Appliance Standards: Comparing Predicted and Observed Prices

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Executive Summary

INTRODUCTION

The federal government first established energy efficiency standards for appliances and other equipment with the passage of the National Appliance Energy Conservation Act of 1987. This law established initial federal standards for a dozen products and directed the U.S. Department of Energy (DOE) to update these standards, establishing new standards at the "maximum level of energy efficiency…which is technologically feasible and economically justified." Subsequent federal laws enacted in 1988, 1992, 2005, and 2007 expanded the number of products covered. DOE has now conducted more than two dozen rulemakings to update standards and, in a few cases, establish initial standards.

When DOE conducts a rulemaking to create or update a product standard, the agency prepares a variety of analyses to guide decisions in accordance with directions in the law. DOE generally selects levels for which the value of the estimated energy savings more than outweighs the estimated impact on product prices. Therefore, the agency's product price estimate has a critical effect on standards selected.

In 1996, researchers at Lawrence Berkeley National Laboratory (LBNL) conducted an analysis looking at refrigerator prices after minimum efficiency standards for refrigerators took effect in 1990 and 1993. They found that "[f]ollowing the introduction of performance standards, real prices for refrigerators did not increase, and in some cases decreased" (Greening et al. 1996).

A few years later, LBNL conducted additional analysis on the actual cost of products after standards took effect, looking at price forecasts made by DOE for refrigerators, room air conditioners, clothes washers, and central air conditioners over the 1982–1995 period (Dale et al. 2002, 2009). This study concluded: "Past retail price predictions made by DOE analyses of efficiency standards, which assume constant prices over time, have tended to overestimate retail prices." The findings from the LBNL research led DOE to make several improvements to their product price estimate techniques.

This report seeks to fill a gap in the evaluation of historical DOE price estimates. Dale et al. (2002, 2009) assessed price estimates made during 1982–1995, a period ending nearly two decades ago. This report looks at price estimates made during 1996–2004 and compares those estimates to actual prices observed after those standards became effective between 2000 and 2010. For this report, we looked at nine major product standards including standards for refrigerators, clothes washers, water heaters, air conditioners, and fluorescent lamp ballasts.

METHODOLOGY

Our basic methodology was to compare DOE's estimate of the incremental increase in manufacturer selling price due to a standard with the actual change in average manufacturers' selling price. We isolated when efficiency improvements were incorporated into new products by examining efficiency time series data. All of our actual price data came from the Current Industrial Reports series published by the U.S. Census Bureau. During the standards development process, DOE generally estimates price increases at both the manufacturer and consumer levels. We obtained DOE's price

estimates from published Final Rules or Technical Support Documents issued in conjunction with Final Rules. These are estimates made before a standard takes effect and not actual selling prices. For looking at price impacts using the Census Bureau data, we looked at changes in manufacturer price over the two-year period when the required efficiency improvement was incorporated into new products.

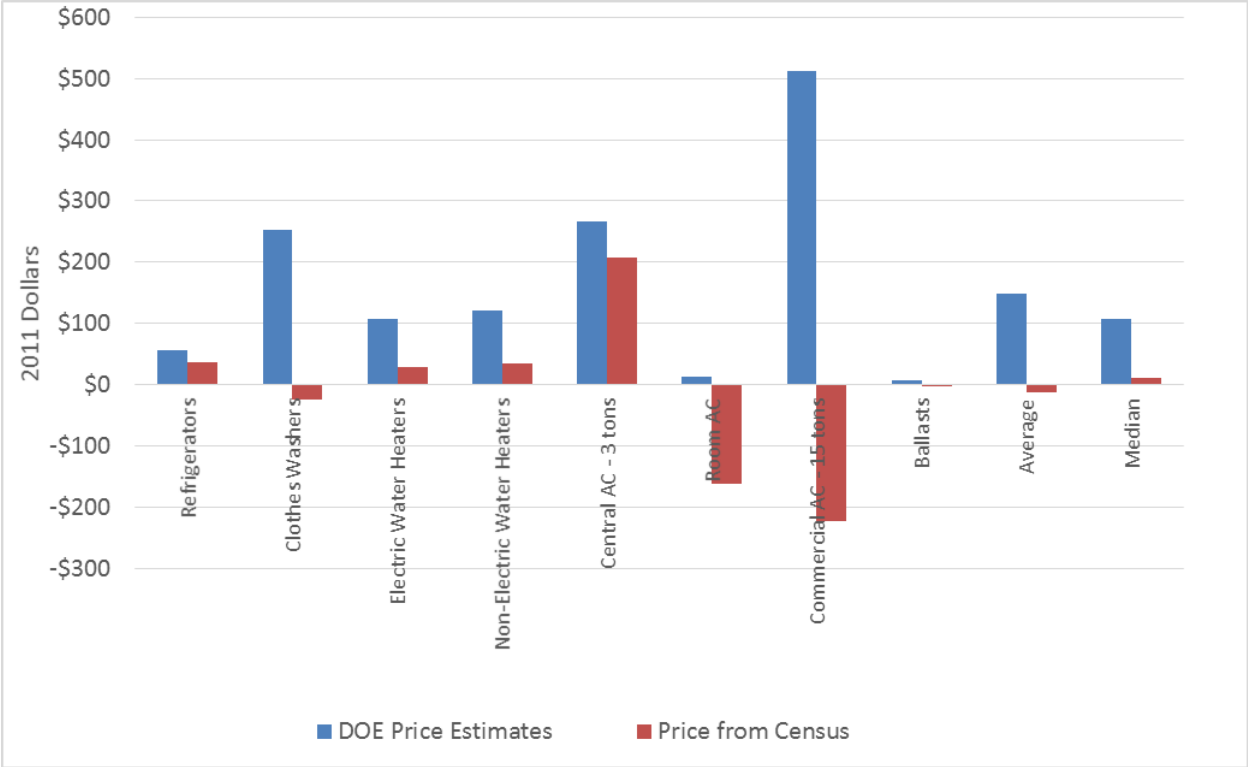
RESULTS

Our results by product are summarized in Table ES-1 and Figure ES-1. For all products we found that the actual price increase was less than the predicted price increase, with the difference often substantial. On average, DOE predicted a manufacturer selling price increase (in 2011 $) of $148 for these products. The actual average across the nine cases was a *decrease* of $12. Looking at medians instead of averages, DOE predicted a median price increase of $108, while the actual increase was $10. In four out of the nine cases examined, manufacturer selling price actually declined over the period analyzed. If we ignore room air conditioners, which declined dramatically in cost, on average, the actual manufacturer selling prices averaged only 9% of DOE's estimates. On a median basis, actual selling prices were 5% of DOE's estimates. In other words, DOE on average overestimated manufacturer selling price increases by about a factor of ten.

Table ES-1. Comparison of Predicted Manufacturer Price Increase for Standards with Actual Price Increase

Product	Standard Effective Date	DOE Estimate of Incremental Price of Standard (Nominal $)	Primary Case (Custom 2-Year Period)					
			Before	After	DOE Estimate (2011$)	Cost from Census (2011$)	Difference (2011$)	Actual as % of Predicted
Refrigerators	7/1/2001	32	2000	2002	56	37	-18	67%
Clothes Washers	1/1/2004	34	2002	2004	54	-35	-89	-66%
Clothes Washers	1/1/2007	126	2006	2008	199	10	-188	5%
Electric Water Heaters	1/20/2004	67	2003	2005	108	28	-80	26%
Non-Electric Water Heaters	1/20/2004	75	2003	2005	121	34	-88	28%
Central AC — 3 tons	1/23/2006	167	2005	2007	267	207	-59	78%
Room AC	10/1/2000	7.50	1998	2000	13	-162	-175	-1246%
Commercial AC — 15 tons	1/1/2010	334	2009	2010	512	-224	-736	-44%
Ballasts	1/1/2005	4.27		2006	6.73	-1.74	8.47	-26%
Average					148	-12	-158	9%
Median					108	10	-88	5%

Figure ES-1. Comparison of Predicted Manufacturer Price Increase for Standards with Actual Price Increase



Note: For clothes washers, this figure shows the sum of the two standards.

The discussion above considers *change* in price. However, the different products we looked at vary widely in their base price, ranging from under $10 for ballasts to several thousand dollars for large commercial air conditioners. It is also useful to compare the DOE and Census price estimates when each are presented as a percentage price increase relative to the base price. On average, DOE estimated that the new standards would increase product prices by 35%. According to the Census data, on average there was no price increase. On a median basis, DOE estimated a price increase of 38% and the actual increase was 4%.

We also conducted two alternative analyses that looked at actual price changes over different periods of time. In both cases the average and median actual price change was a fraction of the price increase DOE had estimated. In addition we examined the impacts of DOE's new learning factors on the analysis and found that while they improve the accuracy of the DOE price estimates some, the majority of DOE's overestimation of prices remain.

The full report includes a discussion of our results and possible contributing factors on a product-by-product basis.

DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

We find that the actual cost of standards was always lower than DOE estimated for the nine product standards we examined. Since DOE only sets standards that result in net economic benefits to consumers, to the extent DOE overestimates product prices it means that DOE is underestimating net consumer benefits.

Our finding that DOE has overestimated the impact of standards on product prices raises the question of why this is the case. Further product-specific investigations and analysis will be needed to find causes, but one hypothesis is that as manufacturers redesign products to meet standards, they discover new, lower cost ways to meet the standard than DOE examined. Also, as discussed in the full report, when manufacturers redesign products and production lines, they can find unexpected ways to reduce costs. In other words, in competitive markets, manufacturers have an incentive to do better than DOE estimated in order to gain a competitive advantage. Other manufacturers generally track innovations by their competitors and it is common for such innovations to spread quickly among manufacturers. Modeling innovation is very difficult, but ignoring innovation tends to lead to overestimating prices.

