Estimating the Cost of Saved Energy

The EIA 861 database

December 2016

AUTHORS

Frank Ackerman, PhD
Pat Knight
Bruce Biewald

Synapse Energy Economics, Inc.

485 Massachusetts Avenue, Suite 2
Cambridge, Massachusetts 02139

617.661.3248 | www.synapse-energy.com

CONTENTS

1. INTRODUCTION: HOW MUCH DOES IT COST TO SAVE ENERGY?

The cost of energy efficiency is a crucial and controversial parameter in the analysis of clean energy and carbon emission reduction. Optimists suggest that saving energy can be much cheaper than generating it, while pessimists argue that efficiency savings are at least as costly as electricity generation.

This paper looks at one important source of data, the energy efficiency savings and expenditures which utilities and others report annually to the United States Energy Information Administration (EIA) on EIA's Form 861. The EIA 861 data are freely available for public download and are released every October for the previous calendar year. The energy efficiency dataset spans many years and currently extends through 2015, although with periodic changes in coverage and definition. Our analysis is confined to the 2010–2015 data.

We found that the EIA data show that the costs of energy efficiency are low. Based on the data analysis described below, we conclude that:

- In the average energy efficiency program, the cost to the utility is $0.039 per kWh of savings. However, this average is heavily weighted by small, high-cost programs: the utility cost of providing energy efficiency when weighted by saved energy is only $0.026 per kWh—far below the average wholesale cost of supplying electricity to customers.
- Larger programs are more cost-effective, with average costs to the utility of only about $0.023 per kWh. Between 2010 and 2015, these large program costs have remained almost unchanged.
- Over time, the costs of the more expensive, smaller programs are dropping, while the more ambitious, low-cost programs are expanding.

This is not a story of unique, best-case results; it is based on thousands of observations, including data from all 50 states.

1.1. Creating the data set

The EIA 861 data include annual reports from thousands of utilities and non-utility energy efficiency program administrators. Unfortunately, many of these reports are incomplete, lacking essential data for analysis. We began by screening the data to exclude all records which lacked data for either first-year energy savings, total energy sales, or total costs of the energy efficiency program. This left 2,730 complete records for the six-year period from 2010 to 2015. We converted all monetary data to 2015 dollars to remove effects of inflation over that period.

The EIA 861 data report only the first year of energy savings attributable to efficiency program expenditures. However, efficiency measures will save energy for years beyond that, although at a declining rate. For comparison to the costs of energy generation, the relevant statistic is the cost per kWh of the present value of lifecycle energy savings. Calculation of this cost requires a projection of lifecycle energy savings, and a conversion to present value (i.e., discounting of future values).

In supporting documents for the Clean Power Plan, the U.S. Environmental Protection Agency (EPA) assumed an average lifetime for efficiency measures of 10.2 years, based on studies at Lawrence Berkeley National Laboratory.[1] This means the savings from the average measure are assumed to decline to 50 percent of the initial value after 10.2 years. Therefore, we assume straight-line depreciation of the energy savings from each installed measure, reaching 50 percent of the initial value after 10.2 years, and zero after 20.4 years.[2]

Based on longstanding guidance from the Office of Management and Budget (OMB), EPA frequently discounts future values at 3 percent and 7 percent. Using an average measure life of 10.2 years, we used a 5 percent discount rate to calculate that the present value of our projection of lifetime savings are 8.0 times the reported first-year savings for all programs. Using a 3 percent discount rate would yield a lifetime energy savings of 8.9 times first-year savings, and using a 7 percent discount rate would yield a life time savings energy of 7.3 times first-year savings. (To convert to a 3 percent discount rate, reduce our costs per kWh by 10 percent; to convert to 7 percent, increase our costs per kWh by 10 percent.)

Of the 2,730 records, a handful had implausible values for key parameters. One program reported data implying that the cost of saved energy was greater than $25 per kWh. Another reported that first-year savings from an energy efficiency program amounted to 73 percent of electricity sales. Such extremes are likely to represent data entry errors; if not, they describe very unusual circumstances that have limited applicability elsewhere.

