APPLIANCE AND EQUIPMENT EFFICIENCY STANDARDS: A MONEYMAKER AND JOB CREATOR

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ABSTRACT

This study estimates net employment and wage impacts of U.S appliance, equipment, and lighting efficiency standards. These standards are a key part of the United States' energy policy, and their contributions to energy and economic savings for consumers and the broader economy is well-documented in previous studies by the American Council for an Energy-Efficient Economy (ACEEE), the U.S. Department of Energy (DOE), and the Lawrence Berkeley National Laboratory (LNBL). But the macroeconomic impacts, like employment and wages, have only been examined for individual standards, and not comprehensively. In this analysis, ACEEE and the Appliance Standards Awareness Project (ASAP) have estimated the number of jobs created in the United States as a result of the standards already in place as of December 2010, most of the standards revisions DOE is now working on and will complete by 2013, and the consensus standards in pending legislation.

We estimate that the standards that are already in effect generated about 340,000 jobs, or about 0.2% of the nation's jobs in 2010, a relatively small but important positive impact. This includes jobs created in 2010 as well as jobs that standards created in earlier years but that were maintained in 2010. As existing standards affect more product purchases, and as new standards take effect, the number of jobs generated will increase to about 380,000 jobs in the year 2030, an increase of 40,000 jobs relative to 2010. This job creation results from shifting consumer spending away from energy utilities, an industry sector with relatively few jobs per dollar of revenue, and into other sectors that have higher job intensity. New job creation is driven by 2010 energy bill savings of $34 billion, which grows to an annual level of $68 billion in 2030. Although the estimates made in this study are subject to some uncertainty, they provide a good approximation of the national macroeconomic benefits that are driven by U.S. efficiency standards for appliances, equipment, and lighting products.

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INTRODUCTION

Appliance, equipment, and lighting efficiency standards[1] have consistently served as a cornerstone of U.S. energy policy for reducing energy waste over the past two decades.[2] Standards save consumers money and reduce harmful energy sector emissions by helping overcome market barriers that hinder the sale of cost-effective and more energy-efficient products.

Although the economic benefits and energy savings for households and businesses are well-documented (Neubauer et al. 2009, Meyers et al. 2008, U.S. Chamber of Commerce 2010, Gillingham et al. 2004), the jobs created by these policies have not been examined as fully. In this analysis, the American Council for an Energy-Efficient Economy (ACEEE) and the Appliance Standards Awareness Project (ASAP) estimate the number of jobs that will be created in the United States as a result of the historical standards already in place as of December 2010, and for revised standards now being developed by the U.S. Department of Energy (DOE) and scheduled for completion by 2013. We also include a prospective standards analysis with the energy savings and jobs created as a result of the consensus appliance standards contained in the *Implementation of National Consensus Appliance Agreements Act* (INCAAA) of 2010 (S. 3925 in the 111th Congress), a bill with broad support but not yet enacted into law.

Using the input-output DEEPER modeling system, we find that standards already in place created about 340,000 jobs in the year 2010. This includes jobs created in 2010 as well as jobs that standards created in earlier years but that were maintained in 2010. Current and future standards will create about 380,000 jobs in the year 2030, an increase of 40,000 jobs relative to 2010. This job creation is driven, in large part, by the energy saved when less efficient appliances are replaced with more efficient appliances, providing energy and dollar savings for consumers. Consumers then have additional money to spend in more labor-intensive but equally productive sectors of the economy, creating a net increase in jobs and wages.

Year	Annual Jobs	Annual Energy Bill Savings
2010	340,000	$34 billion in 2010
2020	387,000	$64 billion in 2020
2030	380,000	$68 billion in 2030

HISTORICAL STANDARDS, 1987–2010

Congress instituted the first national appliance standards in 1987 with the passage of the National Appliance Energy Conservation Act (NAECA), which was based on a consensus agreement between manufacturers, energy efficiency advocates, and states. Major legislation in 1988, 1992, 2005, and 2007 included additional products. In each case, the new laws were based on consensus agreements between manufacturers and energy efficiency advocates, and sometimes states. Most of the initial legislated standards were based on existing state standards. Currently, more than 50 products are covered by a variety of highly cost-effective federal standards.

These laws generally set initial standards and direct DOE to conduct regular reviews to update standards if justified. The law requires DOE to update or establish standards at levels that “achieve the maximum improvement in energy efficiency … which the Secretary determines is technologically feasible and economically justified." The law 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 (42 U.S. Code 6295(o)). Meyers et al. 2008 examined a large subset of existing residential and commercial appliance and equipment standards and found that benefits from 1987–2050 exceed the costs by a factor of 2.7 to 1. Similarly, Neubauer

[1] This report uses “appliance standards” or “standards” as shorthand for appliance, equipment, and lighting standards.
[2] U.S. standards also cover water efficiency for many products, but this report only addresses the energy efficiency aspect of U.S. standards.

et al. 2009 estimated an average benefit-cost ratio of 4:1 for the 26 standards subject to DOE rulemakings between 2009 and 2013. The analysis of employment impacts completed here focuses on historical standards and prospective standards, where "historical standards" are defined as those standards put into place by legislation or through a rulemaking update between 1987 and 2010. This scope includes all of the standards listed in Tables 1 and 2 below.

Table 1. Initial Legislated Appliance Standards Included in Historic Scenario

NAECA 1987	**Compliance Date ***	**EPAct 1992**	**Compliance Date**
Clothes washers	1988	Comm'l furnaces & boilers	1994
Clothes dryers	1988	Comm'l water heaters	1994
Dishwashers	1988	Showerheads	1994
Ranges & ovens	1990	Faucet aerators	1994
Refrigerator-freezers	1990	Toilets & urinals	1994
Freezers	1990	Fluorescent lamps	1994/5
Room air conditioners	1990	Incandescent reflector lamps	1995
Water heaters	1990	Commercial AC & HP	1994/5
Direct-fired space heaters	1990	Electric motors (1-200 hp)	1997
Pool heaters	1990		
Fluorescent lamp ballasts	1990		
Furnaces & boilers	1992		
Central AC & heat pumps	1992/3**		
EPAct 2005	**Compliance Date**	**EISA 2007**	**Compliance Date**
Compact fluorescent lamps	2006	External power supplies	2008
Torchiere lighting fixtures	2006	Reflector lamps (BR and R20)	2008
Pre-rinse spray valves	2006	Walk-in coolers and freezers	2009
Exit signs	2006	Metal halide lighting fixtures	2009
Traffic signals	2006	Additional motors (e.g., large)	2010
Ceiling fan light kits	2007	General service lamps	2012-14 and 2020
Dehumidifiers	2007		
Comm'l clothes washers	2007		
Low voltage, dry-type distribution transformers	2007		
Very large comm'l AC & HP	2010		
Mercury vapor lamp ballasts	2008		
Comm'l unit heaters	2008		
Comm'l ice makers	2010		
Comm'l refrigerators/freezers	2010		

*Compliance date refers to the date at which manufacturers must comply with the new standards. This is often called the effective date in the literature.
** Two compliance date years under one product category indicates that the compliance dates are different for different categories or tiers of the product.

Table 2. Appliance Standards Updates Included in Historic Scenario

Product	Update By	Compliance Date
Small furnaces	DOE	1992
Refrigerators and freezers	DOE	1993
Clothes washers	DOE	1994
Clothes dryers	DOE	1994
Dishwashers	DOE	1994
Room air conditioners	DOE	2000
Refrigerators and freezers	DOE	2001
Water heaters	DOE	2004
Clothes washers	DOE	2004/07
Ballasts	DOE	2005/10
Central air conditioners & heat pumps	DOE	2006
Commercial air conditioners & heat pumps	Congress (EPAct 2005)	2010
Dishwashers	Congress (EISA 2007)	2010
Electric motors	Congress (EISA 2007)	2010
Liquid-immersed transformers*	DOE	2010
Residential boilers	Congress (EISA 2007)	2012
Dehumidifiers	Congress (EISA 2007)	2012
Vending machines*	DOE	2012
Large commercial refrigeration*	DOE	2012
PTACs and PTHPs	DOE	2012
Gas ovens and stoves	DOE	2012
Commercial boilers	DOE	2012
General service fluorescent lamps	DOE	2012
Incandescent reflector lamps	DOE	2012
Direct heaters	DOE	2013
Pool heaters	DOE	2013
Small motors*	DOE	2015
Water heaters	DOE	2015

* Standards marked with the asterisk in this table were the first standards for those products (not updates) since legislation required DOE to set initial standards by rulemaking.
** This does not include the clothes washer standards in EISA 2007, with a compliance date of 2011.

