in 13 Major World Economies	Letschert V, Bojda N, Ke J & McNeil M	LBNL	Various	2012	http://www.superefficient.org/Resources/~/media/Files/BUENAS%20CEP%20Scenario-%20LBNL-5723E.pdf
90	Cost of conserved energy for residential energy appliances in Australia, Japan and Korea	Taylor Zhou	International Appliances Studies	Australia, Japan, Korea	2012	https://nature.berkeley.edu/classes/es196/projects/2012final/ZhouT_2012.pdf
91	Japanese Top Runner Approach for energy efficiency standards	Kimura Osamu	Central Research Institute of Electric Power Industry	Japan	2010	Personal communication
96	Retrospective evaluation of appliance price trends	Dale L; Antinori, C; McNeil, M, McMahon, JE; Fujita, KS	LBNL	USA	2008	https://escholarship.org/uc/item/9r72w9qr

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97	The Induced Innovation Hypothesis and Energy-Saving Technological Change	Newell R, Jaffe A & Stavin R	The Quartery Journal of Economics	USA	1999	http://www.rff.org/documents/RFF-DP-98-12-REV.pdf
99	Energy efficiency and minimum standards: a market analysis of recent changes in appliance energy efficiency standards in the US	Spurlock C, Dale L & Yang HC	LBNL	USA	2013	https://escholarship.org/uc/item/9dj9x078
100	Trends in the cost of efficiency for appliances and consumer electronics	Desroches LB, Yang HC, Kantner C, Garbesi K, Ganeshalingam M, Van Burkirk R	LBNL	USA	2013	http://proceedings.eceee.org/visabstrakt.php?event=3&doc=6-190-13
101	Impact Assessment of BEE's Standard & Labeling Program in India	Market Xcel Data Matrix Pvt. Ltd.	CLASP	India	2015	https://clasp.ngo/publications/impact-assessment-of-bees-standard-labeling-program-in-india
102	Appliance Standards: Comparing Predicted and Observed Prices	Nadel S & deLaski A	ACEEE & ASAP	USA	2013	http://aceee.org/research-report/e13d
103	Better Appliances: An Analysis of Performance, Features, and Price as Efficiency Has Improved	Mauer J, deLaski A, Nadel S, Fryer A & Young R	ACEEE & ASAP	USA	2013	http://www.appliance-standards.org/documents/reports/better-appliances-analysis-performance-features-and-price-efficiency-has-improved
104	The Efficiency Boom: Cashing in on the Savings from Appliance Standards	Lowenberger A, Mauer J, deLaski A, DiMascio M, Amann J & Nadel S	ACEEE & ASAP	USA	2012	http://aceee.org/research-report/a123
105	GHG·Energy Target Management Scheme	KEMCO	KEMCO	Korea	2012	www.kemco.or.kr
106	Korea's Energy Standards and Labelling - Market Transformation	KEMCO	KEMCO	Korea	2011	Personal communication
108	Impacts of China's Current Appliance Standards and Labeling Program to 2020	David Fridley, Nathaniel Aden, Nan Zhou, Jiang Lin	LBNL	China	2007	https://china.lbl.gov/sites/all/files/lbl-62802-appliance-esl-2020march2007.pdf
109	Household refrigerators: Monitoring efficiency changes in Europe and Australia over the last 10 years. in EEDAL. 2015	Michel, A et al	Energy Efficient Strategies P/L	Australia	2015	https://e3p.jrc.ec.europa.eu/publications/proceedings-8th-international-conference-energy-efficiency-domestic-appliances-and-0
110	Energy Technology Perspectives IEA		IEA		2008	https://www.iea.org/topics/energy-technology-perspectives