These extreme values, orders of magnitude greater than the rest of the data, exert an exaggerated influence on averages and trend lines. To address this problem, we eliminated a small number of data points, symmetrically at the high and low ends on the two key ratios. For the cost per kWh of saved energy, we dropped the highest and lowest 1 percent of observations, those with costs per saved kWh above $0.81 or below $0.00090, and retained the middle 98 percent of the distribution. For the first-year savings as a percentage of utility sales, we dropped the highest and lowest 0.5 percent of observations, those with savings above 4.8 percent or below 0.0003 percent of sales, retaining the middle 99 percent of the data. These two steps removed 75 records, leaving a dataset of 2,655 observations with a wide range of values to serve as the basis for the remainder of our analysis.[3]

---

[1] U.S. EPA. 2015. "Demand-Side Energy Efficiency Technical Support Document." Pages 54-56. Available at: www.epa.gov/sites/production/files/2015-11/documents/tsd-cpp-demand-side-ee.pdf.

[2] EPA uses a more detailed, non-linear time profile for savings. In practice, our straight-line depreciation formula yields almost identical results for the present value of savings.

[3] Different standards were used for two ratios because visual inspection of the data showed that the problem of extreme outliers was more pronounced in the distribution of costs per kWh of saved energy. In general, the goal was to cut as little data as possible, while removing obvious outliers. Our two criteria selected 56 records for extremes of cost per kWh, and 28 for extremes of savings as a percent of sales; since some records belong to both groups, only a total of 75 were removed.

1.2. Picturing the data

Summary statistics for the data used in our analysis appear in Table 1. The average and median are based on unweighted data (i.e., giving the same weight to every reported program, regardless of size), while the "savings-weighted average" assigns weights to observations in proportion to their energy savings.

Table 1. Average and median values

	Lifetime savings (GWh)	Electricity sales (GWh)	Total costs (2015 $ thousand)	First-year savings/sales	Cost / kWh of lifetime savings
Average	346	5,568	$8,872	0.59%	$0.039
Median	14	633	$300	0.41%	$0.024
Savings-weighted average				1.25%	$0.026

The distribution of the savings / sales ratio is shown in Figure 1. The largest concentration of programs is in the smallest category, with first-year savings of less than 0.25 percent of sales. At the other extreme, just 33 programs have first-year savings above 2.25 percent of sales.