DOE has continued to refine its methodology for estimating product prices since the standards examined in this report were developed. However, given the long-term track record of over-estimation, DOE should conduct an in-depth retrospective analysis to uncover the sources of error in the incremental cost analyses conducted for the standards evaluated for this report. Such an in-depth effort is beyond the scope of this report but could build on prior work by Dale et al. (2002, 2009) that attempted to disaggregate some of the effects. In addition, DOE should conduct ongoing retrospective analyses as new standards take effect to determine if more recent analyses have more accurately predicted price increases. These retrospective analyses will allow DOE to further improve price estimation techniques, such as by considering ways to better incorporate innovation into its price estimates.

In parallel with such analyses, we recommend that DOE conduct sensitivity cases for future standards rulemakings that assume that actual costs are 25% and 50% of DOE's calculated estimates. Sensitivity cases allow DOE to consider the impact of different assumptions on their results and are particularly useful when there is large uncertainty around a specific assumption. DOE conducts a variety of sensitivity analyses, including some using more conservative assumptions than its primary analysis. Adding some sensitivity analyses based on adjusted price forecasts would provide a range of values for decision-makers to weigh. For example, presently DOE conducts analyses at 3% and 7% discount rates and considers both of them. Addition of sensitivity cases for incremental cost are likely to have at least as much impact on the analysis as discount rate. Consideration of price sensitivity analyses will help better align the calculations with the experience to date. Such adjustments will result in analyses and standards that better reflect real-world markets when standards are revised.

Introduction

The federal government first established energy efficiency standards for appliances and other equipment with the passage of the National Appliance Energy Conservation Act of 1987. This law established initial federal standards for a dozen products and directed the U.S. Department of Energy (DOE) to update these standards, establishing new standards at the "maximum level of energy efficiency…which is technologically feasible and economically justified." The national law built on nearly a decade of experience with state-level efficiency standards. Subsequent federal laws enacted in 1988, 1992, 2005, and 2007 expanded the number of products covered. DOE has now conducted more than two dozen rulemakings to update standards and, in a few cases, establish initial standards.

When DOE conducts a rulemaking to create or update a product standard, the agency prepares a variety of analyses to guide decisions in accordance with directions in the law. These analyses identify different prospective standard levels and assess the likely energy savings and costs of each of these levels. DOE balances a variety of factors in selecting a final standard level. Consumer life-cycle cost, including initial purchase price, installation, maintenance, and operating costs over the life of the product, plays a critical role. Other factors can also be important, particularly impact on manufacturers, effect on competition, and any lessening of consumer utility. Product energy (and sometimes water) use and energy prices determine most of operating costs. DOE generally uses Energy Information Administration (EIA) energy price forecasts. Product life time energy savings are generally modeled and attempt to incorporate field performance. DOE generally selects levels for which the value of the estimated energy savings more than outweighs the estimated impact on product prices. Therefore, the agency's product price estimate has a critical effect on standards selected.

In recent rulemakings, DOE has typically relied on one or more of the following approaches for estimating the cost to improve efficiency: (1) the design option approach, which estimates the incremental cost of adding specific design options to a baseline mode; (2) the efficiency level approach, which estimates the cost of achieving specific efficiency levels without regard to the design options employed; and (3) the reverse engineering approach, which develops a "bottom up" cost estimate based on a bill of materials derived from product teardowns. There are benefits and drawbacks to each of these three approaches. The design option approach has the advantage of allowing for the incorporation of technologies that have only been demonstrated in prototypes and can be used to estimate the cost of efficiency levels beyond the maximum efficiency level of current products. However, the design option approach may not reflect actual manufactured products, and it can be difficult to assess the impact of a combination of design options on overall efficiency. The efficiency level approach has the advantage of simplicity. However, the cost estimates developed for the efficiency level approach typically are based on manufacturer data or retail prices, both of which may not be representative of the actual cost to achieve each efficiency level. For example, a manufacturer opposed to higher standards may have an incentive to submit high costs estimates. Likewise, for situations where high-efficiency but niche products of today may become the mass market products of the future, current prices will not be representative of high-volume, mass-market versions. Finally, the reverse engineering approach has the advantage of using actual manufactured products to determine the components utilized to reach different efficiency levels. However, the reverse engineering approach cannot capture design options that are not employed in

current products and in some cases it may be difficult to isolate components utilized to improve efficiency from components utilized to provide other product features.

In part because each approach for estimating costs includes drawbacks, DOE often uses a combination of these approaches. For example, DOE may first identify specific efficiency levels to analyze, and then utilize a combination of reverse engineering and an examination of prototypes to determine the design options that can be employed to reach each efficiency level. The output of DOE's costs estimates is typically a list of specific design options to reach different efficiency levels along with their associated costs.

In 1996, researchers at Lawrence Berkeley National Laboratory (LBNL) conducted an analysis looking at refrigerator prices after minimum efficiency standards for refrigerators took effect in 1990 and 1993. They found that "[f]ollowing the introduction of performance standards, real prices for refrigerators did not increase, and in some cases decreased" (Greening et al. 1996). The 1990 refrigerator standard was set by Congress and DOE did not estimate the cost of this standard. But DOE did set the 1993 standard, estimating an average increase in manufacturer cost of about $33 (in 1987$) (DOE 1989).

In the late 1990s, the American Council for an Energy-Efficient Economy (ACEEE) began comparing DOE product price estimates developed during rulemakings to the actual price of products after the standards took effect. This analysis was presented to a DOE Appliance Standards Advisory Board but was not formally published. ACEEE found that DOE's price projections were generally significantly higher than the actual prices observed after the standards took effect. Around that time, DOE began to employ more sophisticated methodologies to estimate the price impact of prospective standards levels (e.g., tear-down analyses began) in an attempt to improve accuracy.[1]

A few years later, LBNL conducted additional analysis on the actual cost of products after standards took effect, looking at price forecasts made by DOE for refrigerators, room air conditioners, clothes washers, and central air conditioners over the 1982–1995 period (Dale et al. 2002, 2009). This study concluded: "Past retail price predictions made by DOE analyses of efficiency standards, which assume constant prices over time, have tended to overestimate retail prices." and "The average incremental price to increase appliance efficiency has declined over time. DOE technical support documents have typically overestimated this incremental price and retail prices."

The findings from the LBNL research led DOE to investigate further improvements to their product price estimate techniques. For example, around 2001 DOE changed the method for calculating retail prices from manufacturer prices, recognizing that incremental markup factors are generally lower than average markups.[2] Recently, DOE has begun to include "experience curves" in new analyses. Experience curves look at price trends over time and incorporate these into price forecasts. In particular, for many products DOE has found that product prices are steadily declining in real (inflation-adjusted) terms from year to

[1] These are the recollections of Steven Nadel who conducted this analysis in the 1990s and presented them to DOE. Records of this analysis and these discussions have mostly been lost. The one record we could find was a DOE estimate of $360 as the incremental cost for the 1992 residential central air conditioner standard while the actual data from the Census Bureau showed no incremental cost one year after the standard took effect (Nadel 2000).

[2] See http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/cac_nopr_tsd_apdx_d.pdf. The basis for this change is discussed by Van Buskirk et al. (2001).

year. For example, a paper by Desroches et al. (2013), in summarizing this work, found real price declines of 0.8 to 2.5% per year, varying by product.

Our report seeks to fill a gap in the evaluation of historical DOE price estimates. Dale et al. (2002, 2009) assessed price estimates made during 1982–1995, a period ending nearly two decades ago. This report looks at price estimates made during 1996–2004 and compares those estimates to actual prices observed after those standards became effective between 2000 and 2010.

Methodology

This work is an extension of another research effort by Mauer et al. (2013) that examined how the choices available to consumers changed as new standards took effect. That research looked at 10 major new standards, most of which took effect since 2000. For this report, we looked at the six products included in the previous report for which DOE developed price estimates and for which actual time series market price data could be obtained covering the period from when the standard was finalized until one year after the standard took effect. For the other products examined by Mauer et al., either there were no DOE price estimates (because Congress set the standards), the standards have taken effect too recently to have adequate data since the standards took effect, or price data was not available. In addition, for this report we added one standard (for room air conditioners) to those examined by Mauer et al. because it was covered by Dale et al. (2002, 2009) and price data could be readily obtained.

Our basic methodology was to compare DOE's estimate of the incremental increase in manufacturer selling price due to a standard with the actual change in average manufacturers' selling price. As discussed below, we isolated when efficiency improvements were incorporated into new products by examining efficiency time series data.

We used manufacturer selling price because this was the time series data we could obtain on actual prices. Manufacturer selling price is the price received by domestic manufacturers for their products, including manufacturer markups. We did not look at the impacts of standards on wholesaler and retailer markups nor did we look at impacts on installation costs.

All of our actual price data came from the Current Industrial Reports series published by the U.S. Census Bureau.[3] These data include total domestic manufacturer shipments by product and the total value of these shipments. By dividing shipments into value, an average value to the manufacturer per unit shipped is obtained. Only U.S.-produced units are included in this data, although competition from foreign manufacturers affects U.S. manufacturer prices.

