Title

Energy and Economic Impacts of U.S. Federal Energy and Water Conservation Standards Adopted From 1987 Through 2014

Authors

Meyers, Stephen
Williams, Alison
Chan, Peter
et al.

Publication Date

2015-03-25

Energy and Economic Impacts of U.S. Federal Energy and Water Conservation Standards Adopted From 1987 Through 2014

Principal Authors

Stephen Meyers, Alison Williams, Peter Chan, and Sarah Price

Environmental Energy Technologies Division

Project Contributors

Greg Rosenquist, Helcio Blum, Barbara Atkinson,
Sanaee Iyama, Maithili Iyer
Environmental Energy Technologies Division

Lawrence Berkeley National Laboratory

One Cyclotron Road
Berkeley, CA 94720

March 2015

The work described in this report was funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, Building Technologies Program under Contract No. DE-AC02-05CH11231.

Disclaimer

Copyright Notice

Acknowledgements

The work described in this report was funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, Building Technologies Program under Contract No. DE-AC02-05CH11231.

Table of Contents

Abstract

This paper presents estimates of the key impacts of Federal energy and water conservation standards adopted from 1987 through 2014. The standards for consumer products and commercial and industrial equipment include those set by legislation as well as standards adopted by DOE through rulemaking.

In 2014, the standards saved an estimated 4.29 quads of primary energy, which is equivalent to 4% of total U.S. energy consumption. The savings in operating costs for households and businesses totaled $60 billion. The average household saved $377 in operating costs as a result of residential and plumbing product standards. The estimated reduction in CO_2 emissions associated with the standards in 2014 was 232 million metric tons, which is equivalent to 4% of total U.S. CO_2 emissions.

The estimated cumulative energy savings over the period 1990-2090 amount to 202 quads. Accounting for the increased upfront costs of more-efficient products and the operating cost (energy and water) savings over the products' lifetime, the standards have a cumulative net present value (NPV) of consumer benefit of between $1,327 billion and $1,604 billion, using 7 percent and 3 percent discount rates, respectively.

The water conservation standards, together with energy conservation standards that also save water, reduced water use by 1.9 trillion gallons in 2014, and estimated cumulative water savings by 2090 amount to 55 trillion gallons. The estimated consumer savings in 2014 from reduced water use amounted to $12 billon.

Introduction

The energy conservation program for consumer products and certain commercial and industrial products was established by the Energy Policy and Conservation Act of 1975 (EPCA). EPCA established a program consisting of test procedures, labeling, and energy conservation targets for 19 types of consumer products. The National Energy Conservation Policy Act of 1978 amended EPCA by replacing the energy conservation targets program and directing that energy conservation standards be set for the covered consumer products. With the passage of the National Appliance Energy Conservation Act (NAECA) in 1987, EPCA was further amended to establish the first national energy conservation standards for consumer products. Subsequent amendments in 1988, 1992, 2005, and 2007 further expanded the scope of coverage to include additional consumer products, certain commercial and industrial equipment, as well as water conservation standards for residential and commercial products. EPCA, as amended, requires the Department of Energy (DOE) to update or establish standards at levels that "achieve the maximum improvement in energy [or water] efficiency … which the Secretary determines is technologically feasible and economically justified." EPCA defines "economically justified" standards as those for which benefits exceed the costs, given a number of factors, including impacts on consumers and manufacturers and the nation's need to save energy or water.

This paper presents estimates of the key impacts of the energy and water conservation standards that have been adopted from 1987 through 2014. It updates the results presented in Meyers et al. (2013),[1] which covered standards adopted through 2012. The standards covered include those set by legislation as well as standards adopted by DOE through rulemaking. The estimates cover both historic and projected impacts of these standards. The impacts cover primary energy savings and water savings, net present value of consumer[a] benefits, and estimated reductions in CO_2 emissions.

Table 1 lists products covered by standards, the year(s) compliance was or will be required, and the legislation that initially authorized each standard. The standards that were adopted in 2014 cover the following products (compliance year in parentheses):

- Metal halide lamp fixtures (2017)
- External power supplies (2016)
- Commercial refrigeration equipment (2017)
- Walk-in coolers and freezers (2017)
- Electric motors (2016)
- Furnace fans (2019)
- Commercial clothes washers (2018)
- General service fluorescent lamps and incandescent reflector lamps (2017)

[a] The term "consumer" as used in this report refers to all buyers and users of appliances and equipment covered by standards.

- Automatic commercial ice makers (2017).

Table 1. Federal Energy and Water Conservation Standards for Appliances and Equipment Adopted From 1987 Through 2014

Product	**Compliance Date for Original Standard and Updates**	**Authorizing Legislation***
RESIDENTIAL		
Clothes Washers+	1988, 1994, 2004/2007, 2015/2018	NAECA 1987
Clothes Dryers	1988, 1994, 2014	NAECA 1987
Dishwashers +	1988, 1994, 2010, 2013	NAECA 1987
Refrigerators and Refrigerator-Freezers	1990, 1993, 2001, 2014	NAECA 1987
Freezers	1990, 1993, 2001, 2014	NAECA 1987
Room Air Conditioners	1990, 2000, 2014	NAECA 1987
Central Air Conditioners and Heat Pumps	1992/1993, 2006, 2015	NAECA 1987
Water Heaters	1990, 2004, 2015	NAECA 1987
Furnaces	1992, 2013	NAECA 1987
Boilers	1992, 2012	NAECA 1987
Direct Heating Equipment	1990, 2013	NAECA 1987
Cooking Products	1990, 2012	NAECA 1987
Pool Heaters	1990, 2013	NAECA 1987
Ceiling Fans and Ceiling Fan Light Kits	2007	EPACT 2005
Torchieres	2006	EPACT 2005
Dehumidifiers	2007, 2012	EPACT 2005
External Power Supplies	2008, 2016	EISA 2007
Microwave Oven Standby Power	2016	EISA 2007
Furnace Fans	2019	EISA 2007
COMMERCIAL & INDUSTRIAL		
Electric Motors	1997, 2010, 2016	EPACT 1992
Warm Air Furnaces	1994	EPACT 1992
Packaged Boilers	1994	EPACT 1992
Air Conditioners and Heat Pumps	1994/1995, 2003/2004, 2010, 2012, 2012-14	EPACT 1992
Water Heaters, Hot Water Supply Boilers and Unfired Hot Water Storage Tanks	1994, 2004	EPACT 1992
Distribution Transformers	2007, 2010, 2016	EPACT 1992, EPACT 2005
Refrigerators, Refrigerator-Freezers and Freezers	2010, 2012, 2017	EPACT 2005
Automatic Ice Makers	2010, 2017	EPACT 2005
Clothes Washers+	2007, 2018	EPACT 2005
Unit Heaters	2008	EPACT 2005
Refrigerated Beverage Vending Machines	2012	EPACT 2005
Walk-in Coolers and Walk-in Freezers	2009, 2017	EISA 2007