Figure 1. Distribution of programs by savings / sales ratio

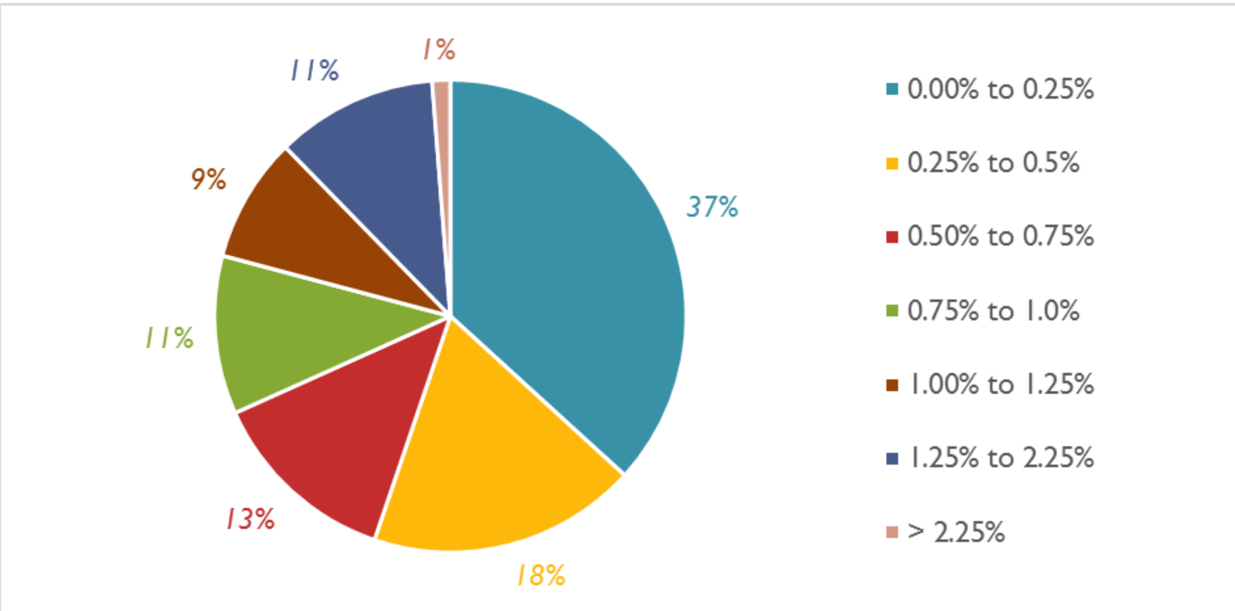
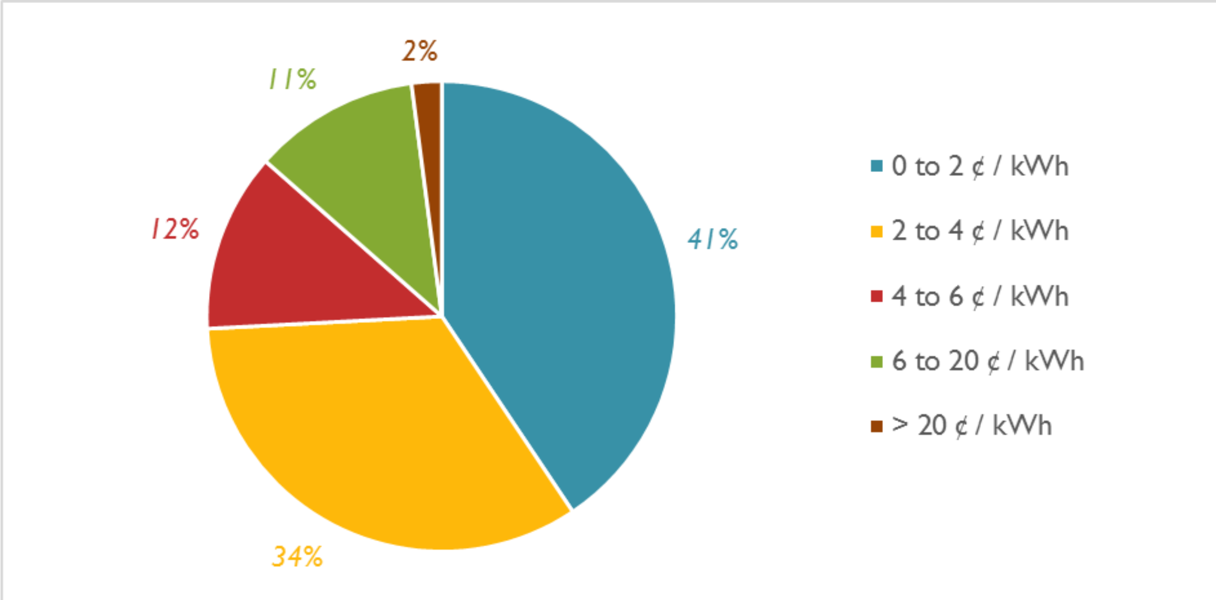


Figure 2 presents a similar picture of the cost per saved kWh. More than 70 percent of all programs are in the two least expensive categories, with costs per kWh below $0.04. At the other extreme, there are just 64 programs with costs above $0.20 per saved kWh.

Figure 2. Distribution of programs by cost per saved kWh



2. The Cost of Energy Efficiency

2.1. Costs vs. savings

A graph of costs versus lifetime energy savings, in Figure 3, primarily illustrates the small size of the great majority of programs, and the unsurprising fact that larger programs have higher costs. It hints at two different patterns for the very largest programs (i.e., the two “arms” or dotted lines extending toward the right of the graph). These could reflect either different approaches to data reporting, or genuine differences in cost-effectiveness. The pattern of costs for the largest programs is a topic that deserves further research.

