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Prepared for the
U.S. Department of Energy and U.S. Environmental Protection Agency

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All opinions, errors and omissions remain the responsibility of the authors. All reference URLs were accurate as of the date of publication.

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Acronyms and Abbreviations

CAGR	Compound annual growth rate
C&I	Commercial, industrial and agricultural
CEE	Consortium for Energy Efficiency
CSE	Cost of saved electricity
DOE	U.S. Department of Energy
DSM	Demand-side management
EE	Energy efficiency
EM&V	Evaluation, measurement and verification
GWh	Gigawatt-hour
HVAC	Heating, ventilation and air conditioning
ISO-NE	ISO New England
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
PA	Program administrator
PA CSE	Program administrator cost of saved electricity
QAQC	Quality assurance and quality control
Total CSE	Total cost of saved electricity

Executive Summary

This report marks the most comprehensive effort yet to quantify the cost of saving electricity through efficiency programs funded by customers of the investor-owned utilities that serve nearly 70% of U.S. electricity needs (EIA 2016). Cost-effective efficiency programs are an important tool used by utilities to provide reliable service at least cost.

Policymakers, regulators, utility resource planners, and efficiency program administrators and implementers rely on cost performance metrics, such as the cost of saved electricity, to assess energy savings potential, to design and implement programs in a cost-effective manner, and to help ensure electricity system reliability at the most affordable cost as part of resource adequacy planning and implementation processes. In addition, declining costs for some supply-side resource alternatives (e.g., wind, solar and natural gas) have sharpened discussion on the composition and market share of clean energy investments. Thus, accurate assessments of energy efficiency program costs and performance are an increasingly important policy and regulatory priority.

Electricity efficiency programs funded by utility customers are offered in nearly every state. These programs target all market segments (residential, commercial, industrial and agriculture) and include financial incentives, technical assistance, education and energy audits. Building on Berkeley Lab's earlier work, this report analyzes cost performance of efficiency programs implemented between 2009 and 2015 which were funded by customers of 116 investor-owned utilities and other program administrators in 41 states (see Figure ES-1).

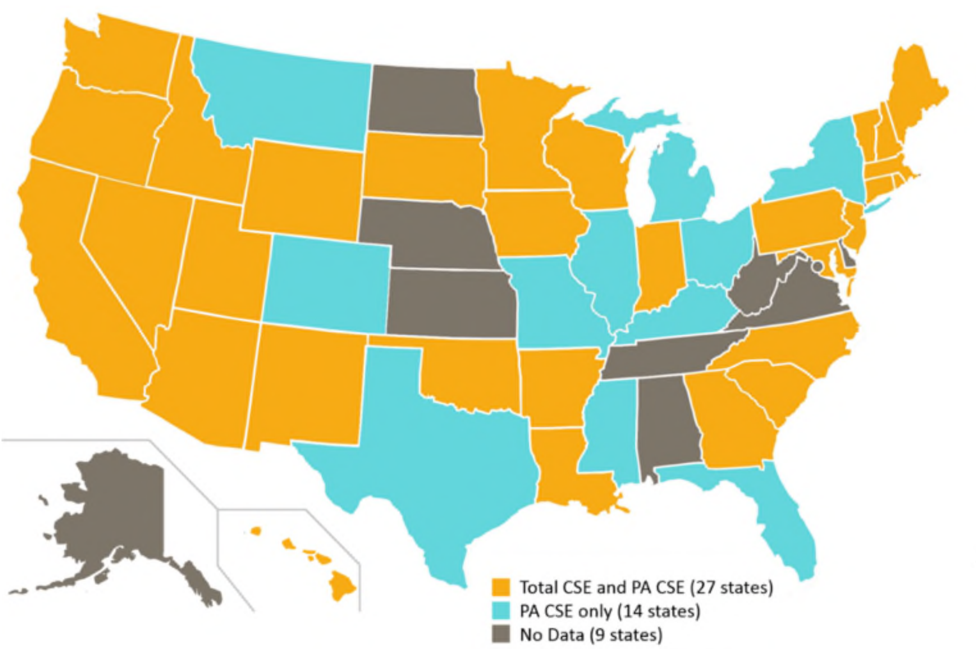


Figure ES-1. States in the LBNL Demand-Side Management Program Database

We quantify the *levelized program administrator cost of saved electricity (PA CSE)* and the *levelized total cost of saved electricity (Total CSE)*—based on costs and savings reported by program administrators—on national, regional and state scales and at the program level (see Key Definitions text box). States, utilities and regional planning entities rely on these cost metrics for many purposes: to project efficiency's impact on load forecasts, model resources to meet future electricity needs, benchmark local programs against regional and national estimates to improve efficiency portfolios, assess how to meet state resource targets, and evaluate how program costs are likely to change over time with funding levels and participation.