LIGHTING PRODUCTS		
Fluorescent Lamp Ballasts	1990, 2005/2010, 2014	NAECA 1988
General Service Fluorescent Lamps and Incandescent Reflector Lamps	1995, 2008, 2012, 2017	EPACT 1992, EISA 2007
Medium Base Compact Fluorescent Lamps	2006	EPACT 2005
Illuminated Exit Signs	2006	EPACT 2005
Traffic Signal Modules and Pedestrian Modules	2006	EPACT 2005
Mercury Vapor Lamp Ballasts	2008	EPACT 2005
Metal Halide Lamp Ballasts and Fixtures	2009, 2017	EISA 2007
General Service Incandescent Lamps, Intermediate Base Incandescent Lamps and Candelabra Base Incandescent Lamps	2012/2014 & 2020	EISA 2007
PLUMBING PRODUCTS		
Faucets[++]	1994	EPACT 1992
Showerheads[++]	1994	EPACT 1992
Water Closets[++]	1994/1997	EPACT 1992
Urinals[++]	1994/1997	EPACT 1992
Pre-rinse Spray Valves[++]	2007	EPACT 2005
* The Energy Policy and Conservation Act of 1975 was amended to set energy or water conservation standards by the National Appliance Energy Conservation Act (NAECA 1987), the National Appliance Energy Conservation Amendments of 1988 (NAECA 1988), the Energy Policy Act of 1992 (EPACT 1992), the Energy Policy Act of 2005 (EPACT 2005), and the Energy Independence and Security Act of 2007 (EISA 2007).		
[+] Water and energy conservation standard [++] Water conservation standard		

Analysis Method Overview

Different analytical methods were used for five sets of standards. For NAECA 1987 and NAECA 1988 standards and DOE updates of those standards issued before 2007, we utilized the analyses conducted by Lawrence Berkeley National Laboratory (LBNL) in 2007-2008.[2] For EPACT 1992 standards, we developed new estimates for this study. For EPACT 2005 standards, we reviewed and utilized an analysis conducted by Nadel *et al.*[3] and added information from DOE analyses where available. For most of the EISA 2007 standards, we drew upon an analysis conducted by DOE.[4] For the other EISA 2007 standards,[b] we used unpublished national impact analyses that were prepared by LBNL for DOE. For standards adopted by DOE in 2007-2013, we drew on the national impact analyses performed for the rulemakings for each of the standards and adapted the results for the framework of this study. Appendix A further describes the use of the above sources in this study.

It is important to note that the analyses performed for the rulemakings for each of the standards adopted by DOE in 2007-2014 were highly detailed and were carefully reviewed by

[b] Dishwashers, residential boilers and dehumidifiers.

stakeholders. All of the other sources used for this study were much less detailed in their approach and less extensively reviewed.

The most challenging aspect of estimating the impacts of standards is characterizing what would have happened without new or amended standards. We call this counterfactual against which impacts of standards is measured the “base case.” The sources used for this study vary in how they characterized the base case. The LBNL analysis of the NAECA standards and DOE updates of those standards before 2007 estimated a dynamic base case in which the energy efficiency of the products improves somewhat even without standards. The analyses performed for DOE’s rulemakings also consider how the market might change in the absence of new or amended standards. In contrast, the analyses used for EPACT 1992, EPACT 2005, and EISA 2007 standards used simple assumptions (in many cases, no change in efficiency) regarding the base case.

We focused on three key impacts associated with standards: (1) primary energy savings; (2) additional installed costs; and (3) operating cost savings. Beginning with standards adopted in 2014, the accounting considers full-fuel-cycle energy use, which includes the energy consumed in extracting, processing, and transporting primary fuels (i.e., coal, natural gas, petroleum fuels), and thus presents a more complete picture of the impacts of energy conservation standards.

Operating cost savings primarily consist of energy cost savings. Energy cost savings were estimated using historical average annual energy prices through 2011, and recent projections of average annual energy prices after 2011. For standards that save water, we also included water cost savings where possible. In some cases (primarily the DOE rulemakings in 2007-2014), the operating cost savings also include changes in maintenance and repair costs associated with the standards.

From (2) and (3) we derived net cost or savings for each year. We also estimated annual reductions in CO_2 emissions associated with the standards using the annual energy savings and annual average CO_2 emissions factors for the electricity generation sector and for natural gas.

For each standard we developed a time series of annual impacts, with economic impacts expressed in constant dollars. For the NAECA standards and DOE updates of those standards before 2007, and for standards adopted by DOE in 2007-2014, we estimated annual impacts for each standard for 30 years worth of shipments. For most of the other standards, for which the base case often assumed no change in efficiency, we used a shorter period of shipments as a way of compensating for the lack of a dynamic base case, which might tend to overstate the savings from standards. For all standards, we estimated annual energy savings and operating cost savings until products installed in the final year considered are retired from the stock. Retirement is based on the average lifetime for each product.