Figure 3. Costs vs. lifetime savings

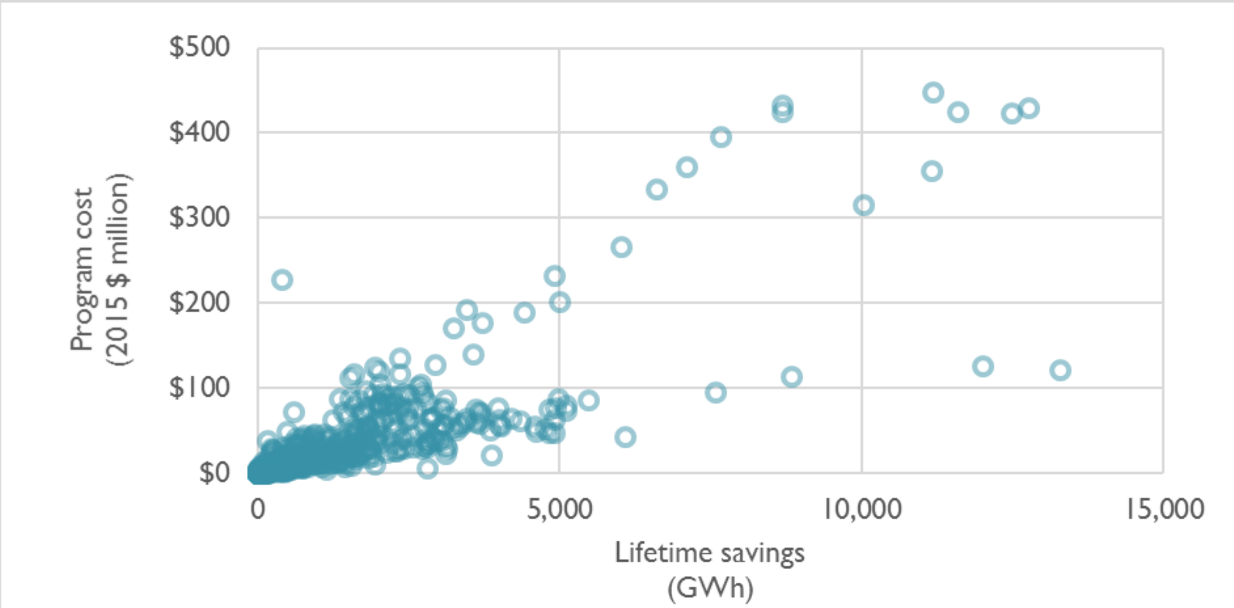


Figure 3 demonstrates that there is a strong relationship between costs and savings. The next section examines the ratio of these two variables, i.e., costs per kWh of savings.

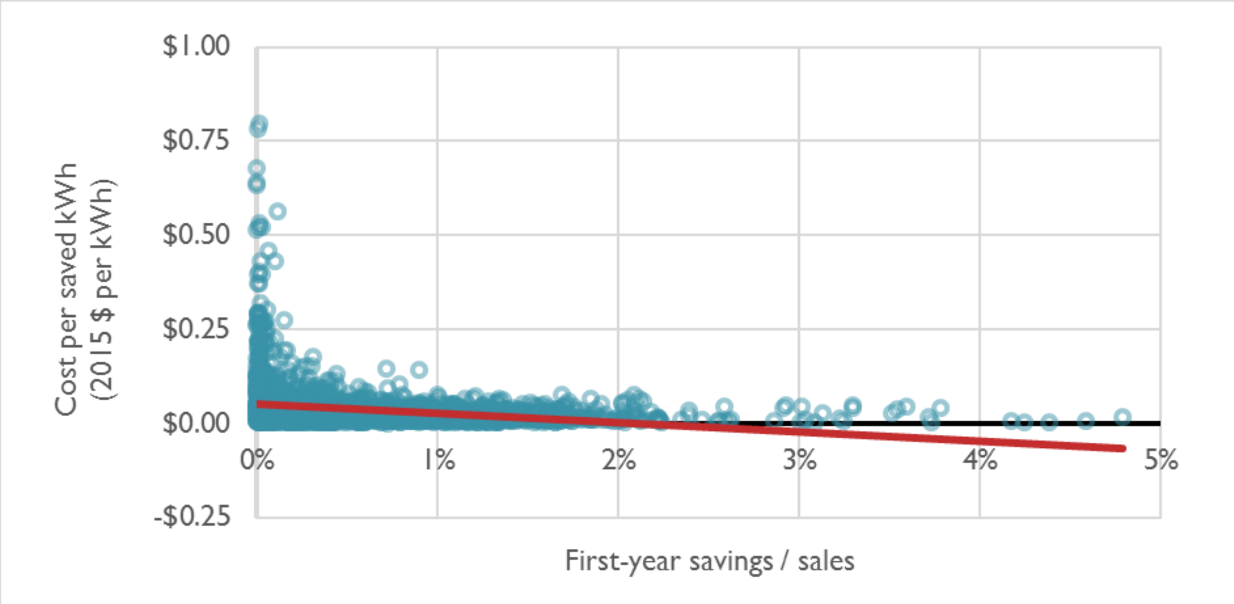
2.2. Explaining costs per kWh

One key finding in our analysis is the relationship between cost per kWh of savings and the extent of savings—i.e., the savings as a percent of sales. All else being equal, a greater extent of savings is associated with lower costs per saved kWh.