Nomenclature: Cost of saved *energy* vs. cost of saving *electricity*

We use two related terms in this report:

- ***Cost of saved energy*** – This broad term refers to how much it costs to save a unit of energy — for example, a kilowatt-hour of electricity or a therm of natural gas — through energy efficiency programs.
- ***Cost of saving electricity*** – This more specific term refers to how much it costs to save a kilowatt-hour of electricity. This cost performance metric, expressed in dollars or cents per kilowatt-hour, is the focus of this report.

These metrics are useful for comparing the relative costs of various efficiency programs, as well as for comparing an energy efficiency option to other demand and supply choices for serving energy needs. See the "Key Definitions" box below for additional terms used in this report.

Key Definitions

Program administrator costs include costs for administration, marketing and outreach, incentives paid to customers (or contractors, retailers, manufacturers), technical assistance (e.g., energy audits), and evaluation, measurement and verification (EM&V).

Net participant costs include the consumer purchase costs of energy-efficient equipment, measures or appliances net of any incentives paid by the program (e.g., rebates).

Total costs include program administrator costs plus costs incurred by participating customers.

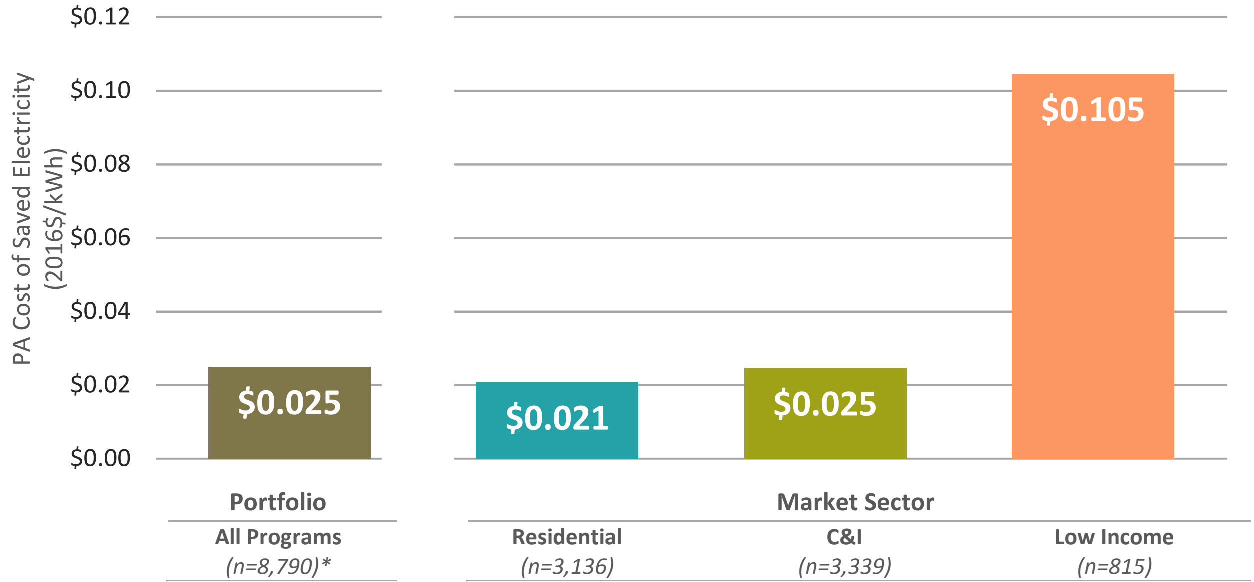
Program savings are primarily based on *claimed gross savings* reported by the program administrator unless indicated otherwise. Savings values are based on *savings at the end-use site*. Lifetime electricity savings, when not reported by the program administrator, were calculated per the approach described in Appendix D.

The **levelized PA CSE** is the cost incurred by the program administrator for achieving electricity savings over the economic lifetime of the measures installed by customers participating in a program, amortized over that lifetime and discounted back to the first year.

The **levelized Total CSE** includes costs incurred by the program administrator and participants for achieving electricity savings over the economic lifetime of the measures installed by customers participating in a program, amortized over that lifetime and discounted back to the first year.

The Program Administrator Cost of Saved Electricity

The PA CSE for the national "portfolio" of all programs and related activities between 2009 and 2015 is $0.025/kWh in constant 2016 dollars (see Figure ES-2).