Using the annual economic impacts, we derived a net present value (NPV) by discounting future impacts to the present (defined as 2015 for this report). For economic impacts occurring after 2015, we used discount rates of 3% and 7%, which are the rates used by DOE in its analyses of national impacts, in accordance with guidance from the Office of Management and Budget to Federal agencies on the development of regulatory analysis.[5] For economic impacts occurring before 2015, we derived estimates of their present value using interest rates of 3% and 7%. This approach reflects the view that the present value of the past stream of benefits should reflect the returns to those "profits" had they been invested elsewhere in the economy.

We estimated a monetary value of the reductions in CO_2 emissions using the most recent mid-range series for the global Social Cost of Carbon (SCC) developed by a Federal interagency process.[c] The series used has a value of $41.3 per metric ton (2014$) in 2015 and increases at 1.6 percent per year.

Product-Level Impact of Standards: The Case of Refrigerator-Freezers

Figure 1 illustrates how standards have had an important effect on the energy efficiency of new products, in this case refrigerator-freezers. The average new refrigerator-freezer in 2010 used only 44% of the energy per year as an average new unit in 1985. Total energy use for these products has declined even as shipments increased and the average size of new units grew. Nationally, in 2010 refrigerator-freezers used one-third less total energy than in 1985 even though there were 70 million more units in use.[d]

[c] *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Interagency Working Group on Social Cost of Carbon, United States Government. May 2013; revised November 2013.
http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

[d] The increase in total energy use depicted after 2025 is due to growth in purchases of refrigerator-freezers. If the standard is updated as required by EPCA, the declining trend would continue.

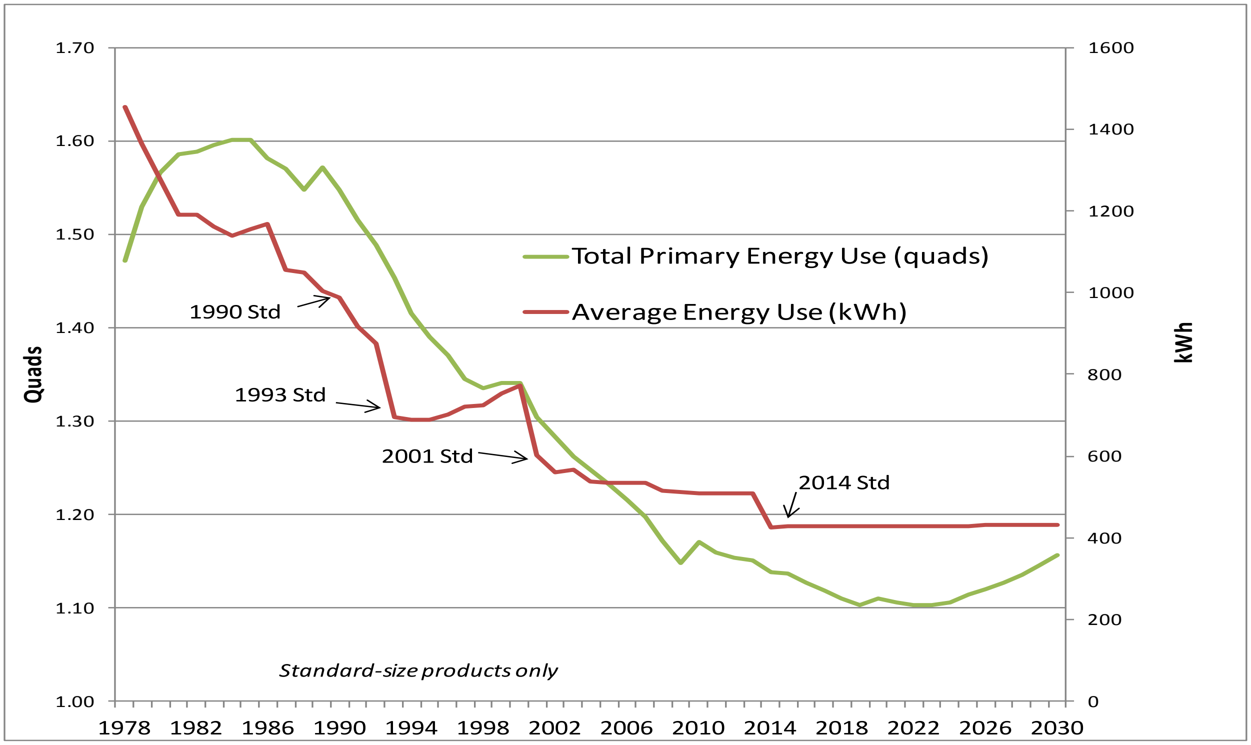

Figure 1. Refrigerator-Freezer Energy Use Trends: Average Energy Use for New Products and Total Energy Use for Refrigerator-Freezers
Source: AHAM Fact Books and 2011 DOE standards rulemaking for residential refrigeration products.[e]

National Impacts[f]

In 2014, the energy and water conservation standards saved an estimated 4.29 quads of primary energy, which is equivalent to 4% of total U.S. energy consumption. The savings in operating costs totaled $60.4 billion.[g]

As shown in Table 2, the cumulative primary energy savings through 2014 amount to 41.0 quads. Residential sector standards account for 58 percent of the total energy savings.

Over the entire time period considered (1990-2090), the cumulative primary energy savings amount to 202 quads and the cumulative consumer NPV is between $1,327 billion and $1,604 billion (Table 3). Residential products account for more than half of the total cumulative primary energy savings. In addition to energy cost savings from energy conservation standards, the consumer NPV includes water cost savings from those standards that affect both energy and water use (such as standards on clothes washers), as well as energy cost savings from water conservation standards that save hot water (i.e., standards on faucets and showerheads).

[e] http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf
[f] Additional results, including impacts by each standard, are available upon request from the authors.
[g] All monetary values reported are in 2014 dollars unless noted otherwise.

The cumulative energy savings achieved through 2014 are only 20 percent of the total cumulative energy savings. Thus, most of the savings from standards already adopted will occur in the future. Furthermore, future savings will grow as new standards are adopted.