A conventional linear estimate, however, does not offer a helpful picture of this relationship. As seen in Figure 4, the linear trend is a poor fit to the data, and makes the implausible prediction that costs turn negative as soon as first-year savings are a little above 2 percent of sales.[4]

[4] The linear regression estimate (the trend line shown in Figure 4) has $r^2 = 0.066$, and implies that costs are zero when the savings/sales ratio is 2.14 percent.

Figure 4. Cost per saved kWh vs. savings / sales ratio, with linear trend



A log-log estimate (a linear relationship between the logs of the two variables) produces a better fit to the data, and does not forecast negative costs.[5] The estimate, shown by the trend line in Figure 5 is

(Equation 1) $\mathbf{C} = 0.0065\ \mathbf{S}^{-0.226}$ $r^2 = 0.162$ (n = 2,655)

—where **C** is cost per kWh of lifetime savings in 2015 dollars, and **S** is first-year savings as a percent of sales. Although the relationship is statistically significant, it can explain only about 16 percent of the overall variation in costs (as shown by $r^2 = 0.162$). Thus other factors—which deserve further research—must account for 84 percent of the variation in program costs per kWh. On average, a doubling of savings is associated with a 14 percent reduction in costs (since $2^{-0.226} = 0.86$).

[5] Equation 1 is the linear regression of log C vs. log S – transformed into the equivalent relationship between the unlogged variables. The same is true for similar equations presented below.

Figure 5. Costs per saved kWh vs. savings / sales ratio, log scale

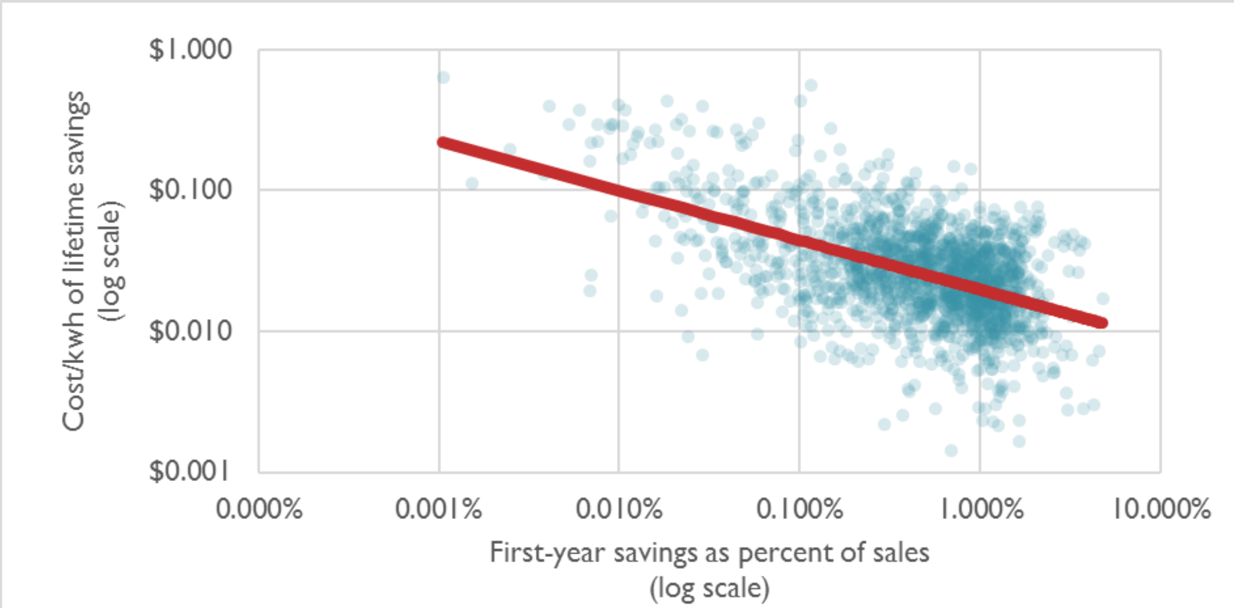
This relationship is robust under several modifications. Additional screening for potential outliers or data entry errors had little effect: elimination of records with total costs under $10,000 or first-year savings under 10 MWh cut some potential data entry errors, but produced only modest changes in Equation 1.

