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Energy efficiency standards for equipment: Additional opportunities in the residential and commercial sectors

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Abstract

Energy efficiency standards for residential and commercial equipment have been a major source of energy conservation in the US This study estimated key national impacts of potential new and upgraded energy efficiency standards. These impacts approximate the opportunity for national benefits that may be lost if energy efficiency standards for residential and commercial equipment are not upgraded and expanded from current levels. The results suggest that national benefits from new and upgraded standards may be substantial. They also indicate that standards for currently unregulated products may yield more benefits than upgrading minimum efficiency standards for products that already have them. The majority of those currently unregulated products are in the commercial sector.
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Keywords: Energy conservation; Efficiency standards; Residential and commercial sector

1. Introduction

Energy efficiency standards set minimum levels of energy efficiency that must be met by new products. Depending on the dynamics of the market and the level of the standard, the effect on the market for a given product may be small, moderate, or large.

In the US, energy efficiency standards for consumer products were first implemented in California in 1977. National standards became effective starting in 1988. By 2004, national standards were in effect for over a dozen residential appliances, as well as for a number of commercial sector products. Updated standards will take effect in the next few years for several products. Outside the US, over 30 countries have adopted minimum energy performance standards (Wiel and McMahon, 2001).

Technologies and markets are dynamic and additional opportunities to improve energy efficiency exist. There are two main avenues for extending energy efficiency standards. One is upgrading standards that already exist for specific products. The other is adopting standards for products that are not covered by existing standards.

In the absence of new and upgraded energy efficiency standards, it is likely that many new products will enter the stock with lower levels of energy efficiency than would otherwise be the case. Once in the stock, it is either impossible or more costly to improve the energy efficiency. Therefore, by not expanding or upgrading energy efficiency standards, opportunities for saving energy would be lost.

In the past two decades, standards have significantly raised the level of energy efficiency for new products (Meyers et al., 2005). How much more might be gained by making standards more stringent on products already subject to them, or by extending standards to products not yet covered?

The main goal of this study is to estimate key national impacts of new and upgraded energy efficiency standards for residential and commercial equipment. These impacts approximate the opportunity for national benefits that may be lost if standards are not upgraded

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and expanded from current levels. This study also identifies the end uses where the largest opportunities exist.

This article is based on a longer report (Rosenquist et al., 2004) prepared for the National Commission on Energy Policy (NCEP). It uses an analytical approach that is similar in concept to that used by the US Department of Energy (DOE) to evaluate and set standard levels. It relies on much less data and uses more simplified assumptions than the detailed and complex formulations used in DOE's standard-setting process. The results of this analysis should thus be viewed as a first approximation of the impacts that would actually be achieved by new standards.

Note: All monetary values in this report are in 2002 dollars.

2. Products considered

Within each of the key end uses, we considered equipment standards for specific products, as shown in Table 1. For some of the products listed, we determined that additional standards would not be cost-effective on a national-average basis. These products are mentioned later.

Products that we did not consider include those listed below. The reasons for not considering them were one or more of the following: (1) recent studies indicate that a more stringent standard is probably not cost-effective; (2) the impact of a new standard would probably be low because the market for the product is small and shrinking; and (3) lack of adequate data. We also did not consider plumbing fixtures that can reduce hot water consumption in the residential and commercial sectors.

Residential equipment not included: Freezer, clothes dryer, oil furnace, boiler, cooking equipment, television, computers and related equipment.

Commercial equipment not included: Electric heat pump, gas unit heater, gas cooking equipment, commercial clothes washer, distribution transformer, miscellaneous (such as service station equipment, automated teller machines, telecommunications equipment, medical equipment, pumps, and emergency electricity generators).

3. Technology cost-efficiency analysis

For each considered product, we estimated the incremental consumer cost of technologies providing higher energy efficiency relative to a specific baseline technology, as well as the associated reduction in annual energy use. We did not perform technology-specific engineering–economic analysis for this study, but instead used available recent studies. The main data sources are the technical analyses published by the DOE for its equipment standards rulemakings, and data from the analysis done by the Interlaboratory Working Group for the "Scenarios for a Clean Energy Future" study (Interlaboratory Working Group, 2000).

Box 1 provides an example of the key data inputs, sources and results for a product. In this and other cases, we selected the most common type of product to serve as a proxy for the product category. Appendix 1 in Rosenquist et al. (2004) provides a description of the cost and efficiency data and the assumptions for each of the several dozen considered products, as well as the sources of data used for each one. Most of the data-source reports were published in the late 1990s or the 2000–2003 period. The data vary among the products with respect to how recent they are. For most of the larger products, detailed engineering–economic analysis was performed in the cited studies. Many of the market projections were made for the present study by the authors.