** The sample size for the full portfolio includes programs for which savings are not claimed, but which support the efficiency activities of the program administrator (e.g., planning, research, evaluation and measurement). Costs for these programs are included in our calculation of PA CSE at the portfolio and market sector level.*

Figure ES-2. Program administrator cost of saved electricity for efficiency programs by market sector: savings-weighted averages

Programs in the residential sector had a savings-weighted PA CSE of $0.021/kWh, excluding low-income programs (see Figure ES-3). Residential lighting rebate programs had an average PA CSE of $0.011/kWh. Lighting programs were a key driver of the low values in the residential sector as they accounted for 45% of the sector's lifetime savings. Appliance and consumer electronics rebate programs had an average CSE of $0.029/kWh and accounted for 10% of the sector's lifetime savings. Whole-home retrofit programs typically have a higher cost of savings ($0.069/kWh) because projects are more comprehensive in scope, often including heating and air-conditioning system replacements. In cold climates, air sealing and insulation are common measures. Further, the full cost to participating customers of these measures, not the incremental cost (the cost above standard practice), is typically used for most cost estimates.

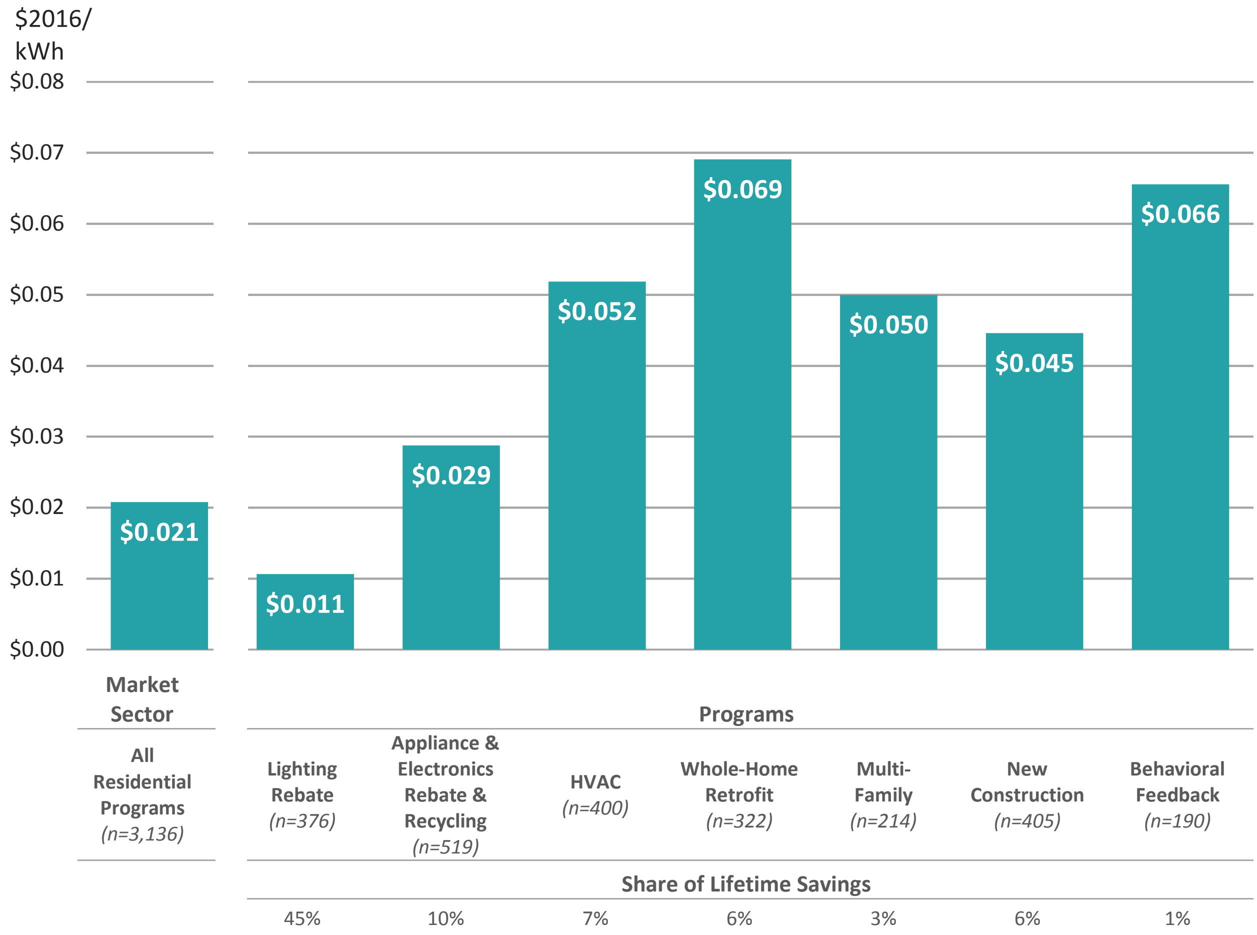


Figure ES-3 Program administrator CSE for the residential sector and select programs: savings-weighted averages