2015/16 ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
111	Energy Labelling and Standards Programs Throughout the world in 2013	Harrington, L et al	Department of Industry, Australia	Australia	2013	https://www.iea-4e.org/publications
112	Office of Atmospheric Programs, Climate Protection Partnerships: Annual Report 2013	US EPA	United States Enviromental Protection Agency	USA	2013	http://www.energystar.gov/ia/partners/publications/pubdocs/ENERGYSTAR_2013AnnualReport-508.pdf
1001	Confronting Regulatory Cost and Quality Expectations: An Exploration of Technical Change in Minimum Efficiency Performance Standards	Margaret Taylor, C. Anna Spurlock, and Hung-Chia Yang	ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY	USA	2015	http://www.rff.org/files/document/file/RFF-DP-15-50.pdf
1002	Promotion of energy efficiency in circulation pumps, especially in domestic heating systems	Niels Bidstrup, Martin van Elburg, Kevin Lane		Europe	2001	Personal communication
1003	Technology procurement for very energy efficient circulation pumps: Overall Evaluation Report	Stefan Thomas, Claus Bartlett	Energy + Pumps	Europe	2008	https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/energy_pumps_energy_pumps_evaluation_report_en.pdf
1004	Energy Efficiency Market Report 2014 - Market Trends and Medium-Term Prospects	IEA	IEA	IEA countries	2014	http://www.iea.org/topics/energyefficiency/publications/energyefficiencymarketreport2014/
1005	Energy Efficiency Market Report 2015 - Market Trends and Medium-Term Prospects	IEA	IEA	IEA countries	2015	https://www.iea.org/publications/freepublications/publication/energy-efficiency-market-report-2015-.html
1006	Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe (COMBI)	Puig, D., Farrell, T.C.	Wuppertal Institute			http://combi-project.eu
1007	MAPLE project?					
1008	Nordic crawler?					
1009	Market Transformation through Emerging Technology: Lessons learned from the introduction of hybrid heat pump clothes dryers into the North America market	Wold C, Granda C, Bush E, Foster R, Badger C, Ton M	CLASP,TOPTEN, VEIC	USA	2015	http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/events/EEDAL15/S22_Appliances2/eedal15_submission_175.pdf

2015/16 ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
1010	Heat pump water heater (GE and ORNL joint R&D) (US)					
1011	The evolving price of household LED lamps: Recent trends and historical comparisons for the US market	Brian F. Gerke, Allison T. Ngo, Andrea L. Alstone, and Kibret S. Fisseha	LBNL	USA	2014	https://ees.lbl.gov/sites/all/files/lbnl-6854e.pdf
1012	Swedish light manufacturer (alternative to fan manufacturer)					
1013	Energy Efficiency – the first fuel for the EU Economy: How to drive new finance for energy efficiency investments	Energy Efficiency Financial Institutions Group (EEFIG)	EC and UNEP	European Union	2015	https://ec.europa.eu/energy/en/news/new-report-boosting-finance-energy-efficiency-investments-buildings-industry-and-smes
1015	Energy Efficiency Market Report 2013 - Market Trends and Medium-Term Prospects	IEA	IEA	IEA countries	2013	
1016	Assessing the Employment and Social Impact of Energy Efficiency: Final Report	Cambridge Econometrics		General	2015	
1017	Energy Efficiency in the United States: 35 Years and Counting : Report E1502	Steven Nadel, Neal Elliott, and Therese Langer	ACEEE	USA	2015	http://aceee.org/sites/default/files/publications/researchreports/e1502.pdf
1018	Verifying Energy Efficiency Job Creation: Current Practices and Recommendations Report F1501	Casey J. Bell, James Barrett, and Matthew McNerney	ACEEE	USA	2015	http://aceee.org/sites/default/files/publications/researchreports/f1501.pdf
1019	Recognizing the Value of Energy Efficiency's Multiple Benefits - Report IE1502	Christopher Russell, Brendon Baatz, Rachel Cluett, and Jennifer Amann	ACEEE	USA	2015	http://aceee.org/sites/default/files/publications/researchreports/ie1502.pdf
1020	Green to Scale	SITRA	SITRA	International	2015	Extracts from http://www.greentoscale.net/en
1021	Impacts Evaluation of Appliance Energy Efficiency Standards in Mexico since 2000 Technical Report	M. McNeil, Ana Maria Carreno	SEAD	Mexico	2015	Personal communication
1022	Impacts Evaluation of Appliance Energy Efficiency Standards in Mexico since 2000 :Technical Report	Michael McNeil, and Ana Maria Carreño	LBNL & CLASP	Mexico	2015	https://mexico.lbl.gov/sites/default/files/lbnl-1003758.pdf
1023	Measuring Market Transformation: Quantitative Analysis of Appliance EE Labeling Program Impacts in the EU, Australia, and India (2014 ACEEE Summer Study)	Taylor Zhou and Michael McNeil LBNL	ACEEE	International	2014	http://aceee.org/files/proceedings/2014/data/papers/2-258.pdf