Prospective Standards, 2010-2013 and Beyond

In addition to those standards that have already been set in place by legislation or rulemaking, this study looks at most of the standards DOE is scheduled to issue between 2010 and 2013.The Obama Administration has made cost-effective appliance standards a key centerpiece of its energy policy. President Obama directed DOE to catch up on legal deadlines missed by prior administrations and to meet all new Congressionally set deadlines for updated standards coming due during his administration (White House 2009). DOE has sought to accelerate the pace of review and to begin to address additional potential standards not subject to specific legal deadlines (DOE 2010c). ACEEE and ASAP's 2009 study (Neubauer et al. 2009) estimated the potential energy, economic, and emissions impacts for most of the new and updated standards scheduled for completion between January 2009 and January 2013. Standards from that analysis that are still pending at DOE are shown in Table 3.

Table 3. Pending Appliance Standards Updates Included in Prospective Scenario

Product	Update By	Compliance Date
Battery chargers*	DOE	2013
External power supplies	DOE	2013
Certain BR and other reflector lamps*	DOE	2013
Dishwashers	DOE or INCAAA	2013
Residential refrigerators and freezers	DOE	2014
Microwave ovens	DOE	2014
Fluorescent lamp ballasts	DOE	2014
Residential clothes dryers	DOE or INCAAA	2014
Room A/C	DOE or INCAAA	2014
Residential central A/C and heat pumps	DOE or INCAAA	2014
Residential furnaces	DOE or INCAAA	2015
Residential clothes washers	DOE or INCAAA	2015
Metal halide lamp fixtures	DOE	2015
Walk-in coolers and freezers	DOE	2015
Commercial reach-in refrigerators and freezers	DOE	2016
Liquid immersed transformers	DOE	2016
Low-voltage dry-type distribution transformers	DOE	2016
Residential furnace fans*	DOE	2016

* For items marked by an asterisk, no current standards exist so the pending standard is the initial one rather than an update.

The prospective standards analysis also includes savings from those standards included in the *Implementation of National Consensus Appliance Agreements Act* (INCAAA), a bill (S. 3925 in the 111th Congress) that nearly cleared the Senate by unanimous consent in December 2010 (Congress 2010) and that is considered highly likely to pass in the 112th Congress. The INCAAA legislation included standards that could save 1.1 quads in 2030, including residential appliances, residential heating and cooling equipment, outdoor lighting fixtures, and other products (ACEEE 2011).[3] Table 3 includes updates included in INCAAA that are also subject to pending DOE rulemakings: either DOE or Congress could complete these updates in the months ahead. Table 4 shows the INCAAA standards that are not currently subject to DOE rulemakings. Together, these tables contain all of the "prospective standards" included in this jobs analysis, including INCAAA standards and previously scheduled 2010–2014 standards.

Table 4. Pending New Appliance Standards Legislation Included in Prospective Scenario

INCAAA (pending)	Compliance Date
Commercial furnaces	2012/2020
Outdoor lighting fixtures	2013
Drinking water dispensers	2013
Portable electric spas	2013
Hot food holding cabinets	2013
Heat pump pool heaters	2013

These analyses of savings from future standards only include near-term standards for which ACEEE and ASAP have previously published energy and economic impact estimates. DOE has recently announced plans to complete additional standards within two years (e.g., for televisions, HID lamps,

[3] 1 quad is 1 quadrillion Btu, which is sufficient energy to provide all of the energy needs for about 5.2 million homes. For comparison, the entire United State used 99.3 quads of energy in 2008, and the state of Oregon used about 1.1 quads of energy in 2008 (EIA 2008).

electric motors, and automatic ice makers). DOE is also considering developing standards for set top boxes and digital communication equipment; blowers, fans, and ventilation equipment; luminaries; and computers (OIRA 2010). Furthermore, additional legally required reviews and potential updates are due after 2014 (e.g., linear fluorescent lamps and water heaters). Finally, Congress could also add new products as it finds the potential for further net economic savings for consumers and businesses. Our analysis' estimates for 2020 and 2030 do not capture the full potential impact of appliance standards since these multiple categories of potential additional standards are not evaluated.[4]

RESULTS

Energy Savings

Energy savings from appliance standards occur as new equipment is purchased. Energy is saved because the standards increase the average efficiency of new products relative to what the efficiency would have been without new or updated standards. To calculate the energy savings from standards, ACEEE and ASAP use estimates of the energy savings from the more efficient device, annual sales, and baseline market share of compliant products. Estimates are based on DOE's rulemaking analyses where available, and other sources such as information from ENERGY STAR, appliance manufacturers, the U.S. Census Bureau, and utility energy efficiency evaluation reports.

After the end of the first measure life (i.e., the average useful life of the product), we assume savings attributable to the standard decays at 5% each year. In other words, 5% of the new, more efficient appliances purchased in each year are attributed to increases in efficiency that would be a part of the business-as-usual scenario, not the standard. In the sensitivity discussion below, we look at some variations on the 5% decay rate. More details on energy savings calculations can be found in Appendix A.

Appliance standards that became effective between 1987 and 2010 saved Americans about 3.6 quads of primary energy in 2010, as detailed in Table 5. As a result, U.S. energy use in 2010 was about 3.6% lower than it would have been absent standards. Savings will increase to about 6.1 quads in 2030, more than the entire annual energy use of a large state such as Florida, Illinois, New York, or Pennsylvania, including transportation (EIA 2008).

Table 5. Savings from Existing and Future Appliance Standards, in Primary Quadrillion BTU

Year	Historical Standards*	Prospective Standards	Total Savings	% of US Energy Use**
2010	3.58 ***	—	3.58	3.6%
2020	5.78	0.58	6.35	5.7%
2030	4.64	1.48	6.11	5.5%

Notes: * These differ slightly from Neubauer et al. (2009) report as a result of the 5% decay rate applied to the savings. See Appendix A for details.

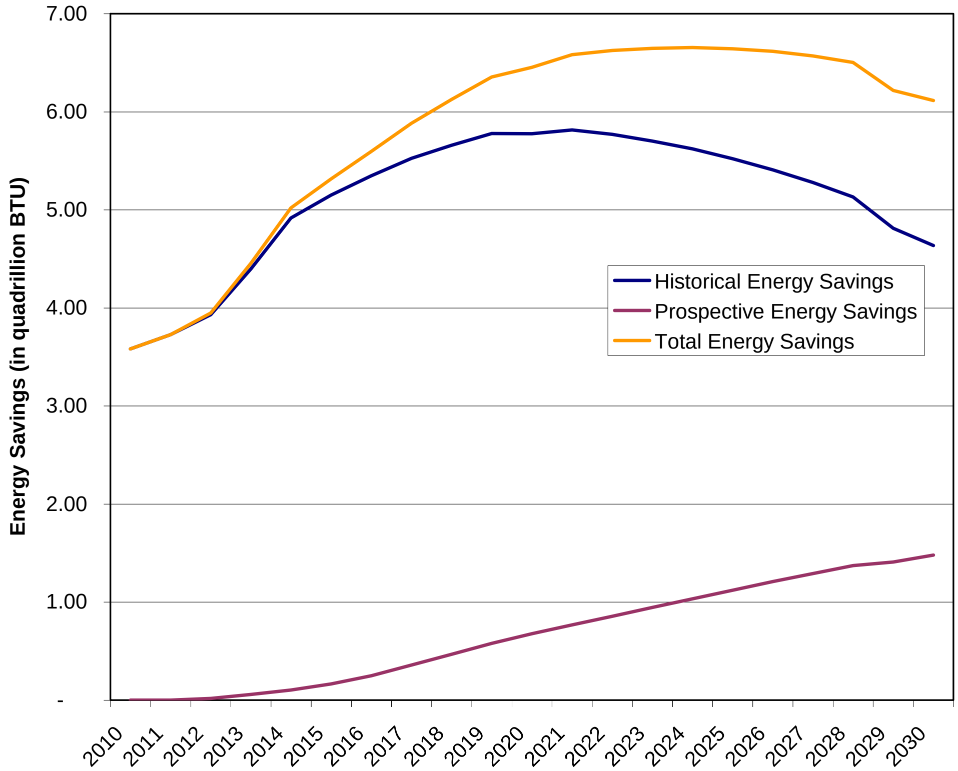
** Based on AEO 2010 projections of total U.S. energy use (EIA 2010). We assume that historical standards are included in the AEO Reference Case, and that the prospective standards are not included in the Reference Case, so we add the historical savings to assume 100.2 quads of U.S. energy use would have occurred without the historical savings for 2010, 110.7 quads for 2020, and 111.2 quads for 2030.