Elimination of programs with total costs under $100,000 cut a larger number of points, but still yielded a qualitatively similar relationship, as shown in Equation 2 and Figure 6.

(Equation 2) $\mathbf{C} = 0.0039\ \mathbf{S}^{-0.352}$ $r^2 = 0.273$ (n = 1,773)

Among this set of larger programs, doubling the size of the program is associated with an average reduction of just over 21 percent in cost per kWh (since $2^{-0.352} = 0.784$).

Figure 6. Cost per saved kWh vs. savings/sales ratio, program costs > $100,000, log scale



3. Trends over Time

Our dataset includes data from six consecutive years, making it possible to examine changes from year to year. Since 2012, the average program has grown slightly more ambitious and the average costs per kWh have declined, as shown in Table 2. This section will demonstrate that these are two separate trends: the programs that have grown more ambitious are not, in general, the same as the ones for which costs have declined.

Table 2. Average savings/sales ratio and cost per kWh saved by year, 2010 to 2015

	First-year savings/sales	Cost per saved kWh
2010	0.533%	$ 0.044
2011	0.544%	$ 0.041
2012	0.556%	$ 0.048
2013	0.610%	$ 0.039
2014	0.602%	$ 0.033
2015	0.639%	$ 0.032

The trends in these ratios are different for large and small programs. To illustrate the differing patterns by size, both ratios can be calculated for programs above and below the median savings / sales ratio of 0.41 percent.

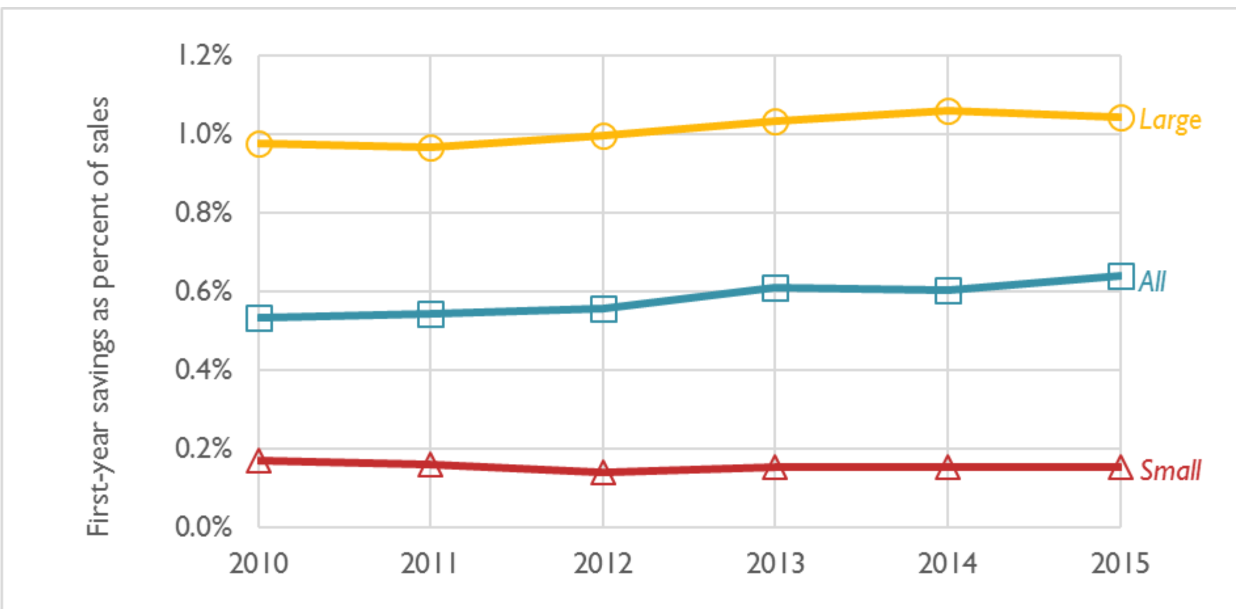
Using this definition of large and small, the trend in the savings / sales ratio is shown in Table 3 and Figure 7. Large programs became slightly larger from 2010 to 2015, while small programs, on average, became slightly smaller. The overall average ratio grew faster than either large or small programs (as shown by the last line of Table 3), due to the growing number of large programs. In 2010, large programs were 45 percent of the total; by 2015 they had grown to 55 percent. That is, large programs not only grew larger, but also accounted for an increased share of the overall average.