Our estimates of technology costs in 2010 and 2020 assume that a decline occurs from current costs due to a

Table 1
End uses and products considered for efficiency standards

End use	Products considered
Residential	
Space heating	Gas furnace
	Heat pump
Air conditioning	Room air conditioner
	Central air conditioner and heat pump
Refrigeration	Refrigerator
Water heating	Electric and gas water heater
Clothes washing	Clothes washer
Dishwashing	Dishwasher
Lighting	Torchiere
Electric motors	Ceiling fan, pool pump, well pump, miscellaneous small motors
Household electronics	Audio, settop box, telephony, microwave oven, misc.
Commercial	
Space heating	Gas furnace and boiler
Air conditioning	Air-source and water-source air conditioner and heat pump
Ventilation	Air distribution
	Hot and chilled water circulation
	Cooling water circulation
	Heat rejection
Lighting	Fluorescent lamp
	HID lamp
Water heating	Gas-fired storage water heater
	Gas-fired instantaneous water heater
Refrigeration	Supermarket units
	Reach-in freezers and refrigerators
	Refrigerated vending machines
	Walk-in coolers and freezers
Office equipment	PCs and monitors
	Other equipment

Box 1
Example of technology cost-efficiency analysis

Sector: Residential
End use: Air conditioning
Product: Room air conditioner
Lifetime (years): 12.5

Baseline technology: 8000–13,999 Btu/h, with louvered sides, without reversing valve, 9.85 EER (Energy efficiency ratio)

	Technology for 2010 standard	Technology for 2020 standard
Description	10.11 EER	Same as 2010
Increase in consumer first cost[a] ($)	$8	$7
Annual energy savings[a] (kW h)	17	17
CCE (¢/kW h)	5.2	4.5
Decrease in LCC[a] ($)	$4	$5

Source: US Department of Energy (DOE)-Office of Codes and Standards. 1997. "Technical Support Document for Energy Conservation Standards for Room Air Conditioners, Volume 2—Detailed Analysis of Efficiency Levels "Washington, DC. September 1997.
[a]Relative to baseline technology with first cost of $482 in 2010, annual energy use of 657 kW h, and LCC in 2010 of $930.

"learning curve" effect. The central idea is that manufacturers develop efficiencies of production as the industry as a whole matures. Accordingly, an empirical learning curve typically uses cumulative production of the product in question as a measure of experience accumulated. The key impact of this learning is the reduction in per-unit production cost.

To estimate a "learning parameter" for this study, we relied on an empirical analysis that developed a product-characteristics model of energy-using consumer durables (Newell, 2000). One result of this analysis is estimates of a "learning parameter" for three appliances. Based on the results for the three appliances, we applied a decrease of 1.5% per year to the current estimates of incremental cost for each product. We also address how the results might change if no learning effect was incorporated.

Our analysis was limited by the existing literature. For some products, particularly in the home electronics end use, there is likely to be technological change that is not captured in our analysis, and a cost-effective standard level could be lower than what we estimated. Technological change also affects what may happen in the absence of new standards (the base case), as discussed in Section 6.

For each higher efficiency technology, we calculated cost-of-conserved-energy (CCE) values that spread the initial incremental cost over the lifetime of the equipment. The CCE in terms of dollars per kWh or GJ (gas) is an expression of the extra first cost incurred to save a unit of energy. Calculation of CCE requires application of a present worth factor (PWF) to spread the initial incremental cost over the lifetime of the equipment. The PWF uses a discount rate to effectively amortize costs over time.

We derived separate discount rates for consumer costs associated with residential and commercial sector standards. The average rate of 5.6% for residential standards is based on the opportunity cost for US households of an investment in energy efficiency in equipment in new homes and replacement equipment. The average rate of 6.1% for commercial standards is based on the weighted cost of capital for typical commercial sector enterprises. Appendix 3 in Rosenquist et al. provides a discussion of the derivation of these discount rates. The rates reflect adjustment for inflation and for tax impacts (such as deduction of mortgage interest).

4. Consumer impacts analysis

To estimate the impacts of new and upgraded standards on residential and commercial consumers, we used life cycle cost (LCC) analysis. The LCC for an appliance includes the initial capital cost and the operating costs over an assumed lifetime, with the operating costs discounted to a present value. Using the data from the technology cost-efficiency analysis, and the discount rates shown above, we calculated the LCC for each technology considered for each product.

For some considered products, technologies that are more energy-efficient than the baseline technology have a higher LCC than the baseline. For these products, we do not include a new or upgraded standard.

Ideally, a consumer impacts analysis should use marginal energy prices to calculate the reduction in energy costs associated with standards. Marginal energy prices are the prices consumers pay for the last unit of energy used in a given billing period. Since marginal prices reflect a change in a consumer's bill associated with a change in energy consumed, such prices are appropriate for determining energy cost savings associated with efficiency standards.

For commercial sector electric end uses, we estimated end-use-specific marginal electricity prices for air conditioning, lighting, and refrigeration. We made use of past analysis by DOE/LBNL on estimating marginal electricity prices for commercial unitary air conditioners in this study (US Department of Energy, 2004b). That analysis looked at actual commercial sector tariffs for utilities across the US to derive the marginal prices faced by consumers. As we did not have similar analysis for commercial sector natural gas prices, we used average prices.