*** These savings are greater than Meyers et al. (2008) estimates by about 1.8 quads largely because of differences in the scopes of the studies. This analysis includes savings from the standards in the Energy Policy Act of 1992, Energy Policy Act of 2005, and Energy Independence and Security Act of 2007, and some of the updates to those standards, in addition to those standards analyzed in Meyers et al. (2008).

[4] A forthcoming ACEEE and ASAP report will estimate the impacts of about 25 additional standards and updates to existing standards that could be completed within the next few years.

The energy savings from historical standards peak in 2021, due to the 5% decay rate assumption: a steadily increasing portion of the savings becomes a part of the baseline. The prospective standards' savings peak after the analysis period.

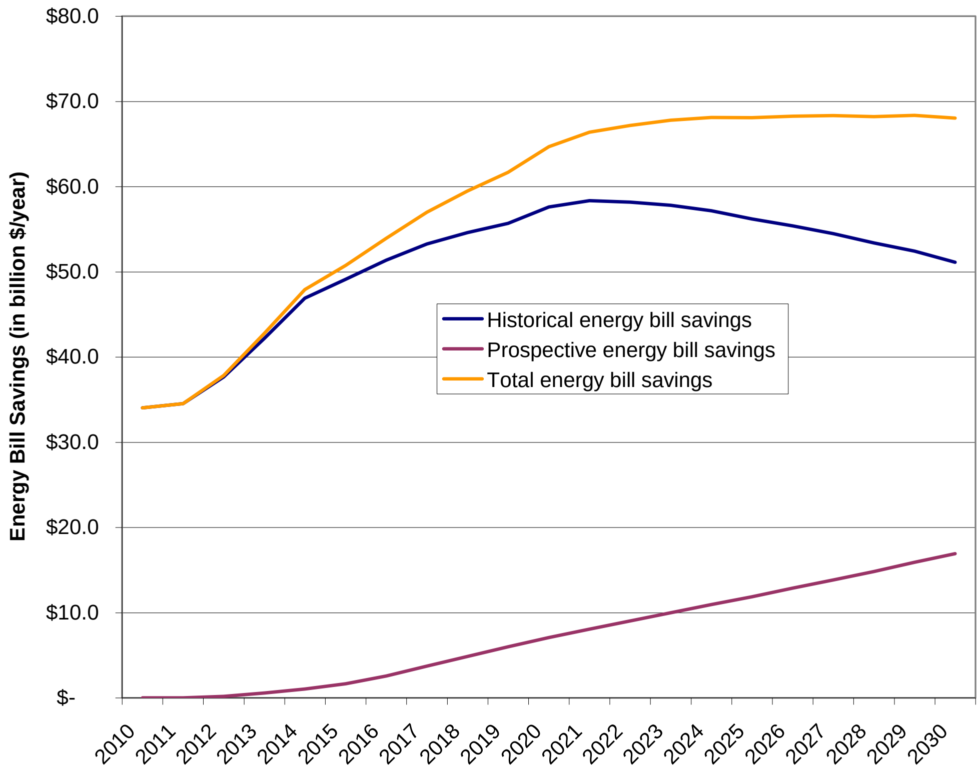
Figure 1. Energy Savings from Historical and Prospective Standards, 2010–2030



Energy Bill Savings and Appliance Costs

In order to calculate the employment impacts from these standards, we calculated the energy bill savings that are generated from decreased (more efficient) energy use as a result of each appliance standard, and the costs imposed from each standard. The latter are the result of incremental costs of more efficient appliances. The benefits in dollars were calculated using *Annual Energy Outlook 2010* prices (EIA 2010).

Figure 2. Energy Bill Savings from Historical and Prospective Standards, 2010–2030



Costs for standards issued since 2005 and prospective standards were also compiled from prior ACEEE and ASAP research (e.g., Neubauer et al. 2009 and Nadel et al. 2006). In addition, some cost information from the former study was updated based upon DOE's recent Technical Support Documents.[5] For standards completed before 2005, costs were estimated using payback periods found in DOE's Technical Support Documents as outlined in Appendix A. Other research has shown that DOE has generally overestimated standards' impacts on product prices due to several factors, including the difficulty of predicting innovation. For example, a Lawrence Berkeley National Laboratory (LBNL) study found that DOE overestimated the price for improved efficiency in six different rulemakings. Actual prices were 20% to 85% lower than DOE predictions (Dale 2009). However, DOE has since modified its approach for estimating product price impacts. Since there is no recent, comprehensive retrospective analysis of price impacts due to standards, this study uses the DOE's predicted prices. In the sensitivity discussion below, we look at the impacts of a case with 20% lower costs.

Neubauer et al. (2009) estimated a net present value of more than $300 billion through 2030 for standards enacted or issued before July 2009, and calculated the potential net present value of DOE rulemakings due between 2009 and 2013 to be $123 billion through 2030. ACEEE calculations for the INCAAA bill, which represent the rest of the prospective standards in this analysis, estimated a net present value (NPV) of $48 billion. Combining these two estimates yields a total NPV for enacted and prospective standards of more than $470 billion.[6] These savings are equivalent to the annual

[5] These standards include ranges and ovens, beverage vending machines, PTACs and PTHPs, and small electric motors (DOE 2009b, 2010b, d , e).
[6] In comparison, Meyers et al. (2008) calculated $240 billion NPV savings from the NAECA standards, the DOE updates to those standards between 1987 and 2007, and some of the EPAct 1992 standards. The significantly broader scope of this study probably accounts for most of the difference.

household income of nine million homes, assuming the U.S. Census average household income of $52,029 in 2008 (Census 2010).

In addition, DOE has estimated bill savings of $250–300 billion for the standards completed during the Obama administration (BTP 2010). Although the figures are not directly comparable since the DOE figures include only savings and not costs, they are similar in range to the estimates of savings in constant dollars (2007 dollars) that ACEEE compiled for this report.

Estimating the Net Employment Benefits

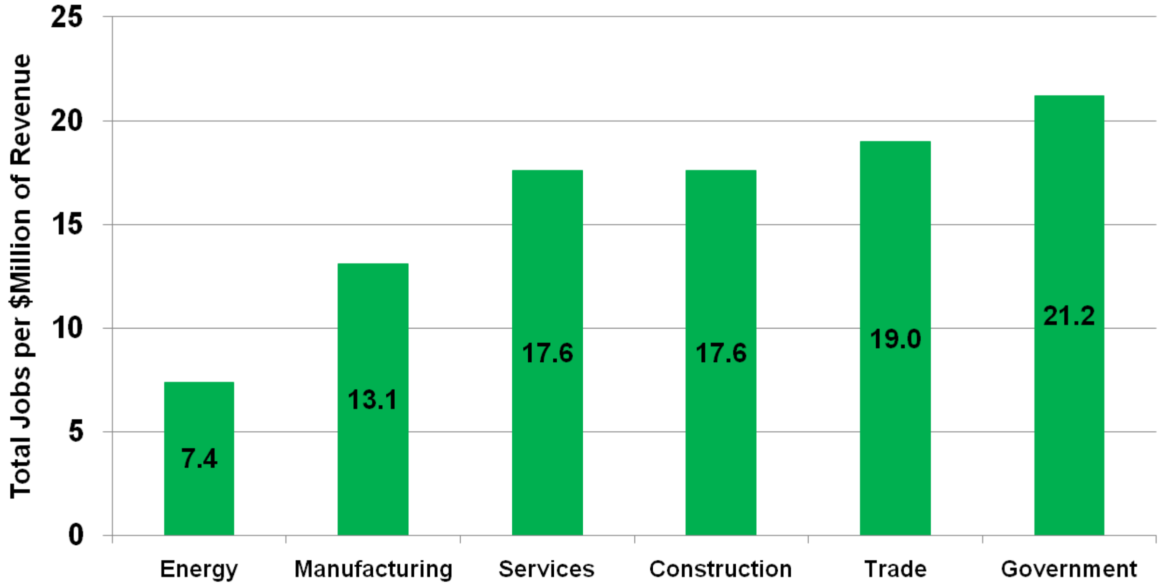
To evaluate the larger macroeconomic benefits of appliance standards, the impact of the aforementioned energy bill savings and increased appliance costs were assessed using ACEEE's DEEPER Modeling System (the **D**ynamic **E**nergy **E**fficiency **P**olicy **E**valuation **R**outine; see Laitner 2009 for a more complete description and prior use of the model to evaluate other policies). This macroeconomic evaluation consists of three steps.