Thus the growth in the overall average size of programs is due to the growing size, and growing number, of large programs.

Table 3. Average savings/sales ratio by size of program and year

	All	Large	Small
2010	0.533%	0.976%	0.171%
2011	0.544%	0.967%	0.161%
2012	0.556%	0.996%	0.140%
2013	0.610%	1.034%	0.155%
2014	0.602%	1.060%	0.152%
2015	0.639%	1.041%	0.155%
Ratio: 2015/2010	***1.20***	***1.07***	***0.91***

Figure 7. Average savings/sales ratio by size of program and year, 2010 to 2015

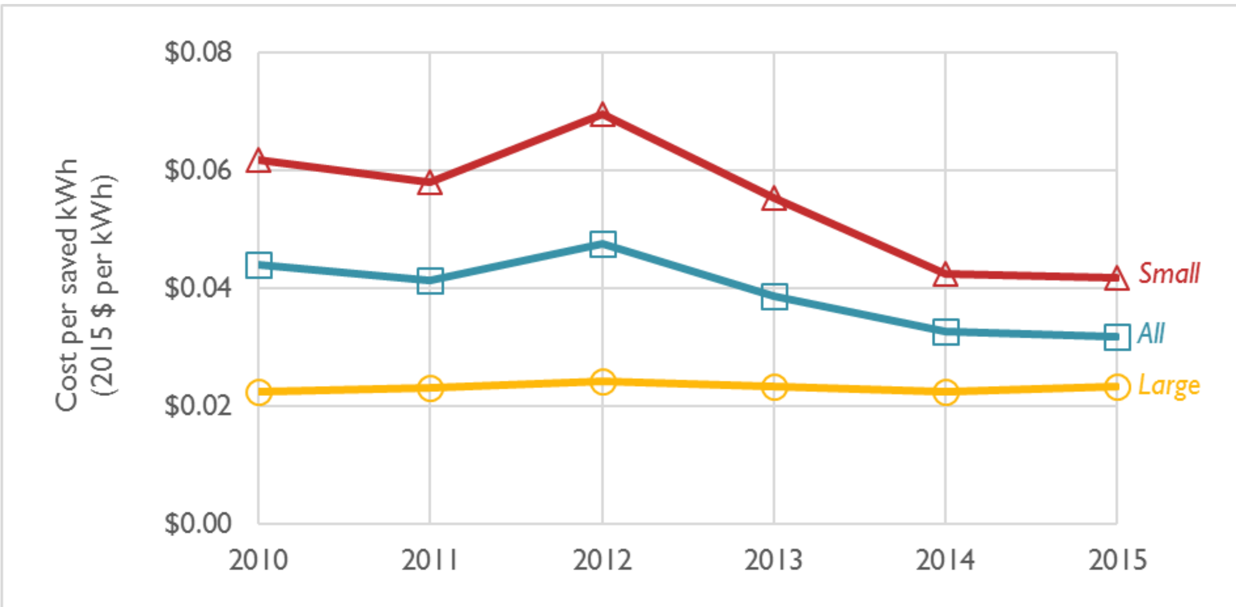


A comparable picture for costs per kWh of savings is presented in Table 4 and Figure 8. In this case, the decline in overall average costs parallels the declining costs of smaller programs (see Figure 8), while the costs of larger programs were nearly constant at around $0.023 per saved kWh. The overall average cost per kWh of these large programs in 2015 was 72 percent of the cost per kWh in 2010; for small programs the 2015 costs fell to 68 percent of the 2010 level (see the last line of Table 4).

Table 4. Average cost per saved kWh by size of program and year, 2010 to 2015

	All	Large	Small
2010	$ 0.044	$ 0.022	$ 0.062
2011	$ 0.041	$ 0.023	$ 0.058
2012	$ 0.048	$ 0.024	$ 0.070
2013	$ 0.039	$ 0.023	$ 0.055
2014	$ 0.033	$ 0.023	$ 0.043
2015	$ 0.032	$ 0.023	$ 0.042
Ratio: 2015/2010	***0.72***	***1.04***	***0.68***

Figure 8. Average cost per saved kWh by size of program and year, 2010 to 2015



In summary, efficiency programs are growing larger over time, while the costs of smaller programs are declining. Meanwhile, the costs of large programs have been roughly constant from year to year, at around $0.023 per saved kWh. This is far below the average wholesale costs of supplying energy.