Table 2. Cumulative Primary Energy Savings Through 2014 for all Standards

Product type	Primary energy savings (quads)	Share of primary energy savings
Residential	23.9	58%
Commercial & Industrial	5.0	12%
Lighting Products	7.8	19%
Plumbing Products	4.3	11%
Total	41.0	100%

* The first value refers to the NPV using 3% interest rate, while the second value refers to the NPV using 7% rate.

Table 3. Cumulative Primary Energy Savings and Consumer NPV for All Standards (1990-2090)

Product type	Cumulative primary energy savings (quads)	Share of total cumulative primary energy savings	Cumulative NPV (billion 2013$)*	Share of total cumulative NPV
Residential	102.6	51%	607- 790	46-49%
Commercial & Industrial	45.1	22%	121 – 204	9-13%
Lighting Products	46.1	23%	242 – 291	18%
Plumbing Products	8.3	4%	357 – 318	27-20%
Total	202.1	100%	1,327 – 1,604	100%

* The first value refers to the NPV using 7% discount or interest rate, while the second value refers to the NPV using 3% rate.

Table 4 presents the annual and cumulative water savings from standards, which include water savings from water conservation standards as well as from energy conservation standards that also save water (such as standards on clothes washers and dishwashers).[h] The annual savings of 1.9 trillion gallons in 2014 are equal to 12 percent of the total water withdrawals for public

[h] Note that water savings estimates are not available for standards on commercial plumbing products (water closets, urinals, and faucets). Thus, the results in Table 4 understate the true savings from standards.

supply in 2010.[i] The estimated dollar savings from reduced water use in 2014 amounted to $12.3 billon.[j]

Table 4. Annual and Cumulative Water Savings for All Water-Conserving Standards

	Water Savings (trillion gallons)	
	Annual	Cumulative through
2014	1.9	20.9
2030	1.2	47.6
2050	0.003	55.3

As shown in Table 5, the estimated reduction in CO_2 emissions associated with the standards in 2014 was 232 million metric tons of CO_2, which amounts to 4.2% of total U.S. energy-related CO_2 emissions in 2011. The estimated economic (present) value of reductions in CO_2 emissions associated with the standards through 2050 is $370 billion.

Table 5. Annual and Cumulative Reduction in Carbon Dioxide Emissions for All Energy Conservation Standards

	CO_2 Emissions Reduction (million tons CO_2)		Present Value (billion 2014$)*	
	Annual	Cumulative through	Annual	Cumulative through
2014	232	2,345	9.6	91
2030	306	6,996	11.4	264
2040	162	9,324	5.3	340
2050	62	10,379	1.7	370

***** The present value was calculated using a discount rate of 3%, in keeping with the method used by DOE in recent rulemakings. See discussion in appendix A.

Figure 2 shows the annual primary energy savings for each sector, and Figure 3 shows the annual undiscounted net consumer impact. The impacts peak in the 2025-2030 period as purchases of products subject to standards increase. The decline in impacts reflects the analytical convention of counting impacts for 25-30 years of shipments for each standard. As current standards are revised and new standards are adopted, the impacts from all standards will likely not decline.

[i] USGS estimates that water withdrawals for public supply were 42 billion gallons/day in 2010. http://water.usgs.gov/watuse/wups.html
[j] Using an average water plus wastewater price of $7.17 per 1000 gallons (2010$).