During the standards development process, DOE generally estimates price increases at both the manufacturer and consumer levels. We obtained DOE's price estimates from published Final Rules or Technical Support Documents issued in conjunction with Final Rules. These are estimates made before a standard takes effect and not actual selling prices. In many cases, the only average price estimate published by DOE was for the retail product price. In these cases, we converted retail price to

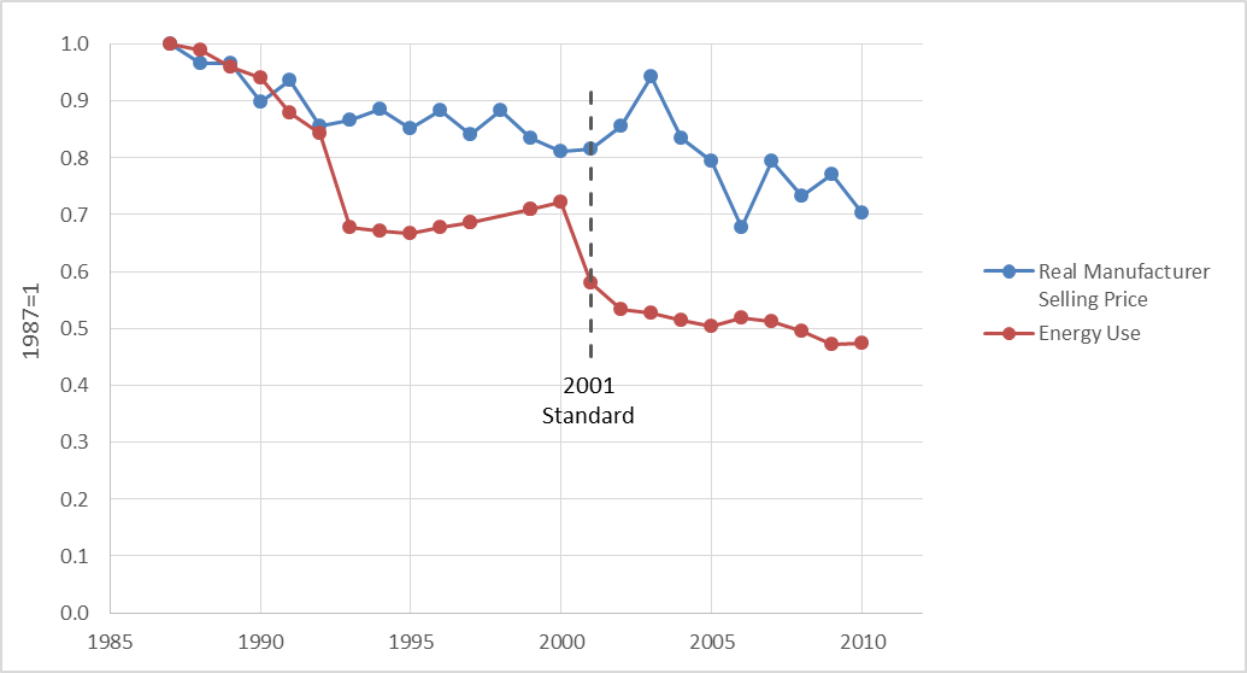
[3] See http://www.census.gov/manufacturing/cir/ .

manufacturer selling price by dividing by the average markup from manufacturer selling price to retail price as published by DOE in recent rulemakings.[4,5]

For looking at price impacts using the Census Bureau data, we looked at changes in manufacturer price over the period when the required efficiency improvement was incorporated into new products. As shown in Figure 1 for four products, the efficiency improvement is generally phased in over a two-year period and thus for each product we compared prices at the beginning and end of this two-year period, with the period custom chosen for each product. For example, for refrigerators we looked at the 2000-2002 period. For the other products we did not have information on product efficiency by year. For these products we assumed the two-year period spanned from the year before the new standard took effect to one year after the new standard took effect. For commercial air conditioners we used only a one-year period, as price data was not available for one year after the standard took effect.

Figure 1. Normalized Energy Use and Price Trends for Four Products

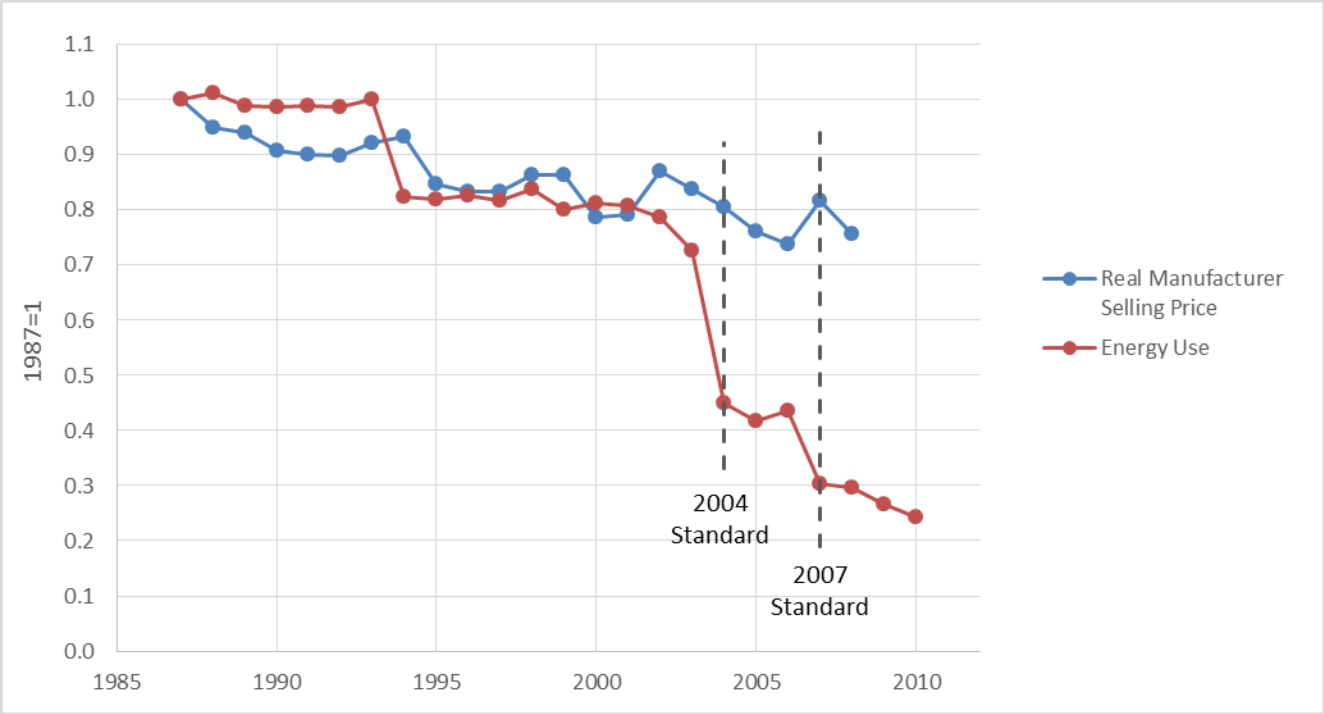
Refrigerators



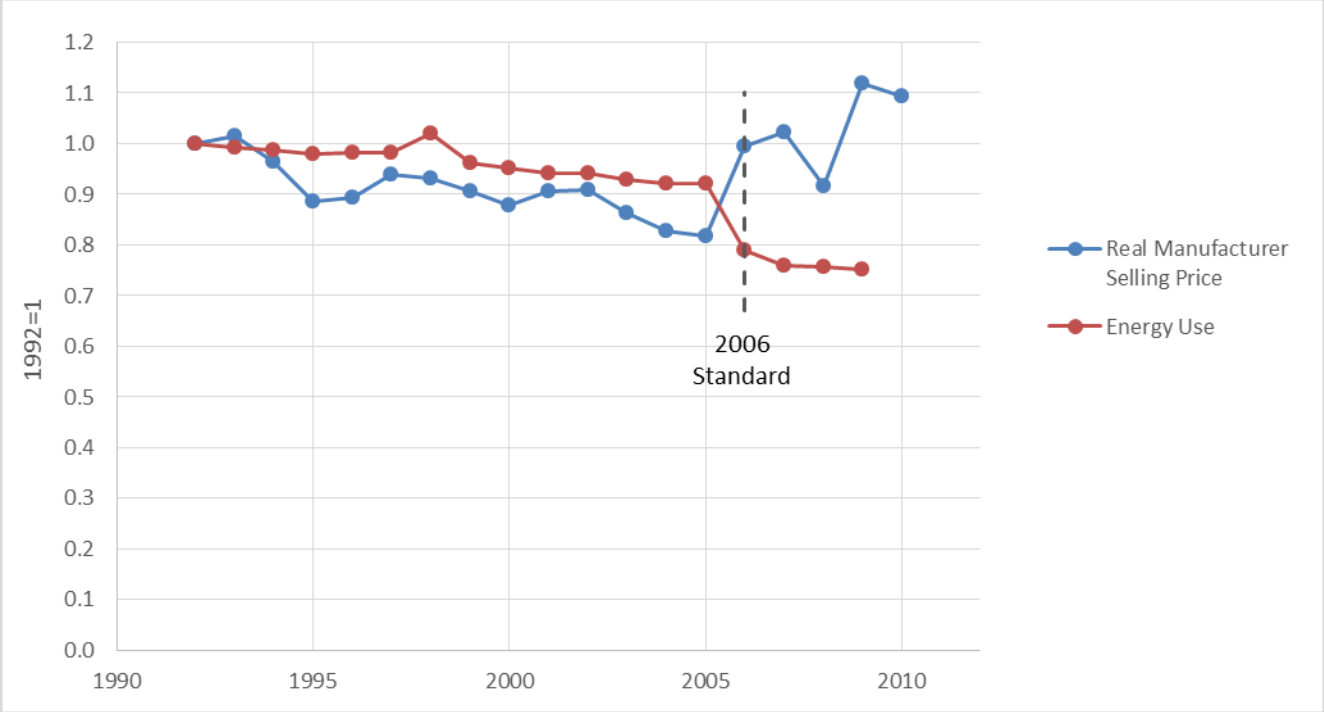
[4] This approach likely slightly *underestimates* the DOE manufacturers' price estimate because we used average mark-ups and DOE now generally uses incremental markups, which are modestly lower. Thus, our approach on this issue is conservative.