2015/16 ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
1024	How energy Efficiency cuts costs for a 2 Degree Future	Fraunhofer Institute for Systems and Innovation Research ISI	Fraunhofer Institute for Systems and Innovation Research ISI	General	2015	https://www.isi.fraunhofer.de/en/presse/2015/presseinfo-34-2015-energieeffizienz-zwei-grad-ziel.html
1025	Energy efficiency standards help businesses thrive and consumers save	David Goldstein and Jason Knopes	NRDC and ANSI	USA	2015	http://thehill.com/blogs/congress-blog/265929-energy-efficiency-standards-help-businesses-thrive-and-consumers-save
1026	Energy efficiency of White Goods in Europe: monitoring the market with sales data. Changes and trends regarding energy efficiency, energy consumption, size and price in the markets of refrigerators, washing machines and tumble driers in the EU, France and Portugal, 2004 to 2014	Anette Michel, Sophie Attali, Eric Bush	TopTen	Europe	2015	https://storage.topten.eu/source/files/White-Goods-in-Europe-short.pdf
1027	Swiss appliance sales data, 2004 – 2014: Analysis and conclusions for EU market monitoring	Anette Michel, Eric Bush	TopTen	Switzerland	2015	http://www.topten.eu/uploads/File/Swiss_appliance_market_2004-2014_and_recommendations.pdf
1028	ECODESIGN IMPACT ACCOUNTING Final – Status May 2015	René Kemna and Leo Wierda	vhk	Europe	2015	Personal communication
1029	Topten Global Impact Assessment	Rolf Iten, Martin Herren, Bettina Schäppi	WWF Switzerland	International	2015	http://www.topten.info/uploads/File/IA-Report_Topten_global_final.pdf
1030	Click your way to energy savings -Euro-Topten Max 2012-14	Sophie Attali, Eric Bush, Therese Kreitz, Marie-Pierre		Europe	2015	
1031	Yearly Appliance Energy Cost Indication (YAECI)			Europe	2015	http://www.appliance-energy-costs.eu/eu/news/yaeci-final-publishable-report
1032	People have the Power Consumers & Energy Efficient Products	EASME	EASME, European Commission	Europe	2015	http://www.svn.cz/assets/files/seven_v_mediich/2015/People-have-the-Power-IEE-report_0.pdf
1033	Lot 11 – Circulators: The stony route to EU regulation 641/2009 (622/2012)	Niels Bidstrup	Grundfos	Europe	2013	Personal communication
1034	Heat Pump Tumble Driers: Market Development in Europe and MEPS in Switzerland	Bush, E; Zuloaga, F.R.; Granda, C and Wold, C		Europe	2015	http://iet.jrc.ec.europa.eu/energyefficiency/conference/eedal2015

2015/16 ID	Title	Authors	Organisation	Jurisdiction	Publication Year	Source/Web
1035	How does Energy Efficiency Create Jobs	ACEEE Fact Sheet	ACEEE	USA	2013	http://aceee.org/sites/default/files/pdf/fact-sheet/ee-job-creation.pdf
1036	It's all about the jobs! Stimulating employment and economic impacts from investments in energy efficiency and renewable energy	Gaffney, K., J. Vencil, L. Petraglia, and M. Rudman.	ECEEE	USA	2015	http://proceedings.eceee.org/visabstrakt.php?event=5&doc=8-439-15
1037	WP6 Macro economy: Literature review on macroeconomic effects of energy efficiency improvement actions. D6.1 report	Sigurd Naess-Schmidt, Martin Bo Hansen, David von Below	Copenhagen Economics	Europe	2015	http://combi-project.eu/wp-content/uploads/2015/09/D6.1.pdf
1038	WP3 Air pollution: Literature review on avoided air pollution impacts of energy efficiency measures	Nora Mzavanadze	University of Manchester for the COMBI project		2015	https://combi-project.eu/wp-content/uploads/D3.1_final_20180515.pdf
1039	Denmark - new indicators (to be done in March 2016) - will be a flyer	Troels	ENS			Personal communication
1040	Evidence of Progress – Measurement of Impacts of Australia's S&L Program from 1990-2010	Danielle Lowenthal-Savy, Michael McNeil, Lloyd Harrington	EEDAL - Nicholas School of the Environment, Duke University, Lawrence Berkeley National Laboratory, Energy Efficient Strategies	Australia	2013	https://ec.europa.eu/jrc/en/publication/books/proceedings-7th-international-conference-eedal-2013-energy-efficiency-domestic-appliances-and?search
1041	Whitegoods Efficiency Trends 1993-2014	Energy Efficient Strategies	Australian Government	Australia	2016	https://www.energyrating.gov.au/document/whitegoods-efficiency-trends-1993-2014