Given the structure of residential tariffs, one would expect that the difference between marginal and average prices is less in the residential sector than in the commercial sector. Indeed, analysis done for DOE's rulemaking process (based on household survey data and analysis of bills) indicates that marginal prices are close to average prices for central air conditioners, water heaters, and furnaces. Therefore, we used average electricity and natural gas prices.

For residential end uses and commercial natural gas end uses, the life cycle energy costs utilize projections of average sectoral natural gas and electricity prices from the Energy Information Administration's (EIA) *Annual Energy Outlook 2004 (AEO 2004)* (US Department of Energy—Energy Information Administration, 2004). These projections go through 2025. We extrapolated the projected trends in 2015–2025 to estimate prices for later years. For commercial sector electric end uses, we applied the trend in the EIA projections to the estimated marginal prices in 2002.

We also consider changes in maintenance costs where the standards have a significant impact.

5. Selection of efficiency levels for new and upgraded standards

For each product, we selected the technology with the lowest LCC in 2010 and 2020 for the 2010 and 2020 standards. Table 2 illustrates the results for the case of residential refrigerators.

Table 2
LCC example—residential refrigerator[a]

Technology option (kW/h/yr)	LCC in 2010	LCC in 2020
484 (baseline)	$1046	$964
473	$1041	$958
444	$1030	$945
437 (2010 std)	$1029	$943
426	$1031	$943

[a]Top-mount freezer with auto-defrost.

Tables 3 and 4 show the technologies selected for 2010 and 2020 standard levels and their cost of conserved energy for the residential and commercial sectors, respectively. As mentioned above, new or upgraded standards were not cost-effective relative to the baseline technology for a few of the considered products; results for these are not shown in the tables.

For many products, an upgrade of the 2010 standard in 2020 is not cost-effective, so the 2020 standard is the same as the 2010 standard. Note that even if the standard is the same, the CCE is lower in 2020 due to the assumed decrease in equipment costs over time. Table 5 shows the relevant energy prices to which the CCEs may be compared.

Product standards that were considered but judged not cost-effective on a national-average basis are those for central air conditioners, electric heat pumps, gas water heaters, and clothes washers. In each case, new DOE standards either took effect in 2004 or will take effect in 2006–2007. Improvement beyond those standards is not cost-effective given the costs and energy prices currently envisioned.

As Figs. 1 and 2 illustrate, the CCE for the 2010 standards is well below the relevant energy price for most products. This result indicates that most of the standards would be cost-effective even if we did not assume that manufacturing costs decline over time due to a learning effect.

Our analysis considers the consumer perspective. Another perspective of interest is how the CCEs compare to the avoided costs of providing a unit of electricity and natural gas to consumers. In the short run, energy conservation mainly affects a utility's energy costs. In the long run, energy conservation may affect decisions about expanding generating and transmission and distribution capacity (Krause and Eto, 1988). The impact of energy efficiency standards on decisions about expanding generating and load distribution capacity varies across the US. On average, however, the impact of such standards is sufficiently large to have an impact on capacity expansion. This situation supports the use of long run avoided costs to measure the impacts of energy efficiency standards.

Determining the appropriate avoided costs at a national level for a future time period is not a simple exercise. One would expect the long run avoided costs of electricity and natural gas to be somewhat less than the retail prices we have used in this analysis. Given that the CCE for most of the considered standards is well below

Table 3
Technologies selected for new and upgraded standards—residential sector

End use/product	Baseline technology	Technology for 2010 standard	CCE for 2010 standard	Technology for 2020 standard	CCE for 2020 standard
Space heating					
Gas furnace	80% AFUE	81% AFUE using 2stage modulation	$6.20/GJ	Same as 2010	$5.40/GJ
Air conditioning					
Room air conditioner	9.85 EER	10.11 EER	5.2 ¢/kWh	Same as 2010	4.5 ¢/kWh
Refrigeration	484 kWh/yr	426 kW/h/yr	4.9 ¢/kWh	Same as 2010	4.2 ¢/kWh
Lighting					
Torchiere	Incandescent	Fluorescent	6.8 ¢/kWh	Same as 2010	5.9 ¢/kWh
Water heating					
Electric	92 EF	92 EF	n/a	Heat pump	3.9 ¢/kWh
Dishwashing[a]	2.14 kWh/cycle	1.96 kWh/cycle	4.2 ¢/kWh	Same as 2010	3.6 ¢/kWh
Motors					
Ceiling fans	Current practice	Higher efficiency	3.4 ¢/kWh	Same as 2010	2.9 ¢/kWh
Pool pumps	Single-speed	Two-speed	4.6 ¢/kWh	Same as 2010	4.0 ¢/kWh
Electronics					
Audio	Current practice	1 W standby	1.2 ¢/kWh	Same as 2010	1.0 ¢/kWh
Settop box	Current practice	7 W standby	0.3 ¢/kWh	Same as 2010	0.2 ¢/kWh
Telephony	Current practice	1 W standby	4.0 ¢/kWh	Same as 2010	3.5 ¢/kWh
Microwave oven	Current practice	1 W standby	0.3 ¢/kWh	Same as 2010	0.2 ¢/kWh
Misc. electronics	Current practice	1 W standby	1.5 ¢/kwh	Same as 2010	1.3 ¢/kwh

Sources: Space heating—US Department of Energy (2002); Air conditioning—US Department of Energy (1997); Refrigeration—US Department of Energy (1995); Water heating—US Department of Energy (2001); Dishwashing—Biermayer (1996); Lighting—unpublished 2003 analysis by Lawrence Berkeley Lab; Motors—US Department of Energy (2004a) and Pacific Gas and Electric Company (2004); Electronics—Rosen and Meier (2001), Rosen (2001) and Sanchez (1998).