[5] As a first check on whether the DOE and Census data can be compared, we examined baseline price estimates from both DOE and the Census. This comparison is provided in Appendix B and shows that on average the two prices are about the same (i.e., the DOE costs averaged 98% of the Census costs).

Clothes Washers[6]

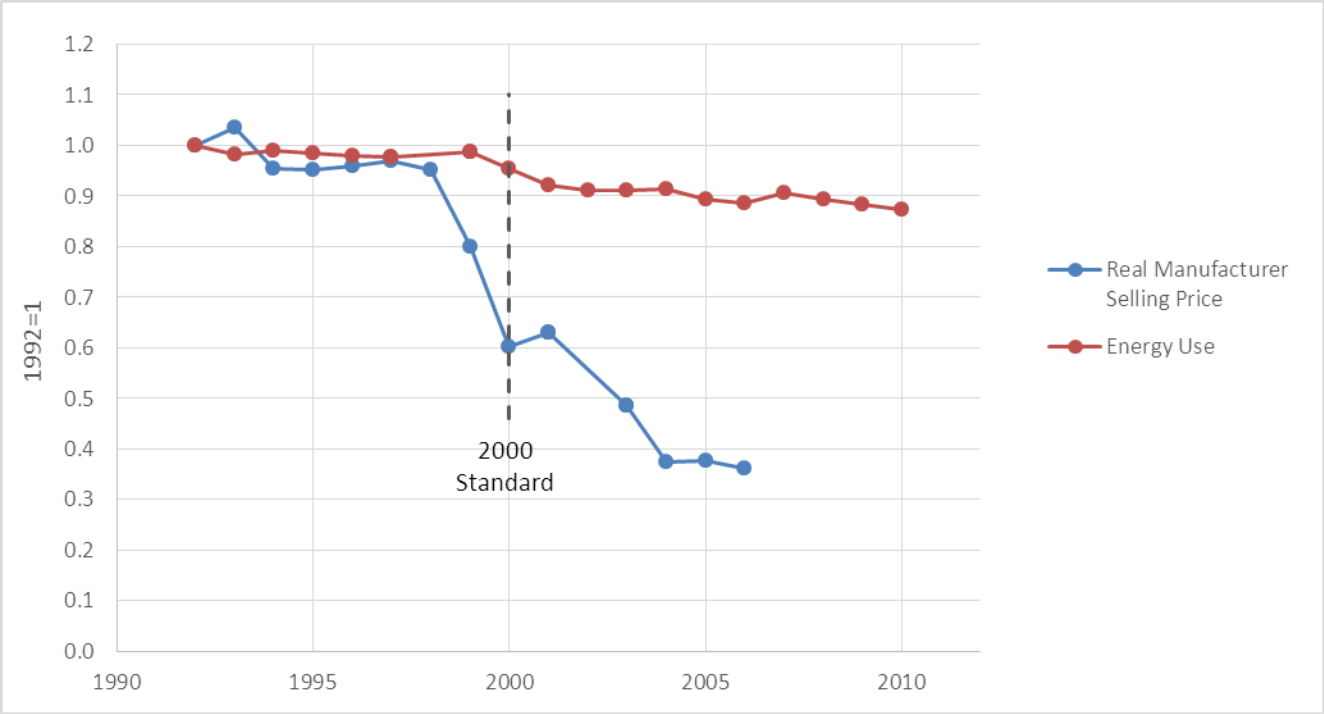


Central Air Conditioners



[6] Water use is also important but year-by-year water use data are not available.

Room Air Conditioners



Source: ACEEE/ASAP analysis. Efficiency data from AHAM 2011 and DOE 2011a. Price data from U.S. Census Bureau *Current Industrial Reports*.

We also conducted two alternative analyses, one comparing prices in the year immediately before and the year immediately after the effective date of the standard, and the other, a multiyear analysis comparing prices at the time the standard was published until one year after the standard took effect. The first alternative scenario minimizes the impact of other factors on price but may not capture the full effect of the efficiency changes caused by the standard (see Figure 1). The second alternative will capture early costs but also will necessarily capture changes in the market that are unrelated to efficiency standards. Where the confounding factors may be significant, we discuss these in sections on individual products.

The DOE and Census Bureau price estimates were prepared at various times using nominal dollars. We converted all price estimates into 2011 dollars, using the Producer Price Index published by the Bureau of Labor Statistics.[7]

Results and Discussion

General Results

Our results by product are summarized in Tables 1 and 2, and Figure 2. For all products we found that the actual price increase was less than the predicted price increase, with the difference often substantial. On average DOE predicted a manufacturer selling price increase (in 2011 $) of $148 for these products. The actual average across the nine cases was a *decrease* of $12. Looking at medians instead of averages, DOE predicted a median price increase of $108, while the actual increase was $10. In four out of the nine cases examined, manufacturer selling price actually declined over the period analyzed. If we ignore room air

[7] See http://www.bls.gov/ppi/.

conditioners, which declined dramatically in cost, on average, the actual manufacturer selling prices averaged only 9% of DOE's estimates. On a median basis, actual selling prices were 5% of DOE's estimates. In other words, DOE on average overestimated manufacturer selling price increases by about a factor of ten.

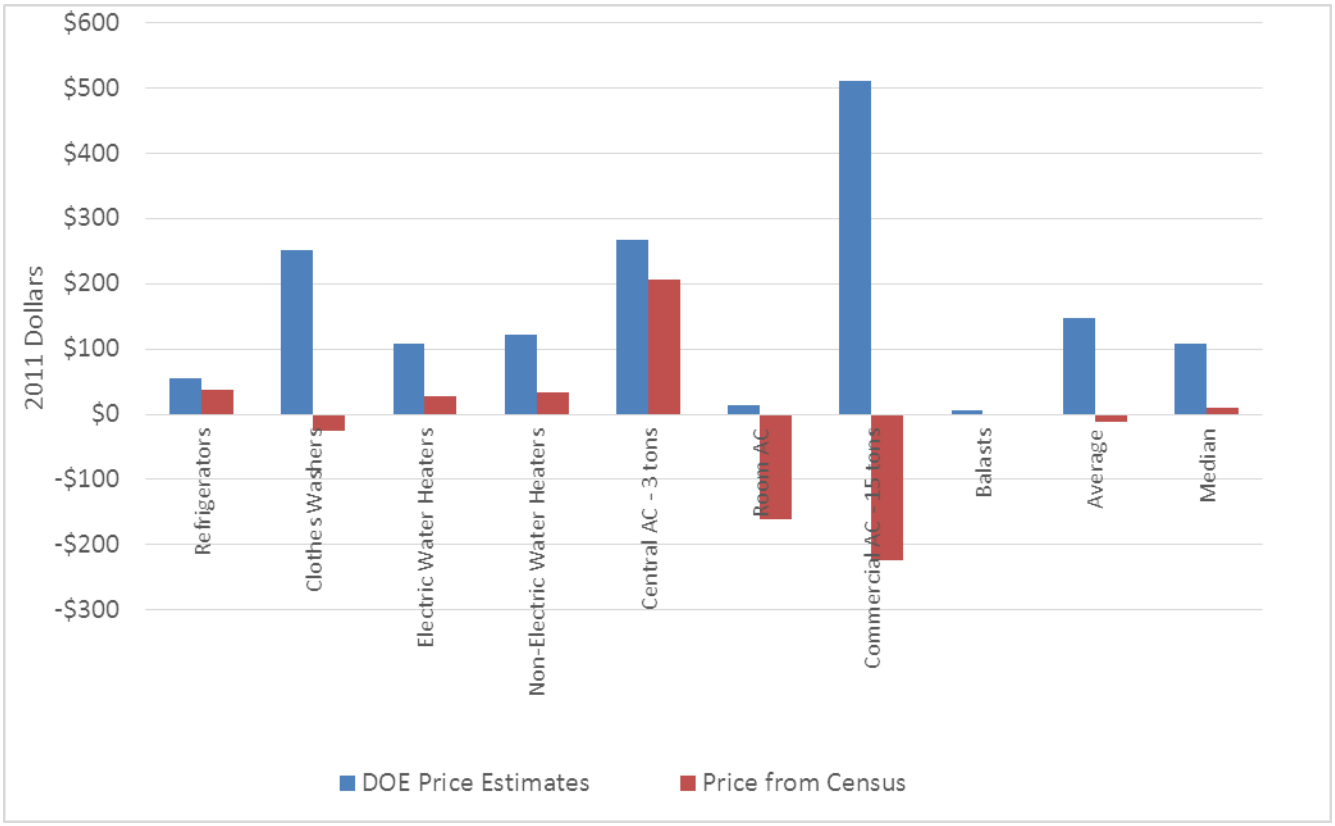
In only two cases (refrigerators and central air conditioners) did the DOE estimate come close to predicting actual market prices, with overestimates of 33% and 22%, respectively. In these two cases, as discussed below, other factors besides standards increased the price of these products. If not for these other factors, the actual price increases for these two products in the year the standard took effect would have been smaller. In all other cases the actual price was less than 30% of DOE's estimate. Details of the analysis can be found in Appendix A.