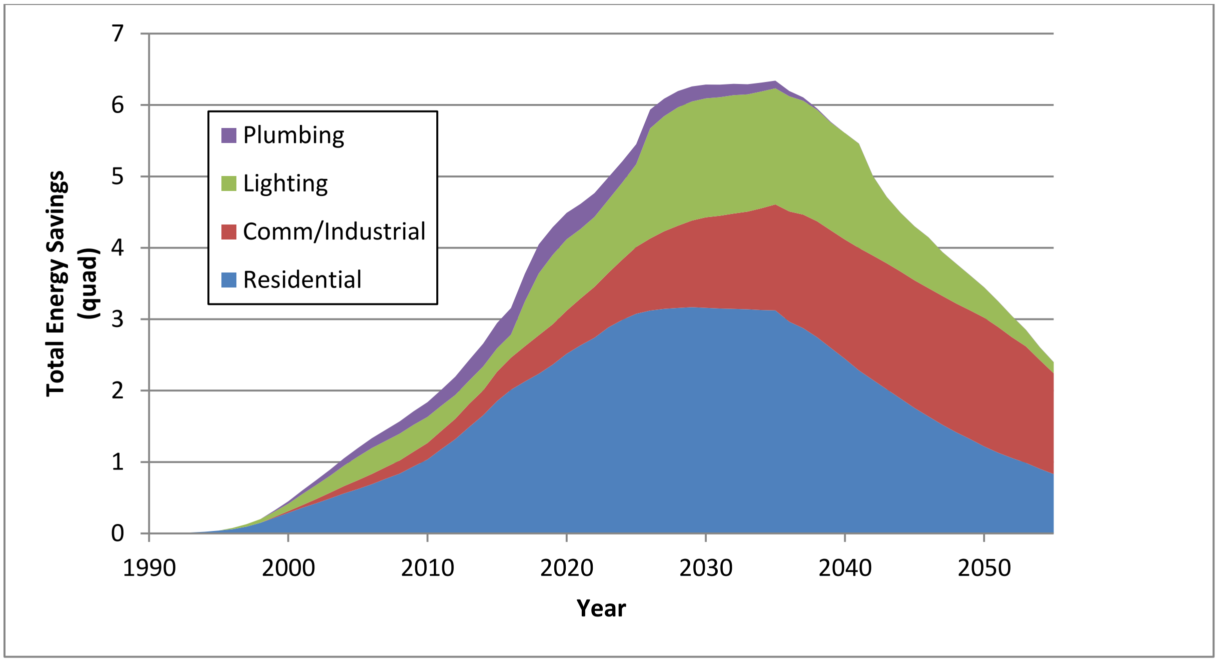

Figure 2. Annual Primary Energy Savings for all Standards by Sector

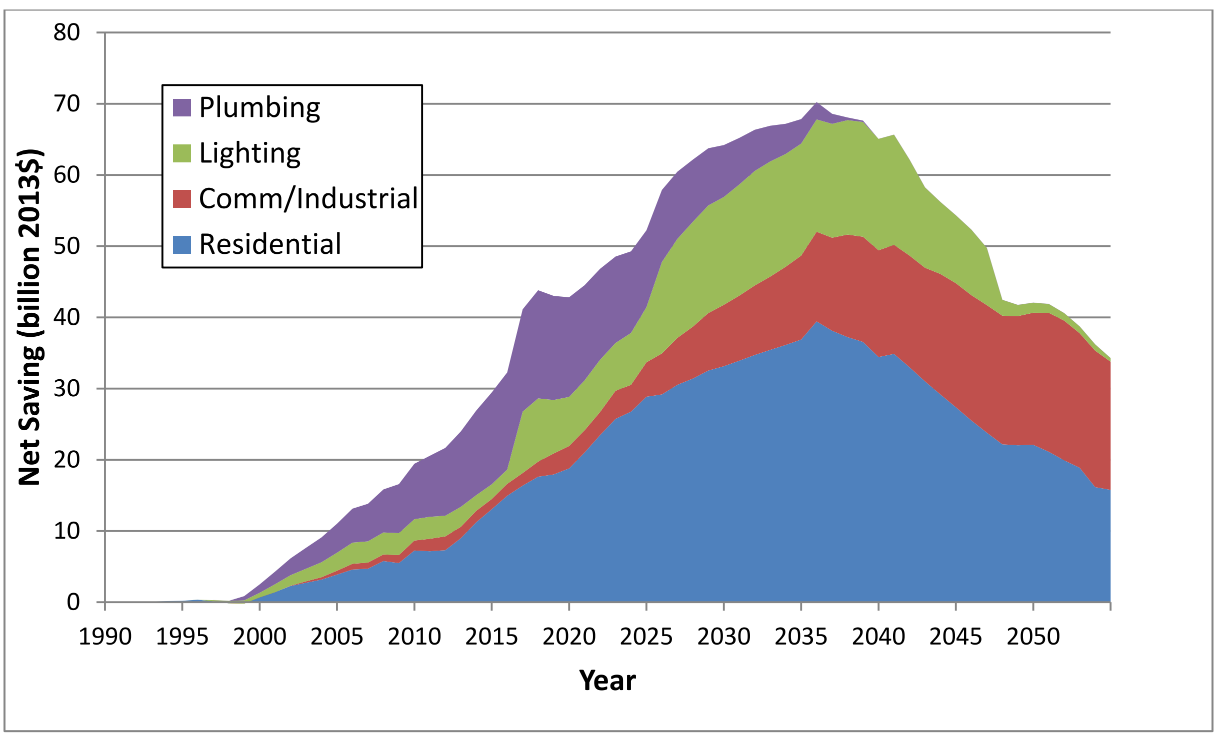

Figure 3. Annual Undiscounted Net Consumer Benefit for all Standards by Sector

Consumer (Residential) Impacts

In 2014, we estimate that the typical household saved $377 in energy and water expenses as a result of residential and plumbing product standards. By now, most U.S. households use one or more appliances that were subject to Federal energy or water conservation standards. On average, the primary energy savings from residential and plumbing standards in 2014 amounted to 23 million Btu per household, which is equivalent to 12 percent of the average total energy use of 185 million Btu per household.[k]

Sources of Uncertainty

The estimates made by this study are subject to considerable uncertainty. A major source of uncertainty is the assumed base case against which the impacts of standards are measured. In principle, a base case should reflect how the market for a given product will evolve without the standards under consideration. Estimating the consumer demand for higher efficiency products and the marketing decisions of product manufacturers is difficult. Even more difficult is estimating what other policies, either Federal or State, might be implemented if there were no Federal efficiency standards for a given product. For the standards adopted by DOE in the past five years, a good amount of consideration and stakeholder input went into the construction of the base case. For many of the other standards included in this report, the base case reflects simple assumptions.

The estimates of per-unit energy savings and additional cost in the sources used for this study are also subject to uncertainty. Most of the sources assume that the incremental costs of higher efficiency remain constant over time.[l] This assumption likely overstates the true costs for two reasons. First, manufacturers of appliances and equipment often find ways to reduce the cost of producing higher efficiency products when forced to adapt to standards. Second, inflation-adjusted prices of many types of appliances and equipment have trended downward in recent decades. To the extent that this trend continues, it means that the incremental cost of higher efficiency products may decline over time.

The estimates of primary energy savings in the sources we used are based on estimates of "site" energy savings (i.e., savings where the product is in operation). Most of the sources we used convert site savings to primary savings using an average multiplier. In contrast, the National Impact Analysis spreadsheets from the DOE rulemakings incorporate marginal site-to-primary energy conversion factors. These factors represent the response of the electricity system to an incremental decrease in consumption associated with appliance standards. DOE uses annual site-to-source conversion factors based on a version of the Energy Information Administration's National Energy Modeling System (NEMS). The marginal factors are lower than average site-to-

[k] Consumers also saved energy from lighting products standards, but we were not able to disaggregate the estimated savings from these standards by end-use sector.
[l] In 2011 DOE began to account for change in product prices in its forecasts.

source conversion factors and are likely more accurate. If we had been able to apply marginal site-to-source conversion factors to all of the standards included, the estimated primary energy savings (and also the reductions in CO_2 emissions) would be lower.

For consumer cost savings that occurred in the past, there is some question as to whether the compounding of past savings used in this study is appropriate. We have not found clear guidance in the literature, but there is some precedent for the practice of compounding past savings to estimate their present value.[m] There is uncertainty regarding the extent to which the savings from appliance standards were invested elsewhere in the economy, and what the appropriate interest rate should be. Without compounding, the cumulative consumer NPV for all standards through 2010 would be around 15 percent less than reported here.