[a]The values include the energy savings from reduced water heating associated with a higher-efficiency dishwasher.

the forecast retail price, however, it is likely that most of the standards would be cost-effective compared to the long run avoided cost.

6. Estimation of national impacts

The base case (business-as-usual) provides a reference against which we measure the potential impacts of upgraded standards. Our base case uses the reference energy consumption projections in *AEO 2004* through 2025 and extrapolated values thereafter. It includes all standards that have already been promulgated by DOE as of 2004. The base case includes standards with effective dates in the future, such as the revised standard for clothes washers that will take effect in 2007. It does not include standards that are still under consideration by DOE. It implicitly assumes that new buildings meet recent state building codes. As a result of these and other factors, the base case shows ongoing efficiency improvement in each end use.

The Upgraded Standards Case assumes upgraded and new standards take effect in 2010, and more stringent standards take effect in 2020 if they are cost effective. The standards affect products installed from the effective date through 2030. We consider the impacts of standards over the lifetime of all products installed in the 2010–2030 period.

To estimate impacts of upgraded standards for each product, we first estimate the fraction of current energy consumption in each end use that is accounted for by the considered product. We assume this fraction remains constant over time. Ideally, one would model potential change in the share. Such analysis was not possible for this study. We then use a stock model to estimate what share of the stock of each product in each future year consists of units installed after the standard effective date. Such products include replacements for retired products as well as products installed in new buildings. The stock model makes use of the estimated current stock, the mean lifetime of each product, a retirement function, and projected installations due to new construction of residential and commercial buildings. Projections of new construction are based on *AEO 2004*.

Appliances installed after the standard effective date are those products potentially affected by standards. For the residential sector, we had data that allowed estimation of the share of the products in the base case that are more efficient than the upgraded standard, and thus would not be impacted by new or upgraded

Table 4
Technologies selected for new and upgraded standards—commercial sector

End use/product	Baseline technology	Technology for 2010 standard	CCE for 2010 standard	Technology for 2020 standard	CCE for 2020 standard
Space Heating	Thermal Effc'y	Thermal Effc'y	$/GJ	Thermal Effc'y	$/GJ
Packaged boilers, gas-fired, HW (400 kBtu/h)	75%	79%	1.00	Same as 2010	0.90
Packaged boilers, gas-fired, HW (800 kBtu/h)	75%	78%	3.30	88%	5.00
Packaged boilers, gas-fired, HW (1500 kBtu/h)	75%	88%	2.70	Same as 2010	2.30
Packaged boilers, gas-fired, HW (3000 kBtu/h)	75%	88%	1.60	Same as 2010	1.40
Packaged boilers, gas-fired, steam (400 kBtu/h)	72%	76%	3.30	Same as 2010	2.80
Packaged boilers, gas-fired, steam (800 kBtu/h)	72%	76%	2.90	Same as 2010	2.50
Packaged boilers, gas-fired, steam (1500 kBtu/h)	72%	79%	3.30	Same as 2010	2.80
Packaged boilers, gas-fired, steam (3000 kBtu/h)	72%	80%	1.90	Same as 2010	1.70
Warm-air furnaces, gas-fired (250 kBtu/h)	78%	80%	6.50	Same as 2010	5.60
Warm-air furnaces, gas-fired (400 kBtu/h)	78%	80%	5.10	Same as 2010	4.40
Air conditioning	EER	EER	¢/kWh	EER	¢/kWh
3-Phase, single-package, air-source AC (<65 kBtu/h)	9.7	12	4.2	Same as 2010	3.6
3-Phase, split-system, air-source AC (<65 kBtu/h)	10	12	6	Same as 2010	5.2
3-Phase, single-package, air-source HP (<65 kBtu/h)	9.7	12	4.6	Same as 2010	3.9
3-Phase, split-system, air-source HP (<65 kBtu/h)	10	13	5.2	Same as 2010	4.5
Central, air-source AC and HP (>65 kBtu/h and <135 kBtu/h)	10.1	11.5	3.2	12	4.5
Central, water-source HP (>65 kBtu/h and <135 kBtu/h)	12	12.5	7.2	13	7.4
Central, water-cooled AC (>65 kBtu/h and <135 kBtu/h)	11.5	12.4	5.9	14	6.9
Central air-source AC & HP (>135 kBtu/h and <240 kBtu/h)	9.5	11.5	2.7	12	3.6
Central, water-cooled AC (>135 kBtu/h and <240 kBtu/h)	11	11.5	2.9	Same as 2010	2.5
Central, water-cooled AC (<65 kBtu/h)	12.1	12.1	0	12.5	7.5
Central, water-source HP (<17 kBtu/h)	11.2	11.2	0	12.5	7.8
Central, water-source HP (>17 kBtu/h and <65 kBtu/h)	12	13.1	7.1	Same as 2010	6.1
Packaged terminal air conditioners (PTACs) (<7 kBtu/h)	9.4	11	5.8	Same as 2010	5.0
Packaged terminal air conditioners (PTACs) (7–10 kBtu/h)	9	10.8	3.8	Same as 2010	3.3
Packaged terminal air conditioners (PTACs) (10–13 kBtu/h)	8.3	10.5	4.1	Same as 2010	3.6
Packaged terminal air conditioners (PTACs) (>13 kBtu/h)	7.9	10	1.9	Same as 2010	1.7
Packaged terminal heat pumps (PTHPs) (<7 kBtu/h)	9.3	10.8	5.8	Same as 2010	5.0
Packaged Terminal heat pumps (PTHPs) (7–10 kBtu/h)	8.9	10.6	3.4	11.4	4.5
Packaged terminal heat pumps (PTHPs) (10–13 kBtu/h)	8.2	9.7	2.8	Same as 2010	2.4
Packaged terminal heat pumps (PTHPs) (>13 kBtu/h)	7.8	10	4.7	Same as 2010	4.0
Ventilation	Efficiency	Efficiency	¢/kWh	Efficiency	¢/kWh
Air distribution					
Large unitary (10 HP)	85%	92%	0.5	Same as 2010	0.4
Exhaust fan (0.5 HP)	60%	80%	0.2	Same as 2010	0.2
Room fan coil (0.17 HP)	50%	75%	0.9	Same as 2010	0.7
Central station air handling unit (10 HP)	87%	93%	0.6	Same as 2010	0.5