Table 1. Comparison of Predicted Manufacturer Price Increase for Standards with Actual Price Increase

Product	Standard Effective Date	DOE Estimate of Incremental Price of Standard (Nominal $)	Primary Case (Custom 2-Year Period)					
			Before	After	DOE Estimate (2011$)	Cost from Census (2011$)	Difference (2011$)	Actual as % of Predicted
Refrigerators	7/1/2001	32	2000	2002	56	37	-18	67%
Clothes Washers	1/1/2004	34	2002	2004	54	-35	-89	-66%
Clothes Washers	1/1/2007	126	2006	2008	199	10	-188	5%
Electric Water Heaters	1/20/2004	67	2003	2005	108	28	-80	26%
Non-Electric Water Heaters	1/20/2004	75	2003	2005	121	34	-88	28%
Central AC - 3 tons	1/23/2006	167	2005	2007	267	207	-59	78%
Room AC	10/1/2000	7.50	1998	2000	13	-162	-175	-1246%
Commercial AC - 15 tons	1/1/2010	334	2009	2010	512	-224	-736	-44%
Ballasts	1/1/2005	4.27		2006	6.73	-1.74	8.47	-26%
Average					148	-12	-158	9%
Median					108	10	-88	5%

Notes: For water heaters, the DOE cost estimate shown here includes the impact of new regulations by other agencies that also affect water heater costs. This point is described more fully in the text. For commercial AC, Census data ends in 2010 and therefore we could not include data for one year after the standard took effect. For ballasts, DOE estimated the difference in cost between electronic and magnetic ballasts. We did the same. Using this approach, there is no "before" year. The average in the last column excludes room air conditioners as this value is an outlier; if we include room air conditioners the average is -131%.

Figure 2. Comparison of Predicted Manufacturer Price Increase for Standards with Actual Price Increase



Note: For clothes washers this figure shows the sum of the two standards.

The presentation in Table 1 and Figure 2 both look at change in price. However, the different products we looked at vary widely in their base price, ranging from under $10 for ballasts to several thousand dollars for large commercial air conditioners. It is also useful to compare the DOE and Census price estimates when each are presented as a percentage price increase relative to the base price. Such a comparison is provided in Table 2, where the base price comes from DOE, using the same sources as the DOE price increase estimates. As can be seen, DOE estimated that the new standards would increase product prices by 35%. According to the Census data, on average there was no price increase.

Table 2.Comparison of Predicted Percentage Price Increase with the Actual Percentage Price Increase

	DOE Wholesale Base Cost	Price Increase		Increase as % of Base	
		DOE	Census	DOE	Census
Refrigerators	688	$56	$37	8%	5%
Clothes Washers -- 2004	427	$54	$(35)	13%	-8%
Clothes Washers -- 2007	480	$ 199	$10	41%	2%
Electric Water Heaters	222	$ 108	$28	49%	13%
Non-Electric Water Heaters	209	$ 121	$34	58%	16%
Central AC - 3 tons	762	$ 267	$ 207	35%	27%
Room AC	495	$13	$ (162)	3%	-33%
Ballasts	8.97	$ 6.73	$(1.74)	75%	-19%
Average				35%	0%
Median				38%	4%

Note: All costs at wholesale level in 2011$. For water heaters, costs include other regulations.

ALTERNATIVE CASES

As discussed above, in addition to our main case in which we selected a two-year period to compare pre- and post-standard prices, we also conducted two alternative cases: (1) comparing prices in the year each standard was finalized and to prices one year after the standard took effect; and (2) comparing prices in the year the standard took effect to the prior year. The first alternative looks at all the changes made in a product since the standard was set and allows for early changes made well before the new standard actually takes effect. However, since this analysis involves many years, there are also more opportunities for other factors besides standards (e.g., changes in material prices) to also affect the results. The second alternative minimizes other factors by just concentrating on the year before and after the standard effective date. On the other hand, this alternative may miss some changes due to the standard in the immediate year before or after the standard took effect.

Table 3 summarizes the results of the two alternative cases. Overall, our finding that on average DOE has substantially overestimated prices is robust across the three cases. On average across eight standards (excluding room air conditioners as an outlier), the actual increase in manufacturer price was 9% of DOE's estimate in our primary case, 26% of DOE's estimate for the multi-year period from rule finalization to one year after the standard took effect, and 7% of DOE's estimate comparing the year the standard took effect with the prior year.

For most products, the results of the three cases are generally similar. However, for refrigerators and commercial air conditioners there were substantial differences between the three cases. We discuss this issue further in the product-specific discussions below. The difference between the cases for commercial air conditioners largely explains why DOE's estimate is more accurate in the multiyear scenario than in the other two scenarios.

Table 3. Alternative Cases

Product	Standard Effective Date	DOE Estimate of Incremental Price of Standard (Nominal $)	Comparison of Year Standard Was Established to 1 Year after Standard Took Effect					
			Before	After	DOE Price Estimate (2011$)	Price from Census (2011$)	Difference (2011$)	Actual as % of Predicted
Refrigerators	7/1/2001	32	1997	2002	56	12	-43	22%
Clothes Washers	1/1/2004	34	2000	2005	54	-13	-67	-25%
Clothes Washers	1/1/2007	126	2005	2008	199	-2	-201	-1%
Electric Water Heaters	1/20/2004	67	2001	2005	108	25	-83	23%
Non-Electric Water	1/20/2004	75	2001	2005	121	70	-51	58%
Central AC - 3 tons	1/23/2006	167	2001	2007	267	118	-149	44%
Room AC	10/1/2000	7.50	1997	2001	13	-157	-170	-1213%
Commercial AC - 15 tons	1/1/2010	334	2005	2010	512	326	-186	64%
Ballasts	1/1/2005	4.27		2006	6.73	-1.74		
Average					148	42	-119	26%
Median					108	12	-116	22%

Product	Standard Effective Date	DOE Estimate of Incremental Price of Standard (Nominal $)	Comparison of Year Standard Took Effect to Prior Year					
			Before	After	DOE Price Estimate (2011$)	Price from Census (2011$)	Difference (2011$)	Actual as % of Predicted
Refrigerators	7/1/2001	32	2000	2001	56	3	-52	6%
Clothes Washers	1/1/2004	34	2003	2004	54	-18	-72	-34%
Clothes Washers	1/1/2007	126	2006	2007	199	42	-157	21%
Electric Water Heaters	1/20/2004	67	2003	2004	108	11	-97	10%
Non-Electric Water	1/20/2004	75	2003	2004	121	27	-94	23%
Central AC - 3 tons	1/23/2006	167	2005	2006	267	178	-89	67%
Room AC	10/1/2000	7.50	1999	2000	13	-91	-104	-706%
Commercial AC - 15 tons	1/1/2010	334	2009	2010	512	-224	-736	-44%
Ballasts	1/1/2005	4.27		2006	6.73	-1.74		
Average					148	-8	-175	7%
Median					108	3	-95	8%

Notes: For water heaters, the DOE cost estimate shown here includes the impact of new regulations by other agencies that also affect water heater costs. This point is described more fully in the text. For ballasts, DOE estimated the difference in cost between electronic and magnetic ballasts. We did the same. Using this approach, there is no "before" year. The average in the last column excludes room air conditioners as this value is an outlier.

Impact of Experience Curves

As discussed above, DOE began including experience curves in many of its cost estimates starting in 2010, seeking to capture long-term trends. For the most part, these long-term trends show prices declining. Desroches et al. (2013) summarize this work. For four of the products in our analysis, DOE has calculated experience curves, estimating the average annual decline in product prices. We incorporated these

experience factors in our analysis to see if that explains the discrepancies between predicted and actual costs. This analysis is provided in Table 4. As can be seen, inclusion of experience curves slightly reduces the DOE price increase estimate and, therefore, the difference between predicted and actual price increases. Without experience curves, DOE predicts an average manufacturer cost increase for these four rules of $147; with experience curves this average declines to $136. The average actual manufacturer price change for these products was a $14 increase, although this includes the outlier room air conditioners. Without room air conditioners, the average price increase is $73. In percentage terms, if we exclude room air conditioners, the actual price was 38% of DOE's estimate without the experience factor and 49% of DOE's estimate with the experience factor. Over time, as the experience factor is applied over additional years in DOE's National Energy Savings model, the difference between the with-experience curve case and the without-experience curves will increase and the experience curve price will likely become more accurate. Experience curves appear to slightly reduce incremental price estimates and, therefore, to bring DOE's estimates a little closer to actual observed price increases for the standards examined. But they do not account for the vast majority of predicted cost increases that did not materialize.

Table 4. Impact of Experience Curves on Predicted Versus Actual Price Increases

Product	DOE Estimate (2011 $)	Experience Curve (%/yr)	Estimate Applying Experience Curves	Price from Census	Difference ($)	Actual as % of Predicted
Refrigerators	56	2.5	49	37	-12	76%
Clothes Washers	252	1.9	229	-25	-254	-11%
Central AC - 3 tons	267	0.8	254	207	-47	82%
Room AC	13	1.7	12	-162	-174	-1335%
Average	147	1.7	136	14	-122	-297%
Avg. w/o Room AC	192	2	177	73	-104	49%
Median	154	1.8	139	6	-110	33%

Note: For this analysis we combine the two clothes washer standards into a single line so that clothes washers are only counted once. For clothes washers actual cost combines the actual cost for the 2004 and 2007 standards.