First, we calibrate the DEEPER model to establish a current set of economic accounts for the United States (IMPLAN 2009) and then use the Energy Information Administration's *Annual Energy Outlook 2010* (EIA 2010) to establish a reference case out to the year 2030. In this respect, we incorporate the anticipated investment and spending patterns that are suggested by the standard forecast assumptions. The spending patterns range from typical spending by businesses and households within the period of analysis to the anticipated construction of new electric power plants and other energy-related spending that might also be reflected in the forecast.

Second, we transform the set of historical and prospective standards policy assumptions into the direct inputs that are needed for the economic model. The resulting inputs include such parameters as the capital and operating costs associated with more energy-efficient technologies, and the energy bill savings that result from the appliance standards described in this report. Once the model is calibrated and tested, we are then able to evaluate the larger economic impacts over the 2010 to 2030 time horizon. More details on the DEEPER model are provided in Appendix B.

The DEEPER model's employment outcomes are driven primarily by changes in the demand for energy services as a result of appliance standards energy savings. When consumers or businesses save money on their energy bills, they spend most of the savings on other goods and services, transferring investment from energy-related sectors. The principal energy-related sectors of the U.S. economy are not especially job-intensive in comparison to the rest of the economy. They support only 7.4 total jobs for every one million dollars of revenue received in utility bill payments in comparison with the rest of the economy, which supports between 13 and 21 direct jobs per million dollars of receipts. Figure 3 illustrates the labor intensities in key sectors of the U.S. economy and demonstrates that the impact of one million dollars in consumer energy bill savings implies a net gain of roughly 10 jobs (or about 17 jobs supported by a more typical set of consumer purchases compared to the 7 jobs supported by electric and natural gas utilities).

Figure 3. Comparing Labor Intensities in Key Economic Sectors within the U.S.



Source: IMPLAN (2009)

The results of the DEEPER macroeconomic analysis are shown in Figure 4. The results are generated over the years 2010–2030, separated by existing and future standards. Similar to the energy savings described above, the larger number of jobs as a result of historical standards peak in the early 2020's, whereas the jobs from prospective standards continue growing through 2030.

The historical standards case included 340,000 more jobs than the baseline in 2010. The historical and prospective standards together will generate a total of about 390,000 net jobs in 2020 and 380,000 net jobs in 2030. The prospective standards generate no jobs by 2010 because they have not yet gone into effect and are not producing energy savings, but quickly ramp up in the 2020–2030 period. In 2030 they represent 35% of the total jobs created from standards. In contrast, the jobs from those standards put in place before 2010 are shown to peak in 2021 when they support a net of about 350,000 jobs. A comparison of the net employment benefits generated by appliance standards is provided in Table 6. The table also includes net wage impacts, which are positive, primarily due to the net gain in employment that standards help create.

Figure 4. Net Employment, Historical and Prospective Standards

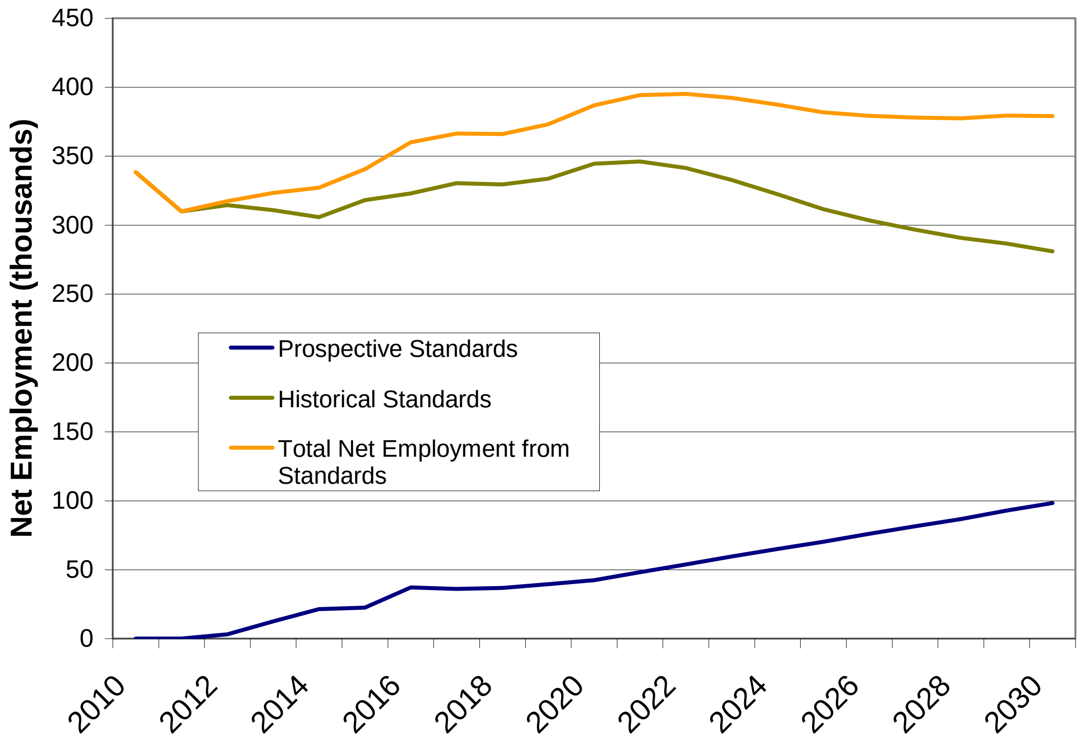


Table 6. Results from DEEPER Appliance Standards Impacts for Key Benchmark Years

	2010	2020	2030	Annual Average 2010–2030
Macroeconomic Impacts Prospective Standards				
Employment (thousands of jobs)	0	42	98	47
Wages (billion 2007 dollars)	$0.01	$1.23	$2.89	1.43
Macroeconomic Impacts Historical Standards				
Employment (thousands of jobs)	338	344	281	318
Wages (billion 2007 dollars)	$10.33	$9.16	$7.71	8.61
Total Employment (thousands of jobs)	**338**	**387**	**379**	**364**
Percent from Reference Case	0.24%	0.25%	0.22%	
Total Wages (billion 2007 dollars)	**$10.34**	**$10.38**	**$10.60**	**$10.04**
Percent from Reference Case	0.13%	0.12%	0.13%	

Appliance standards clearly generate a net positive employment impact as a result of energy savings and movement of investment from the capital-intensive utilities industry towards the more productive general economy. While the impact is small relative to total employment in the U.S. (i.e., less than one-half of 1%), the absolute total number of increased jobs is an important effect of appliance standards. Moreover, these effects should be considered within the broader context of policies to increase efficiency. In other studies, for example, ACEEE has found that enhanced energy efficiency investments could contribute to a net gain of more than 1.1 million jobs by 2050 (Laitner et al. 2010;

see also Laitner 2009, and Laitner and McKinney 2008). In short, the larger the cost-effective energy bill savings more generally, the larger the number of jobs that are likely to be supported.

The jobs referenced in this analysis are "full-time jobs equivalent" — that is, one job as represented in this study can mean one full-time job for one person, or one-half of one full-time job for two people, or any other iteration of job-hours that adds up to a full-time jobs equivalent. In addition, they are jobs created in the year of analysis, or annual jobs directly connected to changes in the investment and spending patterns that are driven by the appliance standards within a given year. These jobs are mostly service and construction jobs, which will tend to be concentrated in the places where the most energy bill savings will occur — that is, in populous states and states with high energy costs.

In addition to the service and construction jobs that make up most of the employment impacts, this analysis indirectly includes jobs produced in the manufacturing of the covered products by explicitly including the manufacturing sector in our modeling system. We find that for every 100,000 net jobs created by the energy efficiency gains, about 6,000 of those jobs are within the broad manufacturing sector. Because the analysis focuses on the aggregate spending that results from the net energy bill savings rather than just the incremental cost of the affected appliance, this analysis does not estimate the number of jobs specifically associated with appliance manufacturing. The gain in manufacturing jobs attributable to appliance standards will be primarily located in states with a lot of manufacturing such as the Midwest and South.

Sensitivity Analyses

ACEEE conducted three sensitivity analyses to determine the effects of certain variables on the final impacts. These included two different versions of the decay rate, which had a high level of uncertainty due to differences among products, and one sensitivity case with lower costs of appliance and equipment standards (since, as discussed above, the costs of standards have historically tended to be overestimated by DOE, our source for the majority of our cost information). For the standard case, a 5% decay rate was used, but we also analyzed the impact on energy savings of a 0% and a 10% decay rate, and estimated the effects on employment. In the standard case, the assumptions about costs from DOE's Technical Support Documents were used for most products, but in the sensitivity analysis, we assumed 20% lower cost and modeled the employment impacts.