Hydronic Hot and chilled water circulation					
Centrifugal chiller (25 HP)	90%	95%	0.5	Same as 2010	0.5
Screw chiller (10 HP)	90%	94%	1.4	Same as 2010	1.2
Reciprocating chiller (10 HP)	88%	93%	1.5	Same as 2010	1.3
Absorption chiller (25 HP)	90%	95%	0.5	Same as 2010	0.4
Hydronic heating (10 HP)	90%	94%	0.8	Same as 2010	0.7
Cooling water circulation					
Centrifugal chiller (25 HP)	90%	95%	0.5	Same as 2010	0.4
Screw chiller (10 HP)	90%	94%	1.0	Same as 2010	0.9
Reciprocating chiller (10 HP)	88%	93%	1.9	Same as 2010	1.6
Lithium bromide water absorption chiller (25 HP)	90%	95%	0.5	Same as 2010	0.4
Heat rejection					
Large unitary (5 HP)	85%	90%	1.4	Same as 2010	1.2
Air cooled screw and reciprocating chillers (2 HP)	85%	92%	0.1	Same as 2010	0.1
Cooling tower (10 HP)	85%	92%	1.4	Same as 2010	1.2
Water heating	Thermal Effc'y	Thermal Effc'y	$/GJ	Thermal Effc'y	$/GJ
Storage water heater, gas-fired (120 kBtu/h)	80%	82%	4.00	Same as 2010	3.50
Storage water heater, gas-fired (199 kBtu/h)	80%	82%	4.10	Same as 2010	3.50
Storage water heater, gas-fired (360 kBtu/h)	80%	82%	4.30	Same as 2010	3.70
Instantaneous water heater, gas-fired (1000 kBtu/h)	80%	83%	4.80	Same as 2010	4.10
Instantaneous tank water heater, gas-fired (500 kBtu/h)	80%	82%	4.30	Same as 2010	3.70
Lighting[a]	Technology	Technology	¢/kWh	Technology	¢/kWh
Fluorescent Lamp/ballast	Current Practice	Hi-perf T8 w/elec and hi-perf ballast	1.9	Hi-perf T8 w/ hi-perf ballast	1.1
HID—Lo Bay	MV 20%, MH 55%, HPS 25%	PMH 75% & HPS 25%	3.0	PMH/SSB 75% & HPS 25%	2.9
HID—Hi Bay	MV 20%, MH 55%, HPS 25%	PMH 75% & HPS 25%	1.0	PMH/SSB 75% & HPS 25%	1.0
Refrigeration	Technology	Effc'y Improvement	¢/kWh	Effc'y Improvement	¢/kWh
Supermarket units	Current technology	16%	1.2	same as 2010	1.1
Beverage merchandiser units	Current technology	61%	2.1	same as 2010	1.8
Reach-in freezers	Current technology	52%	2.5	same as 2010	2.3
Reach-in refrigerators	Current technology	38%	1.9	same as 2010	1.6
Ice machines	Current technology	23%	2.8	same as 2010	2.4
Refrigerated vending machines	Current technology	51%	2.9	same as 2010	2.5
Walk-in coolers	Current technology	46%	1.2	same as 2010	1.0
Walk-in freezers	Current technology	48%	3.0	same as 2010	2.6
Office equipment					
Personal computers & monitors	Current technology	Low standby	1.0	Not applicable	0.1
Other	Current technology	Low standby	1.0	Not applicable	0.2