There is some evidence that consumers use higher efficiency appliances more intensively due to the reduction in operating cost. The extent of this so-called direct rebound effect varies among products.[6] In recent years DOE has accounted for a rebound effect in many of its rulemakings. Thus, the energy savings estimates for many standards adopted by DOE since 2008 include an adjustment (subtraction) for a rebound effect.[n] The other sources used for this study do not include such an adjustment. The lack of this adjustment means that the savings may be overestimated by 5%-10%.

Conclusion

We estimate that energy and water conservation standards for appliances and equipment adopted from 1987 through 2014 have saved a total of 41.0 quads through 2014, an amount equal to 42 percent of total annual U.S. energy use. In 2014, the standards saved an estimated 4.29 quads of primary energy, which is equivalent to 4% of total U.S. energy consumption. The savings in operating costs for households and businesses totaled $60 billion. The average household saved $377 in operating costs as a result of residential and plumbing product standards. The estimated reduction in CO_2 emissions associated with the standards in 2014 was 232 million metric tons of CO_2, which is equivalent to 4 percent of total U.S. CO_2 emissions.

The majority of the savings attributable to the standards adopted thus far are still to come, as products subject to the standards enter the stock. The standards are projected to achieve cumulative energy savings of 202 quads. Accounting for the increased upfront costs of more-efficient products and the operating cost (energy and water) savings over the products' lifetime, the standards have a past and projected cumulative net present value (NPV) of consumer benefit of between $1,327 billion and $1,604 billion, using 7 percent and 3 percent discount rates, respectively.

[m] See for example: http://www.dalemarsden.ca/docs/publications/Marsden_etal_2006.pdf

[n] DOE does not adjust the energy cost savings for the rebound effect because it believes that, if it were able to monetize the increased value to consumers associated with the rebound effect, this value would be similar to the foregone energy savings.

The water conservation standards, together with energy conservation standards that also save water, reduced water use by 1.9 trillion gallons in 2014, and estimated cumulative water savings by 2090 amount to 55 trillion gallons. The estimated consumer savings in 2014 from reduced water use amounted to $12 billon.

Appendix A: Methods for Estimating National Impacts from Standards

General Methods

The energy cost savings were first taken from each of the sources described below. These sources used combinations of historic energy price data and forecasts from specific versions of EIA's *Annual Energy Outlook.* We updated the original energy cost savings estimates using historical average annual energy prices through 2013, and projected average annual energy prices after 2013. The historical prices were taken from various DOE Energy Information Administration (EIA) sources. The projected prices are based on EIA's *Annual Energy Outlook 2013.* The method involved scaling the original energy cost savings estimates using multipliers that relate the price values in the most recent *Annual Energy Outlook (AEO)* to the same-year values in the specific *AEO* that was used in the original source, after expressing both in same-year dollars.

We converted dollars from the year given in the various sources to 2014$ using the GDP implicit price deflator.

For all of the standards adopted before 2009, the reductions in CO_2 emissions related to electricity savings are calculated using annual average CO_2 emissions factors for the electricity generation sector. These are derived for each year through 2012 from EIA statistics on total CO_2 emissions from the electric power sector and total primary energy consumption by the electric power sector. For each year in 2013-2040, they are derived from similar forecasted outputs in EIA's *Annual Energy Outlook 2013.* The values after 2040 are based on the trend seen in the 2020-2040 period.

For DOE standards adopted in 2009 and later, the reductions in CO_2 emissions, which are based on estimated marginal impacts for electricity savings, are taken from the final rule documentation for each rulemaking.

The social cost of carbon (SCC) values from 2010 onward are from the mid-range series developed by a Federal interagency process. This series is based on the average SCC derived from the three integrated assessment models that were examined, using a 3-percent discount rate.[o] Because the SCC values are based on a 3-percent discount rate, we used the same discount rate to discount the future annual estimates of the value of reduced CO_2 emissions. SCC values prior to 2010 were estimated based on the post-2010 trend.

---

[o] *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Interagency Working Group on Social Cost of Carbon, United States Government. May 2013; revised November 2013.
http://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf

NAECA 1987 and 1988 Standards and DOE Updates before 2007

For all of the standards except one, we used the data developed by Meyers *et al*.[1] That study developed a spreadsheet accounting model to calculate energy savings and consumer costs and savings for each product. The model tracks the energy use of products sold in each year, beginning in the late 1980s. The model uses historic and projected data on annual shipments of each product and subtracts units from the stock using a retirement function based on the estimated average lifetime of each product.

The key feature of the model is that it associates a specific average energy consumption and average product price for each vintage of a given product. (A vintage refers to the products shipped in a given year.) Both of these variables are a function of the energy efficiency assigned to each vintage. In most cases, the actual energy efficiency for each vintage of a product is assigned based on industry sources.

The approach for estimating the impacts of standards involves deriving a base case scenario for average energy efficiency and product price that assumes no standards were or will be implemented. In principle, the base case assumes energy efficiency increases over time as a result of all factors that shape energy efficiency other than Federal standards. For further discussion, see section 2 of Meyers *et al*.

For the commercial heating, air conditioning, and water heating standards with compliance dates of 2003 and 2004, we started from the following data reported by Belzer and Winiarski:[7] (1) primary energy savings cumulative through 2030 and (2) net economic impacts at a 7-percent discount rate cumulative from units shipped through 2030. We used an average lifetime for these products of 15 years.

We assume that units retire uniformly over the lifetime and that the annual energy savings will go up after the effective date until it stabilizes when all the pre-standard units have been replaced by units meeting the standards. This period that it takes for the annual energy savings to reach its maximum is equal to the lifetime of the product. Using these assumptions, we calculate the annual site and primary energy savings that will match the given cumulative energy savings from 2003 to 2030. Then we used the Excel Solver to solve for the unit energy saving and incremental equipment cost per unit that will give a net present value (NPV) that closely matches the given NPV at a 7-percent discount rate. We then extended the time series to include shipments through 2032 to yield a 30-year analysis period.

EPACT 1992 Standards

We developed new estimates for this study, as described below. We assumed no change in base case efficiency over time. To compensate for potential overstatement of savings, we counted impacts for only 20 years worth of product shipments. Further details may be found in spreadsheets that are available from the authors.