Discussion of Individual Product Results

We now turn to a discussion of our results product by product, as there are some unique issues for each product that are useful to explore.

Refrigerators and Clothes Washers

For refrigerators, the DOE estimate (DOE 1995) is a $56 incremental manufacturer cost in 2011$. In actuality, the Census data show the average manufacturer price increasing by $37 over the 2000–2002 period. For clothes washers, the difference is even more dramatic. DOE set a two-tier standard in 2000, with the first tier taking effect in 2004 and the second tier taking effect in 2007. DOE (2000a) estimated the two standards together would increase manufacturer price by $253 in 2011 $. The Census Bureau data shows that the average manufacturer price declined $43 (2011 $) over the 2003–2008 period.

For both refrigerators and clothes washers, prices have been steadily declining over the past two decades as shown by Desroches et al. (2013) who estimate an average 2.5% and 1.9% annual decrease respectively.

Mauer et al. (2013) also looked at price data published by *Consumer Reports* magazine over this time period and also found a decline in price, reinforcing the findings from the Census data.

These price declines have been driven by such factors as consolidation in the industry, decreasing labor costs, and competition from foreign manufacturers. In addition, it appears that manufacturers have figured out ways to produce high-efficiency products for much lower costs than DOE estimated. For example, one industry expert interviewed by Mauer noted that when manufacturers redesign products to meet new efficiency standards, they also look for opportunities to make the manufacturing process more efficient, which can reduce costs (Mauer et al. 2013). Similar sentiments were made in an article by two appliance industry employees (McInerney and Anderson 1997).

An example of how this can work is shown by investments made by General Electric to "re-shore" some overseas manufacturing back to its Appliance Park plant in Louisville, Kentucky. GE is moving many production lines to Louisville and in the process redesigning products to reduce manufacturing costs including material and labor. While specific data for clothes washers are not available in the literature, a recent article on GE noted how re-shoring and redesign of their heat pump water heater was able to reduce the number of parts by 20%, material costs by 25%, and labor hours by 80% relative to the predecessor product that was produced in China (Fishman 2012).

It should be also noted that in the case of refrigerators, our estimate of the actual manufacturer price increase varies depending on the period examined, with the actual price change highest for the primary case ($37) and lower for the two alternate cases ($12 and $3). In our primary case, the price increased substantially in 2002, the year after the standard took effect and the second year in our primary case. The price increased even more in 2003, quite likely due to a change in foam blowing agent in response to EPA regulations that took effect in 2003. There is a good chance that the change in blowing agent began affecting manufacturer prices in 2002, raising our primary cost estimate. The change does not show up in the one-year analysis (the second alternate) and is offset by some price declines from 1998–2000 in our multiyear analysis (see Figure 1).

Water Heaters

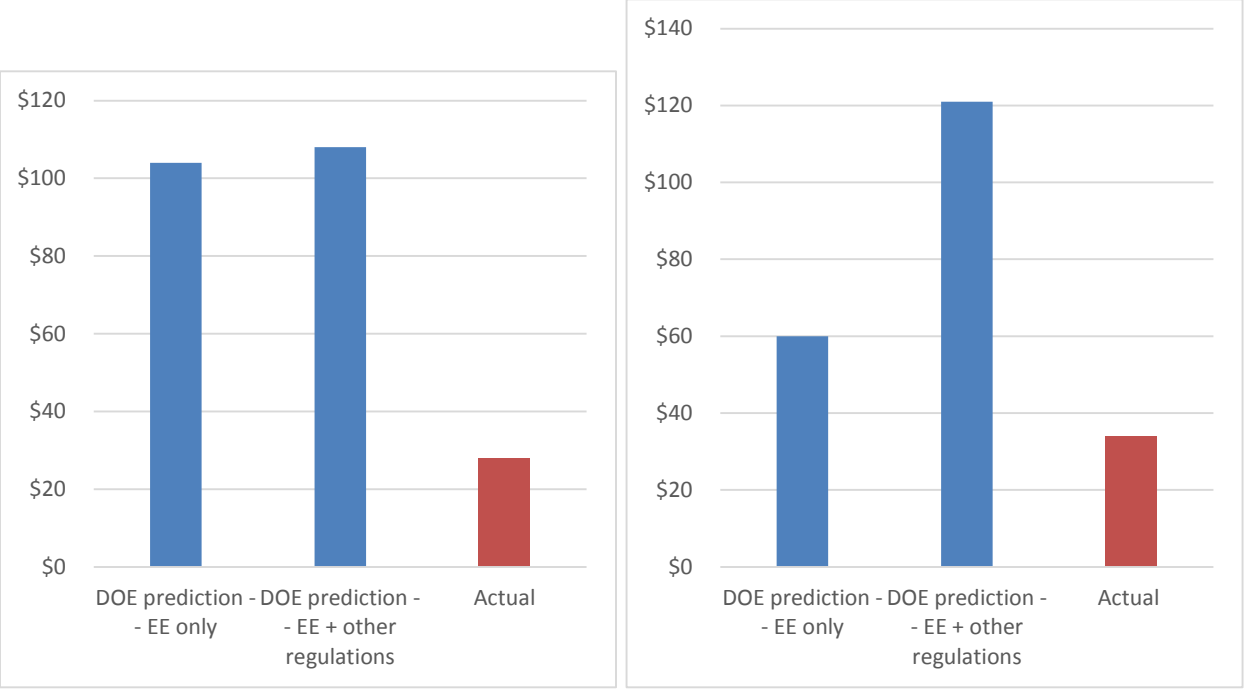
DOE published a new water heater standard in 2000, with the new standard taking effect in 2004. In 2000, DOE estimated (DOE 2000a) an incremental retail cost to meet the new standard that works out to $104 for electric water heaters and $60 for natural gas water heaters in 2011$. However, in this rule, DOE also noted two other regulations by other agencies that would also affect the cost of water heaters over the same time period. These were: (1) EPA regulations to protect the ozone layer by phasing out HCFC compounds that were used as an insulation blowing agent; and (2) Consumer Product Safety Commission (CPSC) regulations to reduce the chances that flammable vapors could be ignited by water heater pilot lights. DOE estimated (DOE 2001) that once these other regulations are accounted for, the retail price of electric and natural gas water heaters would increase further, resulting in manufacturer cost increases in 2011$ of $108 for electric and $121 for natural gas units.

The Census Bureau data show an increase in manufacturer price of shipments of $28 for electric water heaters and $34 for non-electric water heaters (most of which are natural gas or propane fired, where propane water heaters are nearly identical to natural gas units). In other words, for electric and gas units it

appears that DOE over-estimated the price by nearly a factor of four. These differences are illustrated in Figure 3.

Figure 3. Comparison of Predicted and Manufacturer Cost Increases for Residential Water Heaters

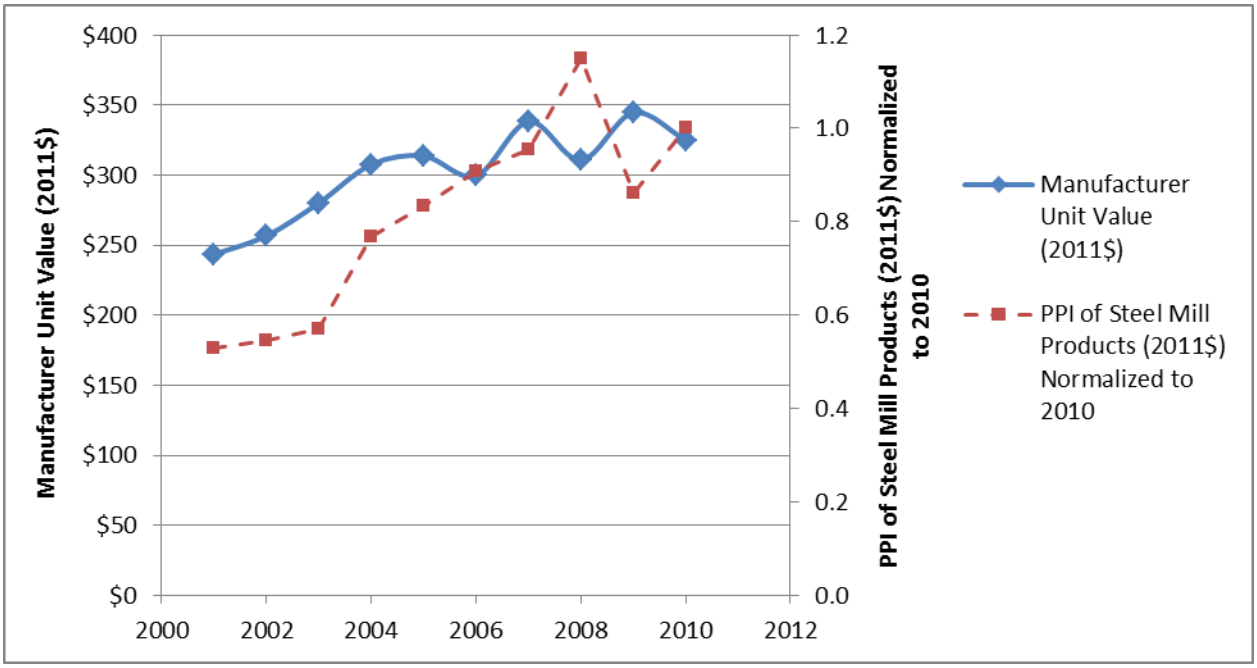
Electric *Natural Gas*



Interestingly, DOE overestimated the cost increase for water heaters despite the fact that prices for steel mill products increased 58% over the 2001–2005 period.[8] Steel is a major component in water heaters, with non-electric water heaters using significantly more steel than electric water heaters (Adams 2013). Trends in prices for non-electric water heaters and in steel prices are illustrated in Figure 4.