Sources: Space heating—US Department of Energy (2000); Air conditioning—US Department of Energy (2000) and US Department of Energy (2004a); Ventilation—Arthur D. Little (1999); Water heating—US Department of Energy (2000); Lighting—unpublished 2003–04 analysis by Lawrence Berkeley Lab; Refrigeration—Arthur D. Little (1996); Office equipment—unpublished 2003 analysis by Lawrence Berkeley Lab.

[a]MV = mercury vapor; MH = metal halide; HPS = high-pressure sodium; PMH = pulse metal halide; SSB = solid-state ballast.

Table 5
Energy prices for CCE comparison

	Residential sector	Commercial sector
Electricity (¢/kW/h)		
Price in 2010–20 period	8.5–9.0	7.0–7.2[a]
Price in 2020–30 period	8.8–9.0	7.2–7.4[a]
Natural gas ($/GJ)		
Price in 2010–20 period	7.7–8.3	6.7–7.3
Price in 2020–30 period	8.3–8.5	7.3–7.5

[a]These are average prices. Prices are 8.5–9.0 ¢/kW/h for air conditioning, 6.5–6.9 ¢/kW/h for lighting and ventilation, and 5.8–6.1 ¢/kW/h for refrigeration.

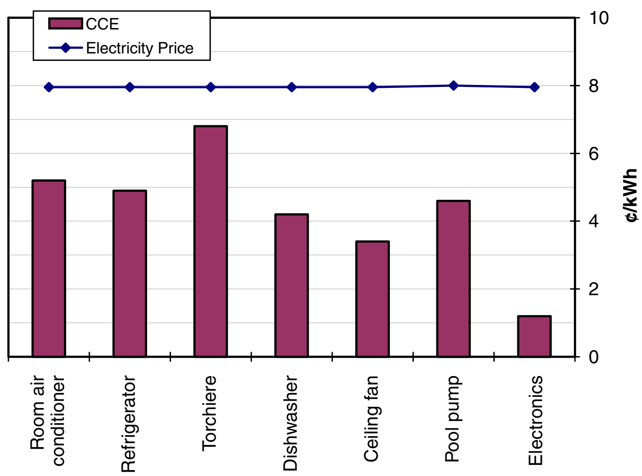

Fig. 1. Comparison of cost of conserved energy for 2010 standards to projected electricity price in the residential sector.

standards. We estimated these shares based on market statistics for high-efficiency products with an "energy star" designation. As similar data were not available for the commercial sector products, we assumed that all of the products installed after the standard effective date would potentially be affected by standards. In the base case, we assume that the eligible products utilize the baseline technology considered in the technology cost-efficiency analysis. Since some commercial sector products installed after 2010 are likely to have a higher efficiency than the baseline technology even without standards, our method leads to some over-estimation of energy savings from standards.

In the upgraded standards case, we apply the percentage reduction in average annual energy consumption associated with the standard (relative to the baseline technology) to the share of base case energy consumption that is accounted for by products installed after the standard effective date. The result is the aggregate energy savings attributable to the standard.

For example, the 2010 standard for refrigerators results in 10% reduction in the average annual energy consumption compared to the baseline technology. We estimated that 25% of the total new units purchased after 2010 would be at least as efficient as the upgraded 2010 standard. Thus, 75% of the total new units purchased after 2010 would be affected by the standard. We assume that these units are the baseline technology. We calculate total annual energy savings by multiplying: (1) the 10% reduction in average annual energy consumption by (2) the average annual energy consumption of the baseline technology by (3) the number of eligible products installed in each year.