In the case of 0% decay, we found energy savings of 7.92 quads in 2030, as opposed to the 6.11 quads found in the 5% decay case. Because of an increase in energy bill savings of about $20 billion in the 0% decay case in 2030, the historical jobs would rise from 280,000 jobs to about 390,000 jobs. This assumes that there would be no change in the efficiency of regulated products in the business-as-usual scenario in the absence of standards. However, efficiency could actually decline over time in the absence of standards, making even this a conservative assumption. Empirically, a decline in efficiency occurred in TVs and associated electronics prior to standards; in water heaters and refrigerators from World War I until standards first took effect; and in telephones since the advent of mobile phones. Further, in some cases, such as high efficiency incandescent (halogen) lamps, the prospect of future standards may encourage more rapid development and introduction of new efficient technologies than would occur in a business-as-usual case without standards.

We also evaluated the case in which 10% of the new, more efficient appliances purchased in each year are attributed to increases in efficiency that would be a part of the business-as-usual scenario, not the standard. In this scenario, we found energy savings of 5.04 quads in 2030, as opposed to the 6.11 quads found in the 5% decay case. Because of a decrease in energy bill savings of about $11 billion in the 10% decay case in 2030, the historical jobs would fall from 280,000 jobs to about 210,000 jobs. Decay rates vary from product to product, so there may be some products for which the decay rate is this high.

Because these cost estimates were based on DOE's predicted prices, we conducted a sensitivity analysis with 20% lower costs. This represents the bottom of the range by which DOE historically tends to overestimate cost, and is therefore still a conservative assumption (Dale et al. 2002). With 20% lower costs, the employment estimates are 99,000 jobs from the prospective standards in 2030, as opposed to the 98,000 jobs estimated from prospective standards in 2030 in the standard case. Costs tend to make less of a difference to the employment impacts because most of the jobs are driven by energy bill savings.

DISCUSSION

This analysis aggregates a great deal of data in a consistent format to estimate the net energy bill savings and the net employment impacts from the appliance standards already in place as well as most of the pending standards planned between 2011 and the end of 2013 plus those likely to be instituted in the 112th Congress. This section addresses three topics not covered above: uncertainty in the analysis; a comparison to other studies; and impacts on manufacturing of the covered products.

Uncertainty

Like any study that provides long-term future impacts and that relies on a variety of economic variables, the suggested net benefits are subject to a significant range of uncertainty. Some of this uncertainty relates to energy prices and the rate of economic growth, either of which could increase or decrease the estimated impacts. At the same time, changing costs and technology performance might also increase or decrease net impacts. However, many of the assumptions in this analysis tend to cause this analysis to *underestimate* the net positive impacts. For example, the energy savings we estimate due to standards peak during the 2020–2030 period, and then gradually fall. This trend is due to our assumption that an increasing portion of the savings would have happened even if the standards had not existed. Therefore the jobs associated with these bill savings are no longer attributed to the standards. This is a conservative assumption because an improving baseline efficiency is not at all certain or guaranteed. In addition, some portion of natural efficiency improvement or improvement induced by policies other than standards may occur in *both* the base case and the standards case. In other words, future improvements may start from the lower baseline established by the standard.

Several other factors are likely to cause this study to underestimate the benefits of current and future standards. First, as noted above, the prospective savings will be larger than estimated in this study because we have not accounted for a number of standards already under consideration at DOE, some of which may be completed within the next two years. Second, we have not accounted for water and sewer bill savings: many existing standards and prospective standards will save considerable amounts of water. The associated water bill savings would increase the job and wage impact estimates if included in this analysis. Third, the incremental costs for more energy-efficient appliances are difficult to predict with any confidence. As discussed above, the evidence suggests, however, that any uncertainty most likely points in the direction of incremental costs being overestimated. If that were to hold true, the resulting analysis would then tend to increase the net job impacts. Finally, this analysis does not model energy saving impacts on energy price levels. In general, a reduction in energy demand will result in a small reduction in energy price levels, which will lead to more energy bill savings. More energy bill savings, as described above, will tend to result in higher U.S. employment levels.

Comparison to DOE Studies

The job impact estimates included in this report are generally consistent with those found in DOE rulemakings. In reviewing five of the most recent rulemakings, we found that all estimated positive net employment impacts for the years 2020/2022 and 2030/2032 (DOE 2009a, b; 2010a, b). A few demonstrated a decrease in net employment in the initial years as a result of "dominance of capital costs in early years," but they all showed net positive employment gains by 2020. For example, DOE estimates for the recent new standards for general service fluorescent lamps (GSFL) and incandescent reflector lamps (IRL) found a net increase in national jobs, characterized by DOE as "indirect employment," of 17,800–25,000 jobs in 2032 (DOE 2009a). For the same standard, we found approximately 18,000 jobs in 2030.[7]

Historically, DOE has generally given little weight to job creation impacts due to standards in selecting future standard levels. Nonetheless, this analysis shows that, in the aggregate, the impact of sustained and continuous efficiency improvement driven by appliance standards is making and can continue to make a measureable impact on U.S, employment levels.

Jobs Realized in Manufacturing the Covered Appliances

As mentioned above, this analysis indirectly includes jobs produced in the manufacturing of the covered products by explicitly including the manufacturing sector in our modeling system. For every 100,000 net jobs created by the energy efficiency gains, about 6,000 of those jobs are within the broad manufacturing sector. However, this model does not predict employment levels in the manufacturing of the affected appliance.

In its rulemakings, DOE conducts an industry analysis that estimates impacts on employment in the manufacturing of the covered product. Through in-depth interviews with manufacturers and independent analysis, DOE typically develops multiple scenarios that can include a range of potential impacts ranging from significant job loss to slight employment gains. Increased product prices can lower sales and employment levels. For some products, efficiency improvements may increase complexity and therefore labor content, which can result in more jobs per volume of output.

The federal standards law is designed to minimize impacts on manufacturers by providing significant time between standards revisions and lead times of three years or more between a new standard's publication and the compliance date. Because the schedule for new standards is well-known, manufacturers can time investments needed to comply with new standards with their normal needs to invest in updated products and production. Thus, standards can affect when manufacturers make investments. However, manufacturers' choices of where to make new product lines appears to have little to do with the specific efficiency level of a standard. Rather, the long-term viability of a given factory and its associated jobs generally depends on other factors including prevailing local wages, distance from suppliers and markets, labor pool skills, and local tax treatment among others.

In practice, manufacturers make a variety of decisions when deciding where to make new product lines. Like most U.S. manufacturers, they are under intense pressure to reduce costs and, as is the case throughout the U.S. economy, moving to lower wage countries is an option, whether or not new standards are imposed. Nevertheless, many manufacturers of products covered by recent standards are choosing to invest in U.S. production facilities. For example, in the wake of Congress' 2007 adoption of new efficiency standards for screw-based light bulbs, many new U.S. lighting manufacturing jobs have been created. These include several thousand jobs by companies working to produce the next generation of efficient LED light bulbs like Cree in North Carolina, Phillips Lighting, and Lighting Sciences Group Corp in Florida (NRDC 2010). Sylvania invested in an existing light bulb factory in Pennsylvania to produce light bulbs that comply with the initial standards taking effect starting in 2011 in California and 2012 nationally. On the other hand, GE recently closed its incandescent bulb plant in Virginia.

With respect to general service fluorescent lamps needed to comply with standards taking effect in 2012, GE recently announced a $60 million investment to increase manufacturing capacity at its Bucyrus, Ohio manufacturing facility. This investment will almost double that plant's jobs (General Electric 2010). GE also has chosen Kentucky as the production location for its new line of heat pump

[7] ACEEE's annual estimate for the GSFL/IRL standards was 0.3 quads in 2030, in comparison with a total annual historical quads estimate of 4.64 quads. This percentage, 6.47%, multiplied by the number of jobs in 2030 from historical standards (281,000), yields a comparison of 18,000 net jobs. This falls in the range of what DOE's ImSET model predicts (between 17,800 and 25,000 net jobs).

water heaters,[8] a technology required to meet standards for some water heaters starting in 2015. In the area of home appliances, a trend to move manufacturing to low wage countries may be slowing or even reversing. Whirlpool, which is subject to pending new standards for several major product categories, increased its U.S. manufacturing employee base by 12% in 2010 (Whirlpool 2010). GE has announced it will be investing $1 billion in its U.S. appliance operations, adding 1,300 jobs over the next four years at plants in Kentucky, Indiana, Alabama, and Tennessee. The investments will apply “lean manufacturing” to its production facilities. In lean manufacturing, cross-cutting teams of engineers, suppliers, production workers, and others work together from concept through the design of the production line. GE has found that this can be a way to lower manufacturing costs as much as 30%. As a result, the new investments will include moving some production lines that have been in Mexico and Korea back to the U.S. (Saporito 2011, Insider Louisville 2010).