Commercial furnaces and boilers, air conditioners and heat pumps, and water heaters

We modified the analytical structure and some of the data developed by Rosenquist et al. for the 2004 study for the National Commission on Energy Policy (NCEP).[8]

We estimated base case efficiencies and unit incremental costs for these products using PNNL (2000). This report presents average efficiencies in 1999 and costs for both an EPACT 1992 baseline product and an average product in 1999. We applied these differentials to derive an approximate pre-EPACT 1992 baseline efficiency and contractor cost for each product.

Electric motors

We developed a simplified NIA model to estimate the impacts of the EPACT 1992 standards for electric motors, using one "average motor" as the basis for the calculations.

The "average motor" energy use was calculated in the base case and in the standards case, using market-weighted averages across the covered horsepower (hp) ranges, pole configurations, and enclosure type to determine the following parameters: operating hours, load, lifetime, horsepower, and efficiency. All inputs were derived from the draft preliminary analysis from DOE's 2011 rulemaking for electric motors.

The base-case efficiency is estimated assuming 30% of shipped motors are at pre-EPACT standard efficiency levels, 30% are already at the EPACT 1992 efficiency levels, and 40% are at National Electrical Manufacturers Association (NEMA) premium efficiency levels. The standards-case efficiency is estimated using a "roll-up" scenario, which leads to assuming 60% of motors are at the EPACT 1992 efficiency levels and 40% are at the NEMA premium efficiency levels.

Motor equipment costs (includes the repair costs) for the "average motor" in the base case and standards case were estimated by extrapolating price and weight data from the preliminary analysis. Repairs are assumed to occur after 5 years of usage and once in a motor's lifetime.

Shipment data were obtained from the preliminary analysis and are assumed to be the same in the base-case and in the standards-case. The market-weighted average lifetime (12 years) was used to calculate the affected stock.

National site energy savings were obtained from multiplying the affected stock by the difference in energy use between the base case and standards case for the "average motor". National equipment incremental costs were calculated using the affected stock multiplied by the difference in equipment costs between the base case and standards case for the "average motor".

Fluorescent lamps and incandescent reflector lamps

Fluorescent lamps

We calculated savings for full-wattage T12 lamps covered by the standards sold after the effective dates of the standards: April 30, 1994 for 8-foot T12 and 8-foot T12/HO lamps and October 31, 1995 for 4-foot lamps. To calculate fluorescent lamp shipments, we adapted the spreadsheet used to analyze the impacts of the NAECA fluorescent ballast standards by Meyers *et al*. The base-case forecast assumed that 60 percent of lamp shipments in 1994 were full-wattage lamps, while 40 percent were reduced-wattage lamps already complying with the EPAct 1992 standards, according to a 1989 report on Massachusetts' lamp standards by Nadel et al.[9]

Since the lamps covered by the EPAct 1992 lamp standards ("covered lamps") were used with magnetic ballasts, and very few T12 lamps used electronic ballasts, we assumed that lamp shipments tracked the pattern of magnetic ballast shipments. When the fluorescent ballast standards came into effect in 2005 for ballasts in new luminaires, there was a corresponding substantial decrease in T12 lamp shipments. By 2010, when the ballast standards took effect for the renovation market as well, very few T12 lamps were sold.

The shipments of covered fluorescent lamps for 1994 were based on estimates by Geller and Nadel.[10] For 1995 - 2010 we scaled this 1994 shipment value to decline according to the annual decrease in magnetic ballast shipments projected in the NAECA ballast standards analysis. Beginning in 2011 we made the simplifying assumption that T12 lamp shipments ceased.

Assumptions for unit wattage savings, product service lifetime, operating hours, and market shares by lamp type and by new vs. renovation market are from DOE's 2000 fluorescent lamp ballast standards analysis. Lamp prices are from the 1992 Lighting Policy Analysis by Atkinson *et al.*[11]

<u>Incandescent reflector lamps</u>

We estimated the impacts of the incandescent reflector lamp standards from 1996 – 2015. (The standards took effect on November 1, 1995, so we assumed that savings began in 1996.) We used shipments data from past and recent analyses to estimate the annual shipments of lamps complying with the standards. For the commercial sector, complying shipments were derived for 1996 - 2000 from the 1992 Lighting Policy Analysis (Atkinson *et al.*), for 2006 - 2015 from DOE's 2009 incandescent reflector lamp standards NIA spreadsheet (DOE 2009),[p] and for 2001 – 2005 by linear interpolation. For the residential sector, we estimated complying shipments for 1995 as 10 percent of total shipments, for 2001 – 2015 from DOE 2009, and for 1996 to 2000 by linear interpolation.

Assumptions for unit wattage savings are from Atkinson *et al.* Product service lifetime and operating hours are from DOE 2009. Lamp prices are from Atkinson *et al.*

---

[p] See: http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps_standards_final_rule_tools.html

Plumbing products

For showerheads and faucets, we started with product lifetime, 2010 site energy savings (from reduced hot water use), and 2010 water savings from Koomey *et al.*[12] For toilets, we used product lifetime and 2010 water savings.

From the energy savings for 2010, we estimated both the site and source energy savings over a 20-year period starting from the compliance date, assuming that shipments retire uniformly over the lifetime and are replaced (constant annual sales). Based on this uniform retirement function, the energy savings from units surviving beyond the 20-year period are also calculated. We performed this same estimation for the annual time series of water savings.

We derived operating cost savings by applying annual time series of average fuel prices and water prices to the site energy and water savings.

We estimated that there is zero unit incremental cost for these products because when manufacturers first started to comply with EPACT 1992, they generally did not make significant changes to the products.

The estimates only cover residential use because no data were available to estimate commercial sector impacts.

EPACT 2005 Standards

For all of the standards except commercial air conditioners (AC) and heat pumps, we started from the following data reported by Nadel *et al.*[3] for each standard: (1) site energy savings in 2020 and 2030, (2) cumulative energy savings through 2030, (3) NPV for products sold through 2030, (4) lifetime, (5) unit annual energy saving, and (6) unit incremental equipment cost. Nadel *et al.* used a constant efficiency base case, but they also did not model any increase in shipments; these two factors would counteract to some extent.