9 References

AS/NZS 6400 2016, *Water efficient products - Rating and labelling*, Standards Australia, Sydney, Australia, retrieved from https://infostore.saiglobal.com/en-au/standards/AS-NZS-6400-2016-100970_SAIG_AS_AS_212146/

AS/NZS4474. 1 2007, *Performance of household electrical appliances—Refrigerating appliances: Part 1: Energy consumption and performance*, Standards Australia, Sydney.

Australian Council of Social Services 2018, *Energy Stressed in Australia*, Australian National University, Sydney, Australia, retrieved from https://www.acoss.org.au/wp-content/uploads/2018/10/Energy-Stressed-in-Australia.pdf

Burrows, L 2021, 'Deaths from fossil fuel emissions higher than previously thought: Fossil fuel air pollution responsible for more than 8 million people worldwide in 2018', *School of Engineering and Applied Sciences*, retrieved from https://www.seas.harvard.edu/news/2021/02/deaths-fossil-fuel-emissions-higher-previously-thought

CLASP 2005, *Standards & Labelling Guidebook* 2nd edn, Collaborative Labelling and Standards Program, Washington, DC, retrieved from https://clasp.ngo/tools/s-l-guidebook

CLASP 2021, 'Collaborative Labelling and Standards Program - policy database', retrieved from https://clasp.ngo/policies

CLASP & Danish Low Carbon Transition Unit 2013, *Energy Policy Toolkit for Energy Efficiency in Appliances, Lighting, and Equipment,* Washington, DC, retrieved from https://clasp.ngo/publications/energy-policy-toolkit-for-energy-efficiency-in-appliances-lighting-and-equipment

Collyer, A 2019, *Independent Review Of The Greenhouse And Energy Minimum Standards (GEMS) Act 2012, FINAL REPORT*, Australian Government, Canberra, Australia, retrieved from http://www.energyrating.gov.au/review-gems-act

Department for Environment, Food and Rural Affairs (UK) 2015, *Emerging Findings from Defra's Regulation Assessment: First update covering 2012*, London, United Kingdom, retrieved from https://www.coolproducts.eu/wp-content/uploads/2020/02/defra-regulation-assessment-2015.pdf

Desroches, L-BG 2012, 'Incorporating Experience Curves in Appliance Standards Analysis', *eScholarship, University of California*.

Desroches, L-BG 2013, 'Incorporating experience curves in appliance standards analysis', *Energy Policy*, vol. 52, pp. 402–416.

Dymond, C & Baker, S 2017, 'Heat Pump Clothes Dryers in the Pacific Northwest', in European Commission, University of California, Irvine, USA, p. 1328, retrieved from https://e3p.jrc.ec.europa.eu/events/eedal17

E3 2014, *Impacts of the E3 program: Projected energy, cost and emissions savings*, Canberra, Australia, retrieved from http://www.energyrating.gov.au/document/report-impacts-e3-program-projected-energy-cost-and-emission-savings

E3 2017, *Decision Regulation Impact Statement – Household Refrigerators and Freezers*, Department of the Environment and Energy, Canberra, Australia, retrieved from http://www.energyrating.gov.au/news/decision-regulation-impact-statement-household-refrigerators-and-freezers

E3 2018a, *Decision regulation impact statement: Air conditioners*, Department of the Environment and Energy, Canberra, Australia, retrieved from http://www.energyrating.gov.au/document/decision-ris-air-conditioners

E3 2018b, *Decision Regulation Impact Statement: Lighting - Regulatory reform opportunities and improving energy efficiency outcomes*, Canberra, Australia, retrieved from http://energyrating.gov.au/document/decision-ris-lighting