CONCLUSIONS

This analysis demonstrates that national appliance, equipment, and lighting standards are a cost-effective public policy instrument that creates significant energy savings which, in turn, generate larger macroeconomic benefits such as increased net employment and associated wage and salary benefits. Although individual standards tend to save or produce small numbers of jobs in comparison to a scenario with no policy, in the aggregate, these policies impact national employment.

In 2010, savings from appliance standards created about 338,000 jobs. The number of jobs that will be generated by appliance and equipment standards in 2020, about 390,000 jobs, is equivalent to the number of employed people in Delaware in November 2010. This job creation is driven by energy savings, estimated at 6.35 quads in 2020, more than the annual use of Florida, Illinois, or Pennsylvania in 2008 (EIA 2008).

Although the standards already in place will produce significant benefits through 2030, they peak in the early 2020s. This analysis also included jobs and energy savings from the *Implementation of National Consensus Appliance Agreements Act* (INCAAA) and many pending DOE rulemakings. In order to realize those benefits, the 112th Congress must pass these consensus appliance standards and DOE will need to follow through on the rulemakings for those prospective standards included in this analysis. Additional cost-effective standards beyond the scope of this study would further increase consumers’ energy bill savings and, therefore, jobs created by new appliance standards.

[8] See http://www.entrepreneur.com/tradejournals/article/202184482.html.

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APPENDIX A. METHODOLOGY FOR APPLIANCE STANDARDS JOBS ESTIMATES

This report's estimates are divided into "historical" savings (those standards which are already in place through legislation or rulemaking by December 2010) and "prospective" savings (most of the standards that are slated to be put in place by the Department of Energy through 2013 or contained in the *Implementation of National Consensus Appliance Agreements Act* — INCAA). See Tables 1 and 2 for a list of those standards that were included in each category.

Energy Savings

Estimates from Kubo et al. (2001)/Nadel et al. (2004)

Energy savings from standards put in place between 1987 and 2005 (in quads, including all fuels) and electricity savings (in TWh) are derived from earlier ACEEE analyses (Kubo et al. 2001; Nadel et al. 2004). These estimates were generated from an American Physical Society article by Geller and Goldstein (1999) for 1987-97 standards, and the DOE Technical Support Documents for 2000 & 2001 standards. Geller and Goldstein estimate savings for 2015 only. The 2015 calculations of energy savings are based on NRDC modifications of the Pacific Northwest National Laboratory-developed model for DOE input to the Government Performance Results Act. Those numbers were extrapolated to estimate savings in 2010 and 2020 using an annual stock growth rate of 1%.

It should be noted that these savings estimates do not include any allowance for "rebound" effects. "Rebound" is the impact of product efficiency on subsequent product use. For example, a consumer purchasing an efficient product could operate it more, reducing the energy savings. We did not include rebound because available evidence is that these affects are small (see, for example, Nadel 2010) and also these affects have mostly been documented when consumers make a conscious decision to purchase a high efficiency product instead of a normal efficiency product. In the case of appliance standards, the efficiency of the baseline product is increased and many consumers do not know they are getting a high efficiency product.

In addition, we assumed that after the first measure life is complete, savings decay at a 5% rate. For the 0% decay rate and 10% decay rate sensitivity analyses, we used the same assumptions below, but replaced a 5% decay rate with either 0% or 10%. To calculate this, we calculated the savings per one year of sales by dividing the savings in 2015 by the average product life, 15, then:

For standards with first measure lives that ended before 2015, we calculated the savings in each year before 2015, using: *savings in year in question = (savings in year after) + (one-year sales savings)*(0.05*2015-year in question*). For example: 2013 savings = (2014 savings) + (one-year sales savings)*(0.05*[2015-2013]).

We then calculated the savings in each year after 2015, using: *savings in year in question = savings in year before – (0.05*[year in question-2015])*(one-year sales savings)-(original savings in year before-new savings in year before after decay rate).*

For standards with measure lives that ended after 2015, we used the calculations from the Kubo and Nadel spreadsheet for the savings until the end of the measure life. To calculate the savings in the years after the first measure life has ended, we used: decayed *savings in year in question = undecayed savings in year in question – (0.05*[year in question-2015])*(one-year sales savings)-(original savings in 2015-new savings in 2015 after decay rate).* The first factor accounts for the 5% degradation in the year in question. The other factor accounts for decay that occurred in the previous year.

Although energy savings are reported as primary energy savings in the report, the inputs to the DEEPER model were delivered energy savings. To report primary energy savings, we used heat rates derived from the *Annual Energy Outlook 2010 Reference Case* (EIA 2010).

Estimates from Ka-Boom! 2009

The estimates of electricity and fuel savings from the historical standards in EISA 2007 and the standards completed between 2008 and 2010 came from the model created for ASAP and ACEEE's *Ka-Boom!* report, as documented in Nadel et al. (2006) and Neubauer et al. (2009). We updated the model to reflect actual standards completed by DOE since publication of *Ka-Boom!.* The estimates of electricity and fuel savings from prospective standards also came from the *Ka-Boom!* model.

The savings in each year between 2010 and 2030 were calculated using:

End-use electricity savings = annual sales volume x per-unit electricity savings x (1 – current market share of new standard) x (years from effective date - 0.5) OR
NG savings = annual sales volume x per-unit NG savings x (1 – current market share of new standard) x (years from effective date - 0.5)

Sector Calculations

In order to use sectoral energy prices, we assessed the relative savings from each major standard by sector.

For historical standards, residential prices were used for: NAECA 1987, NAECA updates in 1989 and 1991, refrigerator/freezer update 1997, room air conditioner update 1997, clothes washers update 2001, water heater update 2001, central air conditioners and heat pumps update 2001, gas ovens and stoves 2009, and water heaters, direct heaters, and pool heaters 2010. Commercial prices were used for: ballasts 1988, ballasts update 2000, packaged terminal air conditioners and heat pumps 2008, commercial refrigeration 2009, commercial boilers 2009, beverage vending machines 2009, and commercial clothes washers 2010.

For prospective standards, residential prices were used for: refrigerators and freezers 2010, microwave ovens 2010, residential furnaces 2010, fluorescent lamp ballasts 2011, clothes dryers 2011, room air conditioners 2011, central air conditioners and heat pumps 2011, battery chargers 2011, external power supplies 2011, clothes washers 2011, metal halide lamp fixtures 2012, and furnace fans 2013. Commercial prices were used for: walk-in refrigerators and freezers 2012, reach-in refrigerators and freezers 2013, and low-voltage dry type transformers 2013. Industrial prices were used for liquid immersed transformers 2013.

Most standards were predominantly one sector, but a number included savings from multiple sectors:

Standard	Year	Sector	Source for Relative Shares
EPAct lamps	1992	RCI (14%/67%/19%)	Geller and Nadel (1992), Navigant (2002)
EPAct others	1992	RCI (65%/31%/3%)	Geller and Nadel (1992)
EPAct 2005	2005	RC (66%/34%)	ACEEE (2005)
EISA	2007	RCI (60%/38%/2%)	ACEEE (2007)
General service fluorescent lamps	2009	RCI(5%/71%/28%)	Navigant (2002)
Incandescent reflector lamps	2009	RCI (43%/56%/1%)	Navigant (2002)
Small motors	2010	C/I (50%/50%)	Elliott (2010)

Consumer Bill Savings

We calculated consumer bill savings using the following formula:

Consumer electricity bill savings = end-use electricity savings x national average electricity price

Consumer natural gas bill savings = natural gas savings x national average natural gas price

The electricity and natural gas prices are constant dollar delivered prices from the *Annual Energy Outlook 2010 Reference Case* (EIA 2010).

Consumer Investment

For the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, and the rulemakings between October 2008 and March 2010, the consumer investment was calculated using the methodology from Neubauer et al. (2009), page 59. This method was also used for prospective rulemakings.