[8] See http://www.bls.gov/ro3/ppimetals.htm.

Figure 4. Average Manufacturer Price of Non-Electric Water Heater Shipments and Producer Price Index for Steel



Sources: Bureau of the Census Current Industrial Reports for water heater costs; Bureau of Labor Statistics Producer Price Index for steel mill products

Contributing factors to DOE's overestimate of costs may include consolidation in the industry, decreasing labor costs, and productivity improvements when products and production lines were retooled to produce the more efficient water heaters (e.g., note the General Electric example for heat pump water heaters discussed in the previous section, although it should be noted that heat pump water heaters dramatically exceed the minimum efficiency standards).

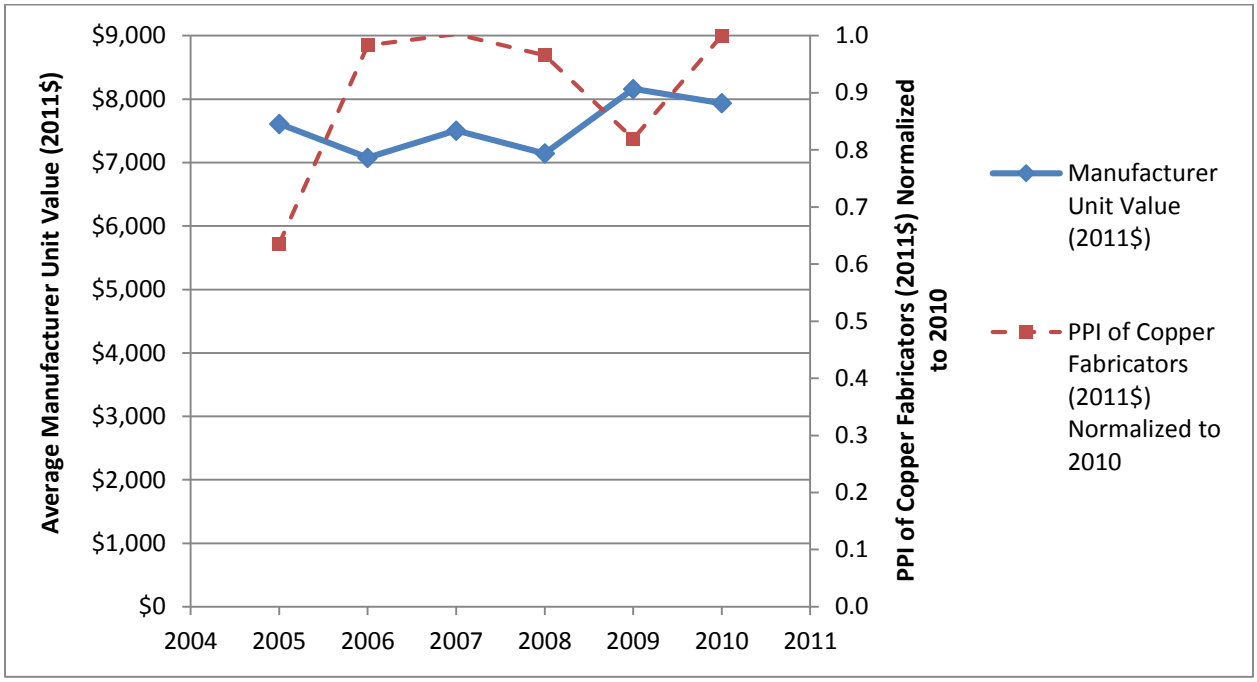
Residential Central and Commercial Air Conditioners

For residential central air conditioners, DOE published a final rule in early 2001 establishing a new standard that took effect in 2006. DOE (2001b) estimated the impact of this new standard on prices, which works out to a $267 increase in manufacturers' costs in 2011$. Likewise, in 2005 Congress enacted a new minimum efficiency standard for commercial packaged air conditioners, effective 2010. DOE was in the middle of a rulemaking for these products and had estimated an increase in manufacturers' costs for an average product with a 15-ton cooling capacity for the standard level Congress enacted (DOE 2004); in 2011$ this was a manufacturers cost of $512.

Census Bureau data show an increase in manufacturer price in 2011$ of $207 over the 2005–2007 period for an average residential unit (with a 3-ton cooling capacity) and a *decrease* of $224 for an average commercial unit (11–15 ton cooling capacity) over the 2009–2010 period (2011 data are not available). These figures are 78% and -44% of DOE's estimates. These overestimates are despite the fact that the price of copper, a significant air conditioner component, increased about 50% in 2006 when the residential air conditioner standard took effect and about 25% in 2010, the year the commercial air conditioner standard took effect (see Figure 5).

As can be seen in Figure 5, commercial air conditioner prices modestly fluctuated from 2005–2008, but then climbed steeply in 2009. The price modestly declined in 2010, the year the new efficiency standard took effect. This was also the year that new EPA regulations took affect that required manufacturers to change refrigerants, as the old refrigerant contributed to depletion of the ozone layer. Due to the 2009 price increase, our multiyear scenario of costs shows a price increase of $326, which is 64% of the DOE estimate of the cost of the 2010 energy efficiency standard. The 2009 price increase does not show up in the other two cases. DOE did not examine the cost of the 2010 refrigerant change, although it did conclude that the cost of the efficiency change would be about the same if the most likely refrigerant was used in both the base case and with new standards case (DOE 2004). It is unclear if the 2009 price increase is related to the energy efficiency standard or the refrigerant regulation. If this price increase is related to the efficiency standard, then the multiyear case is the better one for this product, but if the price increase is due to the refrigerant change, then the shorter-term analyses more accurately portray the impact of the change in efficiency standard.

Figure 5. Average Value of Commercial Packaged Air Conditioner Shipments and Producer Price Index for Copper Fabricators



Sources: Bureau of the Census Current Industrial Reports for air conditioner value; Bureau of Labor Statistics Producer Price Index for copper fabricators

Room Air Conditioners

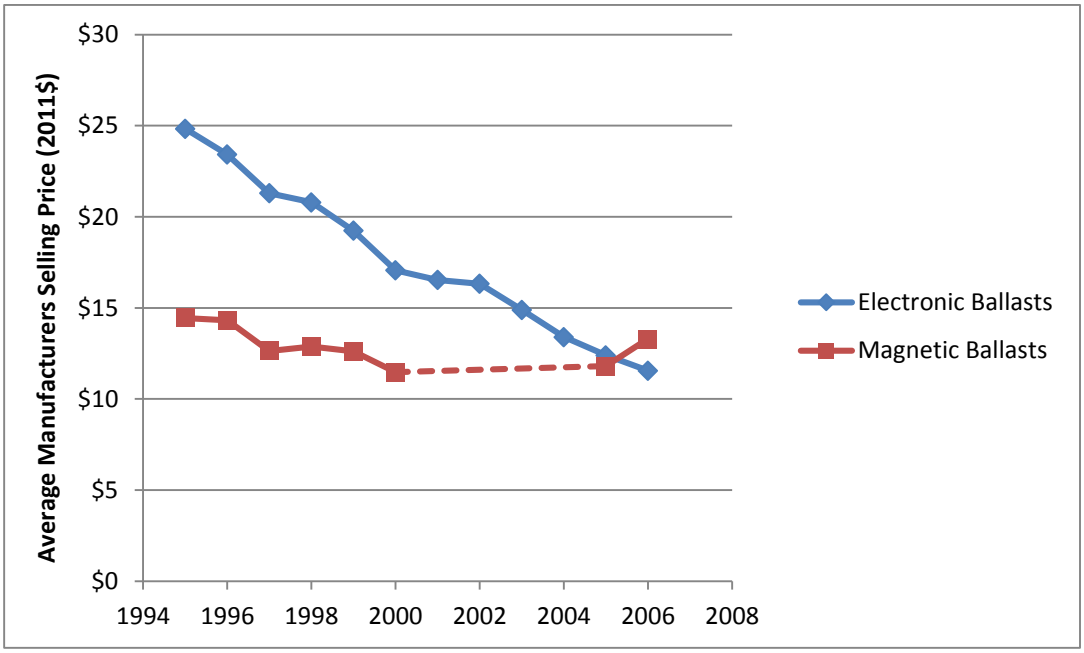
DOE finalized a new standard for room air conditioners in 1997 that took effect in 2000. DOE estimated a very modest manufacturer price increase for this standard, with nominal predicted increases ranging from $6–9 (1990$) depending on the product type. In 2011$, the midpoint of this range is $13. Census Bureau data shows that the average manufacturer price per unit declined dramatically from 1998–2000 (see Figure 1). For example, for an average-sized unit (cooling capacity of 8,000-8,999 Btu/hour), manufacturer price per unit dropped from $441 to $280 (2011$), a decline of $161. During this period the

overwhelming majority of room air conditioner production moved out of the United States, primarily to Asia (DOE 2011b). In order to compete, remaining U.S. manufacturers also needed to reduce their costs. This factor appears to have dwarfed the possible impact of the new standard on product costs.