Ellis, M, Jollands, N, Harrington, L & Meier, AK 2007, 'Do energy efficient appliances cost more?', in *ECEEE Summer Study on Energy Efficiency*, Mandelieu, France, retrieved from https://www.eceee.org/static/media/uploads/site-2/library/conference_proceedings/eceee_Summer_Studies/2007/Panel_6/6.025/paper.pdf

Energy Efficient Strategies 2016, *Whitegoods Efficiency Trends in Australia 1993-2014*, Department of Innovation, Industry and Science, Canberra, Australia, retrieved from http://www.energyrating.gov.au/document/whitegoods-efficiency-trends-1993-2014

Energy Efficient Strategies 2020, *Review of Residential Sector Hot Water Requirements for South Australia*, Department for Energy and Mining, South Australia, Adelaide, South Australia, retrieved from https://energymining.sa.gov.au/__data/assets/pdf_file/0010/384139/EES_Report.pdf

Energy Efficient Strategies & Maia Consulting 2014, *Energy Standards and Labelling Programs Throughout the World in 2013*, Department of Industry, Canberra, retrieved from http://www.iea-4e.org/publications

Harrington, L 2017, 'Dryer usage patterns and energy saving potential during normal use', in European Commission, University of California, Irvine, USA, p. 1328, retrieved from https://e3p.jrc.ec.europa.eu/events/eedal17

Harrington, L & Lane, K 2010, *Evaluation of Energy Efficiency Policy Measures for Household Refrigeration in Australia: An Assessment of Energy Savings Since 1986*, Department of Climate

Change and Energy Efficiency, retrieved from http://www.energyrating.gov.au/document/report-evaluation-energy-efficiency-policy-measures-household-refrigeration-australia

Harrington, L & Wilkenfeld, DG 1997, 'Appliance Efficiency Programs in Australia: Labelling and Standards', *Energy and Buildings*, vol. 26.

IEA 4E Electric Motor Systems Annex 2015, *Energy efficiency roadmap for electric motors and motor systems*, International Energy Agency, retrieved from https://www.iea-4e.org/publications

International Energy Agency 2020, *Key World Energy Statistics*, International Energy Agency, 9, rue de la Fédération 75739 Paris Cedex 15, retrieved from https://www.iea.org/reports/key-world-energy-statistics-2020

International Energy Agency 4E 2015, *Achievements of appliance energy efficiency standards and labelling programs*, Energy Efficient End-use Equipment Annex (4E), Paris, retrieved from http://www.iea-4e.org/publications

International Energy Agency 4E 2016, *Achievements of appliance energy efficiency standards and labelling programs: A Global Assessment in 2016*, Energy Efficient End-use Equipment Annex (4E), Paris, retrieved from http://www.iea-4e.org/publications

Kelly-Detwiler, P 2014, 'LEDs Will Get Even More Efficient: Cree Passes 300 Lumens Per Watt', *Forbes Magazine*, retrieved from http://www.forbes.com/sites/peterdetwiler/2014/03/27/leds-will-get-even-more-efficient-cree-passes-300-lumens-per-watt/

Kuhn, G 2013, 'LED Interior Lighting: Trends and Challenges', in ECEEE, Coimbra, Portugal.

McMahon, J 2011, 'Energy Efficiency is a renewable Resource', in ACEEE, USA, retrieved from https://www.aceee.org/files/proceedings/2012/data/papers/0193-000411.pdf

McNeil, MA, Letschert, V & de la Rue du Can, S 2008, *Global Potential of Energy Efficiency Standards and Labeling Programs*, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California.

Michel, A & Bush, E 2015, *Swiss appliance sales data, 2004 – 2014: Analysis and conclusions for EU market monitoring*, Top Ten, retrieved from https://storage.topten.eu/source/files/Swiss%20appliance%20market%20analysis%202004-2013%20and%20recommendations.pdf

Michel, A, Bush, E, Attali, S, Harrington, L, Bertoldi, P & De Luca, A 2015, 'Household refrigerators: Monitoring efficiency changes in Europe and Australia over the last 10 years', in *8th International Conference on Energy Efficiency in Domestic Appliances and Lighting*, Luzern, Switzerland, retrieved from https://ec.europa.eu/jrc/en/publication/proceedings-8th-international-conference-energy-efficiency-domestic-appliances-and-lighting