For each of the pieces of legislation or rulemakings passed before 2005, we used a payback period to calculate the investments given our data on savings. These payback periods were found or derived from information in DOE Technical Support Documents or ACEEE savings estimates. For the sensitivity analysis with 20% lower costs, we decreased the consumer investment figures calculated below by 20%. Consumer investment was then calculated using the following method:

The incremental energy savings in the year after the effective date was calculated. These were calculated by: *(2010 savings) / (number of years between 2010 and the effective date).* In the case of room air conditioners, the savings in year one were generated from shipment and per-unit energy savings data from DOE Technical Support documents by: *(number of sales)*(per-unit energy savings in year after effective date).*

We collected electricity and/or natural gas prices from the *Annual Energy Outlook* cited in the payback period calculation in the Technical Support Document (TSD).

Electricity bill savings in billion $ were calculated in the year after the effective date by: *(energy savings in TWH in effective date year) * (electricity prices in effective date year using AEO $ year cited in TSD)/100*. Natural gas benefits were calculated similarly.

Electricity bill savings in billion $ were multiplied by the payback period cited in the original DOE technical support document to get costs in the effective date year from the *Annual Energy Outlook* cited in the TSD, using: *consumer investment in effective date year = (incremental energy savings (in billion $)) * (payback period).*

To take into account the changes in the costs of production of different appliances between the effective date year and the year of analysis in the DEEPER model (2008), we converted to $2008 using the Produce Price Indices that match each product. The following formula was used:

*(Costs in effective date year) * (PPI in 2008/PPI in effective date year)*

We then applied a 5% per year decay rate after the end of the measure life, which assumes that for the next replacement, the standard can be credited for some of the savings, but the rest are incorporated into the basecase. We use the following method to make this adjustment:

> We assumed the costs were as described above for the years within the measure life, with a 1% growth rate due to increased sales. To calculate the costs in the years after the first measure life was complete, we used this formula: *costs in given year = costs in previous year – ([0.05 x years since end of measure life] * costs in previous year).*

Legislation/ Rulemaking	Payback Period	AEO Year Cited/ Energy Price	Original $ Years	Effective Date	PPI Used	Measure Life	Source
NAECA 1987	1.63elec; 1.39 gas	7.8c/kWh 6.06$/Mbtu	1985	1991	appliances, WPU1241	15	Geller (1987)
Ballasts 1988	1.52	7.1 c/kWh	1987	1991	ballasts, WPU117402	15	Geller and Miller (1988)
NAECA Updates 1989 and 1991	4.36	6.87c/kWh; 5.73$/mbtu	1987	1993-1994	appliances, WPU1241	15	DOE (1988, 1990)
EPAct Lamps 1992	0.460	8.23 c/kWh	1990	1995	lighting, WPU1245	9	Geller et al. 1989
EPAct Others 1992	2.246	6c/KWh	1990	1996	motors, WPU117304	15	Nadel et al. (2002)
Refrigerator/Freezer Update 1997	4.1	AEO 1994	1992	2000	WPU124103	19	DOE (1997a)
Room AC Update, 1997	3.8	AEO1997	1995	2000	AC, WPU114802	15	DOE (1997b)
Ballasts Update, 2000	7.23	AEO 1999	1997	2005	ballasts, WPU117402	13.9	DOE (2000)
Clothes Washer, 2001	5	AEO1999	1997	2004	Major appliances, WPU1241	14	DOE (2001a)
Water Heater, 2001	7.4 elec, 3.6 gas	AEO 2000	1998	2004	Heating equipment, WPU106	12	DOE (2001b)
CAC and HP, 2001	10	AEO 2000	1998	2006	AC, WPU114802	18	DOE (2002)

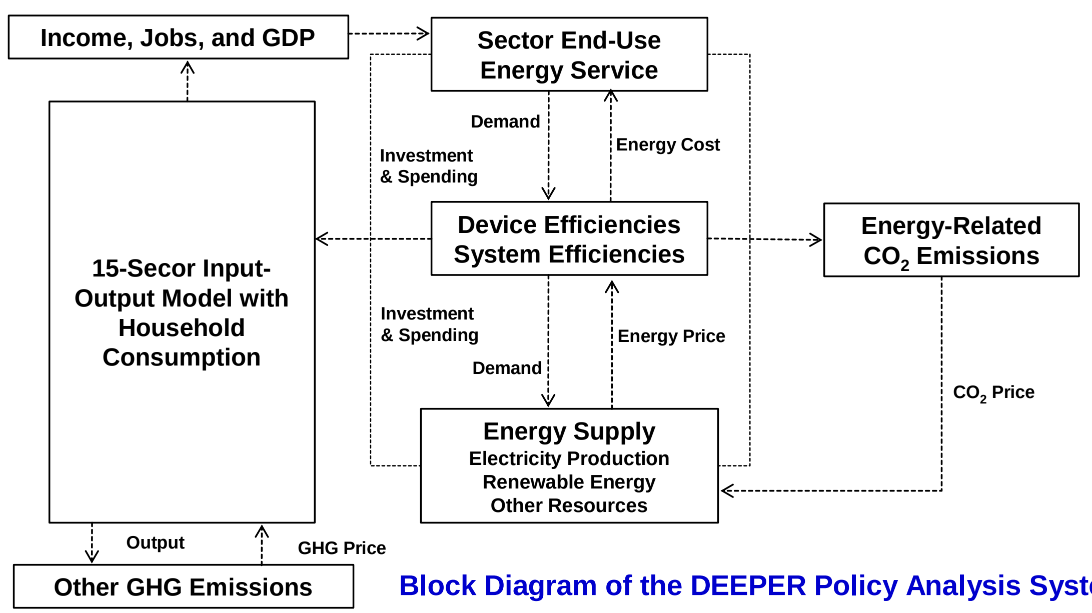
Program/Federal Government Spending

In addition to consumer energy bill benefits and consumer investment, the DEEPER model required inputs for program spending. In this case, the Department of Energy spent about $20 million in FY 2008 for the Appliance Standards Program and about $35 million in FY 2010, which we estimated as an average of $25 million over the last three years (ASE 2008; Cymbalski 2010). Because this cost is just being applied to prospective standards, we have assumed that the federal government spending is zero for historical standards, and that the $25 million is being used for prospective standards. We assumed a 1% per year growth in funding and prorated those costs amongst the sectors based on savings.

APPENDIX B. METHODOLOGY OF THE DEEPER MODELING SYSTEM

The **D**ynamic **E**nergy **E**fficiency **P**olicy **E**valuation **R**outine — the DEEPER Modeling System — is a 15-sector quasi-dynamic input-output model of the U.S. economy.[9] Although an updated model with a new name, the DEEPER model has an 18-year history of use and development. See Laitner et al. (1998) for an example of an earlier set of modeling results. Laitner and McKinney (2008) also review past modeling efforts using this modeling framework. The model is used to evaluate the macroeconomic impacts of a variety of energy efficiency, renewable energy, and climate policies at both the state and national level. The timeframe of the model for evaluating policies at the national level is 2010 through 2050, or in the case of evaluating the variety of energy efficiency appliance standards, the period 2010 through 2030. As we chose to implement it for this analysis, the model maps in the changed spending and investment patterns based on the off-line analysis described in the main body of this report. The model then compares that changed spending pattern to the employment impacts assumed within a standard reference case.

Although the DEEPER modeling system includes a representation of both energy-related CO_2 emissions and all other greenhouse gas emissions, in this analysis it focuses on the use of energy in all sectors of the economy. DEEPER is an Excel-based analytical tool with three linked modules combining approximately two dozen interdependent worksheets. The primary analytic modules are: (i) the Energy and Emissions Module, (ii) the Electricity Production Module, and (iii) the Macroeconomic Module. The block diagram of the DEEPER Modeling System below lays out the analytical framework of the model.