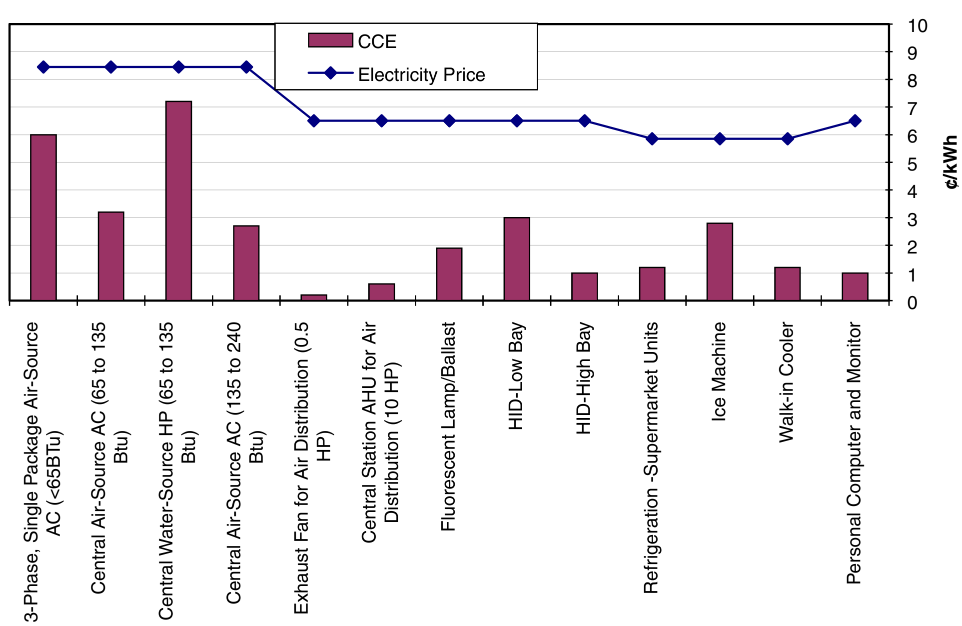

Fig. 2. Comparison of cost of conserved energy for representative 2010 standards to marginal electricity price in the commercial sector.

Appendix 4 in Rosenquist et al. provides further discussion of the accounting framework used to estimate national-level impacts. The approach used is obviously a simplification of a complex reality, and many of the assumptions are subject to uncertainty.

We express the annual electricity and natural gas savings from upgraded standards in total primary energy using annual primary-to-site energy factors based on *AEO 2004*. These projections go through 2025. We extrapolated the past trends to estimate values for later years.

7. Value of energy savings

One way to measure the value of the energy savings due to standards is to consider the costs avoided by energy suppliers. In the short run, energy conservation mainly affects a utility's energy costs (though there may also be short-run avoided capacity costs). In the long run, energy conservation may affect decisions about expanding generating and transmission and distribution capacity.

The view that the long run avoided utility cost is the appropriate measure for energy efficiency was actively discussed in the context of utility energy conservation programs and various approaches for estimating it were debated for many years. *Least-Cost Utility Planning,* a handbook for public utility commissioners published by the National association of Regulatory Utility Commissioners, discusses several methods for measuring long run avoided costs of conservation programs (Krause and Eto, 1988).

The impact of energy efficiency standards on decisions about expanding generating and load distribution capacity varies across the US. On average, however, the impact of such standards is sufficiently large to have an impact on capacity expansion, which suggests that long run avoided utility costs are a more appropriate measure of the avoided cost associated with energy efficiency standards. Estimating such costs on a national level is difficult, however. For this report, we calculated the value of the energy savings from new and upgraded standards by using the same energy prices as in the consumer impacts analysis. This value reflects the consumer perspective.

We calculated the net present value (NPV) to consumers as the difference between the national operating cost savings due to the equipment standards and the increased national equipment costs associated with the standards. We expressed future costs and benefits in present (2004) value terms by using alternative national-level discount rates.

The 7% discount rate is based on guidance issued by the Office of Management and Budget (OMB), which states: "In general, public investments and regulations displace both private investment and consumption. … Constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7%. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years" (Office of Management and Budget, 1992). OMB's guidance reflects the view that—from a national perspective—the opportunity cost of capital invested to improve appliance efficiency is best approximated by using the return on an average investment in the private sector. In DOE's analyses of the national economic impacts of equipment energy efficiency standards, it relies on the OMB guidance.

The OMB guidance notes that regulations may displace both private investment and consumption. Most estimates of the rate of return on consumption are in the order of 3% or 4% (Arrow, 2000). In 2003 the OMB advised Federal agencies to use a 3% discount rate to express the "social rate of time preference" when regulation primarily affects private consumption (e.g., through higher consumer prices for goods) (Office of Management and Budget, 2003). Thus, we also apply a "consumption discount rate" of 3%.

8. Results

Figs. 3 and 4 show the cumulative primary energy savings and cumulative net present value due to new and upgraded efficiency standards by end use for the residential and commercial sectors. The values reflect the lifetime impacts from products installed in the 2010–2030 period. The largest energy savings are associated with standards for residential electronic products, but the estimate for this group of products is subject to a high degree of uncertainty. The next largest savings in the residential sector come from standards for electric water heaters and torchieres. Apart from electronics, the greatest savings come from standards for commercial refrigeration, followed by lighting and air conditioning.

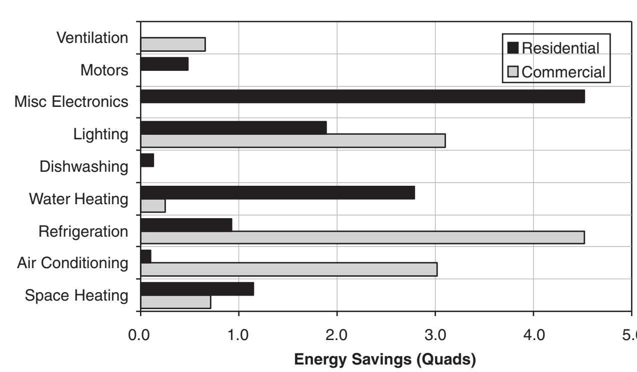

Fig. 3. Cumulative primary energy savings from upgraded standards for products installed in 2010–2030 period.