Michel, A, Bush, E, Attalie, S & Paolo Bertoldi 2017, 'How has the European White Goods market changed in the past 10 years? – Analysis based on sales data reveals constant improvements, contradictory trends, and big successes for a new technology.', in *Energy Efficiency in Domestic Appliances and Lighting*, University of California, Irvine, retrieved from https://ec.europa.eu/jrc/en/publication/proceedings-9th-international-conference-energy-efficiency-domestic-appliances-and-lighting

Milne, G & Boardman, B 2000, 'Making cold homes warmer: the effect of energy efficiency improvements in low-income homes A report to the Energy Action Grants Agency Charitable Trust', *Energy Policy*, vol. 28, no. 28(6–7):, pp. 411–424.

Navigant 2016, *Energy Savings Forecast of Solid-State Lighting in General Illumination Applications*, US Department of Energy, retrieved from https://www.energy.gov/sites/prod/files/2016/09/f33/energysavingsforecast16_2.pdf

Phadke, A, Shaha, N, Lin, J, Park, WY, Zhang, Y, Zaelke, D, Ding, C & Karali, N 2020, 'Chinese policy leadership would cool global air conditioning impacts: Looking East', *Energy Research and Social Science*, vol. 66, retrieved from https://eta-publications.lbl.gov/sites/default/files/1-s2.0-s2214629620301468-main.pdf

Preval, N, Chapman, R, Pierse, N & Howden-Chapman, P 2010, 'Evaluating energy, health and carbon co-benefits from improved domestic space heating: A randomised community trial', *Energy Policy*, vol. 38, no. 8, pp. 3965–3972.

Ryan, L & Campbell, N 2012, *Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements*, International Energy Agency, Paris, France, retrieved from https://doi.org/10.1787/5k9crzjbpkkc-en

Stewart, LA 2010, *The Impact of Regulation on Innovation in the United States: A Cross-Industry Literature Review*, Institute of Medicine Committee on Patient Safety and Health IT, retrieved from https://itif.org/files/2011-impact-regulation-innovation.pdf

Strategy Policy Research 2019, *Energy Efficiency Forecasts: 2019 –2041: Final Report*, Australian Energy Market Operator, Sydney, Australia, retrieved from https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/StrategyPolicyResearch_2019_Energy_Efficiency_Forecasts_Final_Report.pdf
.

Sust, CA, Dehoff, P, Lang, D & Lorenz, D 2012, *Zumtobel Research: Improved quality of life for resident dementia patients:St. Katharina research project in Vienna*, Vienna, Austria, retrieved from https://www.zumtobel.com/PDB/teaser/EN/Study_Health_and_Care_StKatharina.pdf

Sustainability Victoria 2016, *Clothes Dryer Retrofit Trial*, Melbourne, Australia, retrieved from https://www.sustainability.vic.gov.au/About-Us/Research/Household-retrofit-trials

Taylor, M, Spurlock, CA & Yang, H-C 2015, *Confronting Regulatory Cost and Quality Expectations: An Exploration of Technical Change in Minimum Efficiency Performance Standards,* Lawrence Berkeley National Laboratory, retrieved from https://media.rff.org/archive/files/document/file/RFF-DP-15-50.pdf

United for Efficiency 2017, *Accelerating the Global Adoption of Energy-Efficient Electric Motors and Motor Systems*, UN Environment, Geneva, Switzerland, retrieved from https://united4efficiency.org/resources/accelerating-global-adoption-energy-efficient-electric-motors-motor-systems/

United for Efficiency 2021, *Protocols to Conduct Market and Impact Assessments*, retrieved from https://united4efficiency.org/resources/protocols-to-conduct-market-and-impact-assessments/

US Department of Energy 2011, *Using the Experience Curve Approach for Appliance Price Forecasting*,

Vohra, K, Vodonos, A, Schwartz, J, Marais, EA, Sulprizio, MP & Mickley, LJ 2021, 'Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem', *Environmental Research*, vol. In press, retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0013935121000487

Weiss, M, Patel, MK, Junginger, M & Blok, K 2010, 'Analyzing price and efficiency dynamics of large appliances with the experience curve approach', *Energy Policy*, vol. 38, pp. 770–783.