Block Diagram of the DEEPER Policy Analysis System

The model outcomes are usually driven by the demands for energy services and alternative investment patterns as they are shaped by changes in policies and prices. In this case, however,

[9] There are two points worth noting here. First, the model solves recursively. That is, the current year set of prices and quantities is dependent on the previous years' results. As the model moves through time, there are both secular and price-quantity adjustments to key elasticities and coefficients within the model. Second, there is nothing particularly special about this number of sectors. The problem is to provide sufficient detail to show key negative and positive impacts while maintaining a model of manageable size. If the analyst chooses to reflect a different mix of sectors and stay within the 15 x 15 matrix, that can be easily accomplished. Expanding the number of sectors will require some minor programming changes and adjustments to handle the larger matrix.

because the economy-wide impacts are reasonably small, we maintain the current set of electricity and other prices as established by the *Annual Energy Outlook* projections (EIA 2010). This tends to provide a conservative result in that even small downward pressure on the price of remaining uses of energy would provide further net benefits to the larger economy. Although the DEEPER Model is not a general equilibrium model, it does provide sufficient accounting detail to match import-adjusted changes in investments and expenditures within one sector of the economy and balance them against changes in other sectors.[10]

In addition to energy prices as noted above, the DEEPER Model is benchmarked to the larger macroeconomic parameters of *Annual Energy Outlook* (EIA 2010), which now extends out through 2035. In the event we want to provide an assessment over a longer time horizon, as noted earlier, and shown in the table below, the model has the capacity to evaluate policies through the year 2050.

Key Reference Case Scenario Data for DEEPER Policy Runs in Key Benchmark Years						
	2010	**2013**	**2020**	**2030**	**2050**	**Annual Growth Rate 2010-2050**
Gross Domestic Product (Billions of 2007 Dollars)	13,711	15,122	18,472	23,824	38,217	2.6%
Energy-Use or Delivered Energy (quads)	69.46	72.4	75.5	79.9	91.4	0.7%
Electricity Consumption (Billion kWh)	3,617	3,809	4,083	4,472	5,307	1.0%
Energy-Related CO_2 Emissions ($MMTCO_2e$)	5,527	5,718	5,807	5,919	6,085	0.2%
Non-Energy GHG Emissions ($MMTCO_2e$)	1,034	1,100	1,218	1,173	1,206	0.4%
Total GHG Emissions ($MMTCO_2e$)	6,562	6,818	7,026	7,092	7,290	0.3%
Household Electricity Price (2007 $/kWh)	0.103	0.105	0.106	0.112	0.128	0.5%
Household Natural Gas Price (2007 $/MBtu)	10.65	11.22	11.69	13.15	16.92	1.2%
Total Household Energy Bill (Billion 2007 $)	220.84	225.68	241.36	275.61	361.30	1.2%
Total Economy-Wide Energy Bill (Billion 2007 $)	1,093.1	1,259.1	1,449.5	1,686.4	2,407.3	2.0%
Ecomomy-Wide Average Energy Price (2007 $/MBtu)	15.74	17.39	19.21	21.11	26.34	1.3%

The main reference case assumptions are shown in the table above for key benchmark years 2010 through 2050. In general the economy is expected to grow at a rate of about 2.6% annually; total end-use energy consumption will grow 0.7% per year while electricity use is expected to grow at about 1% per year. Rising energy prices (with all values in 2007 dollars) will increase total household energy expenditures at a rate of about 1.2% annually. Because of the expected growth in petroleum fuel (not shown here) and natural gas prices, the nation's total energy bill (across all sectors and all fuels) will grow about 2.0% per year — escalating from an estimated $1.1 trillion dollars in 2010 to about $2.4 trillion by 2050.

In this macroeconomic module of DEEPER, a set of spreadsheets contains the "production recipe" for the U.S. economy for a given "base year." For this study, the base year used was 2007. The input-output (or I-O) data, currently purchased from the Minnesota IMPLAN Group (IMPLAN 2009), is essentially a set of economic accounts that specifies how different sectors of the economy buy (purchase inputs) from and sell (deliver outputs) to each other. Further details on this set of linkages can be found in Hanson and Laitner (2009).

Although IMPLAN now has a 2009 set of accounts, there has been insufficient time to update DEEPER to a 2009 base year. However, a preliminary review suggests there is little additional benefit in updating to the later data set. For this study, the model was run to evaluate impacts of the selected policies upon 15 different sectors, including: Agriculture, Oil and Gas Extraction, Coal Mining, Other Mining, Electric Utilities, Natural Gas Distribution, Construction, Manufacturing, Wholesale Trade, Transportation and Other Public Utilities (including water and sewage), Retail

[10] When both equilibrium and dynamic input-output models use the same technology assumptions, both models should generate reasonably comparable set of outcomes. See Hanson and Laitner (2005) for a diagnostic assessment that reached that conclusion.

Trade, Services, Finance, Government, and Households.[11] As described below, examining the job intensities of the different sectors in Figure 3 in the main report provides early insights of likely scenario outcomes.

The principal energy-related sectors of the U.S. economy are not especially job-intensive. It turns out, for example, that the nation's utilities and energy sectors support only 7.4 direct and indirect jobs for every one million dollars of revenue received in the form of annual energy bill payments. The rest of the economy, on the other hand, supports between 13 and 21 direct and indirect jobs per million dollars of receipts (again, see Figure 3 in the main part of the report). *Thus, any productive investment in energy efficiency that pays for itself over a short period of time will generate a net energy bill savings that can be spent for the purchase of goods and services other than energy.* The impact of a one million dollar energy bill savings suggests there may be roughly a net gain of about 10 jobs (that is, 17 jobs supported by a more typical set of consumer purchases compared to the 7 total jobs supported by the electric and natural gas utilities). Depending on the sectoral interactions, however, this difference may widen or close as the changed pattern of spending works its way through the model, and as changes in labor productivity changes the number of jobs needed in each sector over a period of time.[12]

Based on the scenarios mapped into DEEPER, the set of worksheets in the Macroeconomic Module translates the selected energy policies into an annual array of physical energy impacts, investment flows, and energy expenditures over the desired period of analysis. DEEPER evaluates the policy-driven investment path for the various appliance efficiency standards, as well as the implied energy bill savings anticipated over the modeling time horizon (again, through 2030 for this analysis). It also evaluates the impacts of avoided or reduced investments and expenditures otherwise required by the electric generation sector. These quantities and expenditures feed directly into the final demand worksheet of the module. The final demand worksheet provides the detailed accounting that is needed to generate the implied net changes in sector spending.

Once the mix of positive and negative changes in spending and investments have been established, the net spending changes in each year of the model are converted into sector-specific changes in final demand. This then drives the input-output model according to the following predictive model:

$$X = (I-A)^{-1} * Y$$

where:

X = total industry output by sector
I = an identity matrix consisting of a series of 0's and 1's in a row and column format for each sector (with the 1's organized along the diagonal of the matrix)
A = the matrix of production coefficients for each row and column within the matrix (in effect, how each column buys products from other sectors and how each row sells products to all other sectors)
Y = final demand, which is a column of net changes in spending by each sector as that spending pattern is affected by the policy case assumptions (changes in energy prices, energy consumption, investments, etc.)

This set of relationships can also be interpreted as

$$\Delta X = (I-A)^{-1} * \Delta Y$$

[11] While there are only 14 sectors shown in the table above, household spending is allocated to each of the sectors using the personal consumption expenditure data provided with the IMPLAN data set.
[12] Note that unlike many policy models, DEEPER also captures sector trends in labor productivity. That means the number of jobs needed per million dollars of revenue will decline over time according to sector-specific trends published by BLS (2009). For example, if we assume a 1.9% labor productivity improvement over a 20-year period, one million dollars today might provide work for 17 people; by the year 2030, however, it might be more like 12 jobs.

which reads, a change in total sector output equals the expression $(I-A)^{-1}$ times a change in final demand for each sector.[13] Employment quantities are adjusted annually according to exogenous assumptions about labor productivity in each of the sectors within the DEEPER Modeling System (based on Bureau of Labor Statistics forecasts; see BLS 2009). From a more operational standpoint, the macroeconomic module of the DEEPER Model traces how each set of changes in spending will work or ripple its way through the U.S. economy in each year of the assessment period. The end result is a net change in jobs, income, and GDP (or value-added).

For each year of the analytical time horizon (i.e., 2010 to 2030 for the applicant standards evaluated in this report), the model copies each set of results into this module in a way that can also be exported to a separate report. For purposes of this separate report, and absent any anomalous outcomes in the intervening years, we highlight the decadal results in order to focus attention on the differences in results emerging from various alternative policy scenarios. For a review of how an I-O framework might be integrated into other kinds of modeling activities, see Hanson and Laitner (2009). While the DEEPER Model is not an equilibrium model, as explained previously in this appendix, we borrow some key concepts of mapping technology representation for DEEPER, and use the general scheme outlined in Hanson and Laitner (2009). Among other things, this includes an economic accounting to ensure resources are sufficiently available to meet the expected consumer and other final demands reflected in different policy scenarios.

[13] Perhaps one way to understand the notation $(I-A)^{-1}$ is to think of this as the positive or negative impact multiplier depending on whether the change in spending is positive or negative for a given sector within a given year.