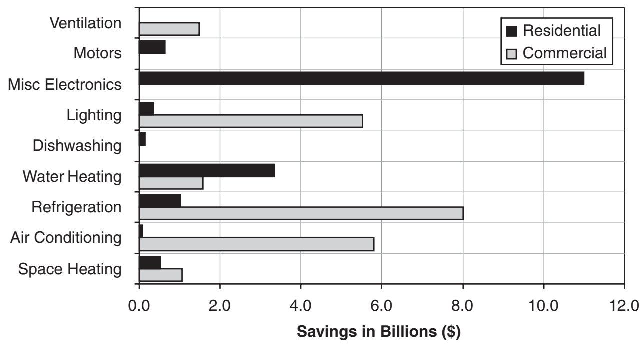

Fig. 4. Net present value of consumer benefit from upgraded standards for products installed in 2010–2030 period (7% discount rate).

Table 6
Residential sector energy savings and consumer benefit for products installed in the 2010–2030 period

End use/ product	Cumulative primary energy savings (EJ)	NPV of consumer benefit (billion $)	
		7% discount rate	3% discount rate
Space heating			
Gas furnace	1.1	0.5	3.1
Air conditioning			
Room air conditioner	0.10	0.08	0.30
Refrigeration			
Refrigerator	0.92	1.0	3.6
Lighting			
Torchiere	1.9	0.36	1.5
Water heating			
Electric	2.8	3.3	11.8
Dishwashing[a]	0.13	0.13	0.35
Motors	0.48	0.62	1.5
Electronics	4.5	11.0	22.9
Total	12.0	17.0	45.1

[a]Includes water heating savings derived from the higher-efficiency dishwasher, which uses less hot water.

The largest net present value comes from residential electronic products, but the caveat mentioned above applies here. Apart from residential electronics products, standards in the commercial sector yield more NPV than do those in the residential sector.

In tabular form, Tables 6 and 7 show the cumulative primary energy savings and cumulative net present value due to new and upgraded equipment standards by end use for the residential and commercial sectors, respectively. The total cumulative energy savings amount to just under 26 exajoules (EJ).[1] The total NPV is $42 billion using a 7% discount rate, but $104 billion using 3%. The commercial sector products accounts for a greater share of the total energy savings and NPV than the residential sector ones.

[1]One EJ is approximately equal to one quadrillion Btu.

Table 7
Commercial sector energy savings and consumer benefit for products installed in the 2010–2030 period

End use/ products	Cumulative primary energy savings (EJ)	NPV of consumer benefit (billion $)	
		7% discount rate	3% discount rate
Space heating			
Various	0.71	1.1	2.7
Air conditioning			
Various	3.0	5.8	14.0
Ventilation			
Various	0.66	1.5	3.2
Water heating			
Various	0.25	1.6	3.2
Lighting			
Various	3.1	5.5	12.8
Refrigeration			
Various	4.5	8.0	16.6
Office equipment	1.6	3.7	6.0
Total	13.8	27.2	58.6

9. Conclusion

This study estimated key national impacts of potential upgrades in energy efficiency standards for residential and commercial equipment. These impacts approximate the opportunity for national benefits that may be lost if energy efficiency standards for residential and commercial equipment are not upgraded and expanded from current levels.

The study used an analytical approach that is similar to the one used by the US Department of Energy to evaluate and set standard levels. Since it relies on much less data and uses simplified assumptions rather than the detailed formulations used in DOE's standard-setting process, the results of this analysis should be viewed as a first approximation of the impacts that would actually be achieved by new standards.

Our estimate of total cumulative energy savings from new and upgraded standards that would be effective in 2010–2030 amounts to just under 26 EJ. This amount is equal to approximately 4% of the cumulative energy consumption in the base case. The annual savings amount to around 1 EJ in 2015 and 2 EJ in 2025. These figures compare to total projected residential and commercial primary energy consumption of 46 EJ in 2015 and 52 EJ in 2025 (according to *AEO 2004*).

The largest energy savings are associated with standards for residential electronics products, but this estimate is subject to a high degree of uncertainty. Apart from electronics, the greatest savings come from standards for commercial refrigeration, followed by lighting and air conditioning. The next largest savings in the residential sector come from standards for electric water heaters and torchieres.

The total NPV is $42 billion using a 7% discount rate, but $104 billion using 3%. The largest net present value comes from residential electronics products, but the caveat mentioned above applies here. Apart from residential electronics products, standards in the commercial sector yield more economic benefit than do those in the residential sector.

In assessing the results, the limitations of this study should be borne in mind. As mentioned in the introduction, this study relied on much less data and more simplified assumptions than does DOE's standard-setting process. Despite this caveat, our results suggest that national benefits from new and upgraded standards may be substantial. They also indicate that standards for currently unregulated products may yield more benefits than upgrading minimum efficiency standards for products that already have them. The majority of those currently unregulated products are in the commercial sector.

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