From the energy savings for 2020 and 2030, we estimated both the site and source energy savings for 25 years of shipments starting from the compliance year. Using the energy savings per unit and the annual energy savings, we calculated the shipments in each year. Once we derived the shipments, we could calculate the total incremental equipment cost.

We accounted for impacts to shipments through 2030. The number of years of shipments ranges from 21 to 25, depending on the particular standard.

For commercial AC and heat pumps, DOE National Impact Analysis spreadsheets were available. For these products, we followed the methods described in the DOE Standards 2007-2010 section.

EISA 2007 Standards

For most EISA 2007 standards, we started from the following data for each product reported by DOE in its technical report:[4] (1) cumulative energy savings (through 2038), (2) NPV at 3-percent and 7-percent discount rates. From other relevant DOE sources, we obtained the lifetimes of the products. The DOE report used a constant efficiency base case, which may tend to somewhat overestimate the savings from the standards. To compensate, we used 25 years of shipments instead of 30 years.

We assumed that units retire uniformly over the lifetime and that the annual energy savings will go up after the compliance date until it stabilizes when all the pre-standard units have been replaced by units meeting the standards. The period that it takes for the annual energy savings to reach its maximum is equal to the lifetime of the product. Using these assumptions, we calculated the annual site and source energy savings that will match the given cumulative energy savings. Then we used the Excel Solver to solve for the unit energy savings and incremental equipment cost per unit that will give an NPV that closely matches the given NPV at a 7-percent discount rate. We then adjusted the calculations to account for 25 years of shipments.

For a few EISA 2007 standards (residential boilers, dishwashers, and dehumidifiers), DOE National Impact Analysis spreadsheets were available. For these products, we followed the methods described in the following DOE Standards 2007-2010 section.

DOE Standards 2007-2014

We used the Final Rule NIA spreadsheets from the DOE rulemakings for each of these standards.[q] We set up the spreadsheets for the compliance year and standard levels that were selected in the Final Rules. This gave the annual time series for primary energy savings, additional installed cost, and operating cost savings. In some cases, the time series presented in the spreadsheets were by individual product classes, so we summed them to arrive at totals for the product category or categories in question. In some cases we also made modifications to the spreadsheets to arrive at consistent results across products—for instance, always using 30 years of shipments and extending energy cost savings and energy savings to the end of the lifetime of the units shipped in the 30th year.

[q] The NIA spreadsheets and associated documentation may be found under the product name at the DOE Appliance and Equipment Standards web site: http://energy.gov/eere/buildings/standards-and-test-procedures.

REFERENCES

[1] Meyers, S., A. Williams, and P. Chan. Realized and Projected Impacts of U.S. Energy and Economic Impacts of U.S. Federal Energy and Water Conservation Standards Adopted From 1987 Through 2012. LBNL- 6217E. Lawrence Berkeley National Laboratory, Berkeley, CA. http://eetd.lbl.gov/publications/energy-and-economic-impacts-of-us-fed

[2] Meyers, S., J. McMahon, and B. Atkinson. Realized and Projected Impacts of U.S. Energy Efficiency Standards for Residential and Commercial Appliances. LBNL-63017. Lawrence Berkeley National Laboratory, Berkeley, CA. 2008. http://www.osti.gov/bridge/purl.cover.jsp?purl=/938510-IKYBEw/

[3] Nadel, S., A. deLaski, J. Kleisch, and T. Kubo. Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards. American Council for an Energy-Efficient Economy and Appliance Standards Awareness Project. Washington, DC. January 2005. http://www.aceee.org/sites/default/files/publications/researchreports/a051.pdf

[4] Technical Support Document-Impacts on the Nation of the Energy Independence and Security Act of 2007, March 2009; Available at: http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/en_masse_tsd_march_2009.pdf

[5] Office of Management and Budget. OMB Circular A-4, Regulatory Analysis. Washington, D.C. September 17, 2003. www.whitehouse.gov/omb/assets/omb/circulars/a004/a-4.pdf

[6] S. Sorrell, J. Dimitropoulos, and M. Sommerville, "Empirical estimates of the direct rebound effect: a review," Energy Policy 37(2009) pp. 1356–71.

[7] Belzer, D. and D. Winiarski. EPACT-Covered Commercial HVAC and Water Heating Equipment: Summary of Energy Savings and Economic Benefits – 2004. 11/4/2004. Pacific Northwest National Laboratory.

[8] Rosenquist, Greg, Michael McNeil, Maithili Iyer, Steve Meyers, and Jim McMahon. Energy Efficiency Standards for Equipment: Additional Opportunities in the Residential and Commercial Sectors. Energy Policy 34(2004) pp 3257-3267.

[9] Nadel, S., H. Geller, F. Davis and D. Goldstein. 1989. Lamp Efficiency Standards for Massachusetts: Analysis and Recommendations. June, 1989. American Council for an Energy-Efficient Economy (Washington DC), Fred Davis Corporation (Medfield MA), Natural Resources Defense Council (San Francisco CA). Prepared for Massachusetts Executive Office of Energy Resources. Research Report A891.

[10] Geller, H., and S. Nadel. Consensus National Efficiency Standards for Lamps, Motors, Showerheads and Faucets, and Commercial HVAC Equipment. American Council for an Energy-Efficient Economy. Washington, DC. June 1992. http://www.aceee.org/sites/default/files/publications/researchreports/A921.pdf

[11] B. Atkinson *et al*., Analysis of Federal Policy Options for Improving U.S. Lighting Energy Efficiency: Commercial and Residential Buildings. LBL-31469. December 1992. Lawrence Berkeley Laboratory.

[12] Koomey, Jonathan, Camilla Dunham, and James D. Lutz. The Effect of Efficiency Standards on Water Use and Water Heating Energy Use in the U.S.: A Detailed End-use Treatment. LBL-35475. Lawrence Berkeley Laboratory. May 1994.