Fluorescent Lamp Ballasts

Fluorescent lamp ballasts provide the high voltage necessary to start fluorescent lamps and regulate the current provided to the lamps to produce even light. DOE set a new fluorescent ballast standard in 2000 that took effect for many products in 2005, and remaining products in 2010. When the standard was set, the market was split between magnetic ballasts that were less expensive but had higher energy losses, and electronic ballasts that were more expensive but had very low energy losses. The DOE standard essentially required electronic ballast levels of performance, effective 2005 for ballasts sold with new lighting fixtures, and 2010 for replacement ballasts designed to be installed in existing fixtures. DOE estimated the new standard would increase average retail ballast prices by $8.38 based on the difference in price between electronic and magnetic ballasts (DOE 2000b). This works out to an average manufacturer price increase of $6.73 in 2011$. Census Bureau data show that the price of electronic ballasts declined substantially, so that by 2006 (the last year for which data are available), the average electronic ballast manufacturer price was $1.74 *less* than a magnetic ballast. The anticipated increase in ballast prices did not occur as it appears that competition from foreign manufacturers and economies of scale in ballast production reduced electronic ballast costs to the point that they became cheaper than magnetic ballasts by 2006 (see Figure 6).

Figure 6. Average Manufacturer Selling Price for Power Factor Corrected Magnetic and Electronic Ballasts from 1995-2006 (2011$)



Source: Bureau of the Census, Current Industrial Reports. 1995-2000 are not part of our analysis but are included in this figure to show decade-long trends.

UNCERTAINTY

Predictions of the future are inexact: no one can know with precision what prices for a given product will be several years in the future. Sources of uncertainty for incremental price estimates include changes in materials prices, changes in labor rates (perhaps due to factory relocation or new union contracts); changes in labor costs (perhaps due to improved productivity or automation); increased competition due to new market entries; industry consolidation; technological breakthroughs; and unexpected design improvements. These sorts of variables change all the time; therefore, we should not expect DOE's estimates to precisely predict observed prices. However, if DOE's estimation techniques are robust, we should expect estimates to fall within some reasonable band around observed prices (e.g., within plus or minus 25%). Estimates that consistently miss in one direction or the other would suggest that the estimation techniques are biased. Estimates that consistently miss by a wide margin would suggest that the techniques used need to be improved.

Scenario analysis is a common tool used for addressing uncertainty: If you know your estimate is not very robust, it generally makes sense to analyze other possible scenarios. Depending on whether the alternate scenario affects the outcome of interest, more work may be warranted to better understand which scenario is most likely. DOE regularly uses scenario analysis for some of the variables that go into estimating consumer lifecycle costs. For example, DOE relies on EIA's reference case for future electricity prices, but runs scenarios using the high and low case. Occasionally, DOE has run scenarios for incremental costs. For example, in the 2001 central air conditioner rule, DOE ran scenarios based on two price estimates, one based on DOE's reverse engineering and another based on costs submitted by manufacturers. Similarly, for the 2013 distribution transformer rule, DOE ran scenarios based on different assumptions about electrical steel prices (DOE 2013).

Discussion, Conclusion and Recommendations

This analysis examines nine major standards that took effect over the 2000–2010 period. In each case we examined, the actual increase in manufacturers' selling price was less than DOE's estimate during the rulemaking process, generally substantially so. This finding is in line with prior findings by LBNL and ACEEE, which examined standards that took effect prior to the period covered by this report. In the present analysis, on average, the actual impact on manufacturers' price was a decrease of $12, not the $148 average increase DOE had predicted. The actual increase in manufacturer price was only 9% of DOE's estimate and in no case was the actual price increase more than 78% of DOE's estimate. As a result, the net present value benefits to consumers of products subject to standards has been substantially higher than DOE predicted.

However, we should caution that our analysis compares the average actual price change across the market for each product to a specific estimate of the impact of efficiency changes on individual products. The latter does not consider broader market changes, including changes in labor or materials costs, industry consolidation, and other factors listed in the "Uncertainty" discussion above. While market and product changes are related, they are not exactly the same. In our analysis, we have attempted to isolate product changes by focusing on the specific, relatively short period when the efficiency time-series data shows that energy-saving improvements were incorporated into products. But we have not been able to remove the

effect of any underlying, broader market change happening during that same period. DOE sometimes conducts scenarios on broader market changes (e.g., the impact of refrigerant and blowing agent changes), but we did not examine these as such data is not available for all products, and where available, there are often several scenarios, making the analysis very complicated.

Our finding that the actual cost of standards was always lower than DOE estimated raises the question of why this is the case. Further product-specific investigations and analysis will be needed to find causes, but one hypothesis is that as manufacturers redesign products to meet standards, they discover new lower cost ways to meet the standard than DOE examined. Also, as discussed previously for General Electric water heaters, when manufacturers redesign products and production lines, they can find unexpected ways to reduce costs. In other words, in competitive markets, manufacturers have an incentive to do better than DOE estimated in order to gain a competitive advantage. Other manufacturers generally track innovations by their competitors and it is common for such innovations to spread quickly among manufacturers. Modeling innovation is very difficult but ignoring innovation tends to lead to overestimating prices.

DOE has continued to refine its methodology for estimating product prices since the standards examined in this report were developed. However, given the long-term track record of overestimation, DOE should conduct an in-depth retrospective analysis to uncover the sources of error in the incremental cost analyses conducted for the standards evaluated for this report. Such an in-depth effort is beyond the scope of our report but could build on prior work by Dale et al. (2002, 2009) that attempted to disaggregate some of the effects. In addition, DOE should conduct ongoing retrospective analyses as new standards take effect to determine if more recent analyses have more accurately predicted price increases. These retrospective analyses will allow DOE to further improve price estimation techniques, such as by considering ways to better incorporate innovation into its price estimates.

In parallel with such analyses, we recommend that DOE conduct sensitivity cases for future standards rulemakings that assume that actual costs are 25% and 50% of DOE's calculated estimates. Sensitivity cases allow DOE to consider the impact of different assumptions on their results and are particularly useful when there is large uncertainty around a specific assumption. DOE conducts a variety of sensitivity analyses, including some using more conservative assumptions than its primary analysis. Adding some sensitivity analyses based on adjusted price forecasts would provide a range of values for decision-makers to weigh. For example, presently DOE conducts analyses at 3% and 7% discount rates and considers both of them. The addition of sensitivity cases for incremental cost are likely to have at least as much impact on the analysis as discount rate. The consideration of price sensitivity analyses will help better align the calculations with the experience to date. Such adjustments will result in analyses and standards that better reflect real-world markets when standards are revised.

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Appendix A: Full Analysis and Sources

Product	Standard Effective Date	DOE Estimates		Markup	Wholesale	Year $	DOE Estimate (2011$)	Experience Factor Where Available (%/year)	DOE Estimate Applying Experience Curve	Years Used for Actual Costs		Actual Price Change from Census	Reference for DOE Estimate
		Base Cost	Increase w/ Std.							Start	End		
Refrigerators	2001	$619	$50	1.56	$32	1990	$55.54	2.5	$48.94	2000	2002	37	DOE 1995
Clothes Washers	2004	$421	$53	1.55	$34	1997	$53.73	1.9	$48.81	2002	2004	-35	DOE 2000a
Clothes Washers	2007	$474	$196	1.55	$126	1997	$198.68	1.9	$180.51	2006	2008	10	DOE 2000a
Electric Water Heaters	2004	$380	$101	1.57	$64	1998	$104.08			2003	2005	28	DOE 2001a
(including other regulations)	2004		$105	1.57	$67	1998	$108.20			2003	2005		DOE 2001a
Non-Electric Water Heaters	2004	$383	$58	1.57	$37	1998	$59.55			2003	2005	34	DOE 2001a
(including other regulations)	2004		$118	1.57	$75	1998	$121.15			2003	2005		DOE 2001a
Central AC - 3 tons	2006	$957	$335	2.01	$167	1999	$266.78	0.8	$254.23	2005	2007	207	DOE 2001b
Room AC	2000	$507	$8	1.77	$8	1990	$12.96	1.7	$12.10	1998	2000	-162	DOE 1997
Commercial AC - 15 tons	2010	NA	$334	2.31	$334	2002	$512.08			2009	2010	-224	DOE 2004
Ballasts	2005	13.16	$8.37	1.96	$4.27	1997	$6.73			*	2006	-1.74	DOE 2000b

Notes: For room AC and commercial AC, DOE estimates are at wholesale level and markup is not applied. For ballasts we compared the cost of electronic and magnetic ballasts in 2006 and did not use data from before the standards took effect. NA = not available

Appendix B: Comparison of DOE and Census Price Estimates for Baseline Products

	Base Retail Cost		
	DOE	Implied by Census	Ratio DOE to Census
Refrigerators	1,070	1,120	0.96
Clothes Washers	663	646	1.03
Electric Water Heaters	347	309	1.13
Non-Electric Water Heaters	330	323	1.02
Central AC — 3 tons	1,533	1,772	0.86
Room AC	876	786	1.11
Ballasts	21	27	0.77
Average			0.98

Notes: All figures converted into 2011$. For "Implied by Census" used year before final rule and applied DOE average markup.
For water heaters and central air conditioners, DOE costs include installation, so we subtract these costs to make the two columns comparable. Data sources are documented in Appendix A.