Behavioral feedback programs rapidly proliferated among program administrators from 2009 to 2015. These programs use mailed and online messages to customers to persuade them to reduce their consumption by comparing their energy use to that of similar households. These behavioral feedback programs appear to be among the costlier sources of residential electricity savings ($0.066/kWh) during our study period. Nearly all program administrators assumed that savings from behavioral feedback programs lasted one year, and we rely on *reported* lifetimes from program administrators in calculating the CSE. However, a growing number of evaluations suggest that participants' efficiency behaviors last longer.[1] If we had assumed that all behavioral feedback programs had an effective useful lifetime of three years, then the savings-weighted average CSE for these programs would have been much lower—$0.028/kWh.

The average PA CSE for programs that targeted commercial, industrial and agricultural customers (collectively "C&I" sector) was $0.025/kWh. Three types of C&I programs—rebates for custom retrofits;

[1] One meta-analysis (Khawaja and Stewart 2014) of evaluations of the five longest-running behavior feedback programs recommends using a measure lifetime of 3.9 years.

prescriptive rebates for installation of high-efficiency lighting, HVAC equipment and controls, refrigeration and motors; and new construction—accounted for 74% of the C&I sector's annual and lifetime savings. Average CSE values for these three program types are quite attractive, ranging between $0.019/kWh and $0.026/kWh (see Figure ES-4). Programs that specifically target small C&I customers contributed 10% of the lifetime electricity savings in the C&I sector with an average CSE of $0.038/kWh.

Market Sector	Select Programs				
Commercial, Industrial & Agricultural *(n=3,339)*	Custom Rebate *(n=1,002)*	Prescriptive Rebate *(n=863)*	New Construction *(n=242)*	Small Commercial *(n=414)*	MUSH & Other Gov't *(n=481)*
	Share of Lifetime Savings				
	37%	27%	10%	10%	3%

Figure ES-4. Program administrator CSE for the C&I sector and select programs: savings-weighted averages

Programs aimed at low-income households were costlier at $0.105/kWh, but accounted for a modest share of spending (9%). These programs also accounted for a small share of overall savings (2%). Program administrators typically pay the full cost of measures for these programs and often incur costs to address issues related to the poor condition of older homes and health and safety issues (e.g., asbestos removal, old wiring) before efficiency measures can be installed. Low-income programs also often have aims beyond energy savings (e.g., lower energy bills, improved health and safety of occupants, better comfort).

Trends in PA CSE over time

We also examined trends in the cost of saved electricity over time.[2] Our sample of 116 program administrators includes program-level data for 51 administrators for the entire study period. That enables a comparable longitudinal analysis as well as separating out the potential impact of new administrators who may be ramping up efficiency programs in the later years of the study period. The average CSE for this sample trends upward over time from $0.022/kWh in 2010 to $0.026/kWh in 2015. This translates into a compound annual growth rate of about 3.5% (accounting for inflation).

Further, we segmented the 51 program administrators into three equal groups, by annual energy savings, which tends to be correlated with the size of the utility (i.e., its retail electricity load). The increase in the savings-weighted PA CSE for this sample was driven primarily by the 3.5% increase in the PA CSE for the largest program administrators, accounting for almost two-thirds of annual savings. In contrast, the savings-weighted PA CSE declined slightly (-0.6% per year) for the generally smaller and newer program administrators, accounting for just 7% of annual savings among the 51 PAs.

Regional and State Trends

The cost of saving electricity varied significantly among U.S. Census regions ranging from a low of $0.015/kWh in the Midwest to $0.033/kWh in the Northeast. The CSE values were comparable in the South and West ($0.025/kWh).

Figure ES-5 shows average CSE values for all 41 states in our dataset with the dotted red line showing the national savings-weighted average value. CSE values for 16 states were less than or equal to $0.02/kWh during the 2009-2015 study period. These states tended to be concentrated in the Midwest, South and Intermountain West. Some of these states were relatively new to energy efficiency, were just ramping up their programs with a heavy focus on lighting, or had program design restrictions that limited savings acquisition (e.g., caps on customer payback periods).

Five states had average CSE values that exceeded $0.04/kWh during the study period. Four of these are Northeast states (CT, VT, MA, NH) with relatively high electricity prices, extensive histories in pursuing energy savings and strong policy commitments (e.g., statutory mandates to acquire all cost-effective energy efficiency or meet specified energy savings targets). Thus, they tend to have greater market saturation for efficiency measures and have mined more of the lowest cost savings opportunities.

[2] A previous LBNL study (Hoffman et al. 2017) examining such trends involved a smaller dataset and shorter timeframe (2009-2013).

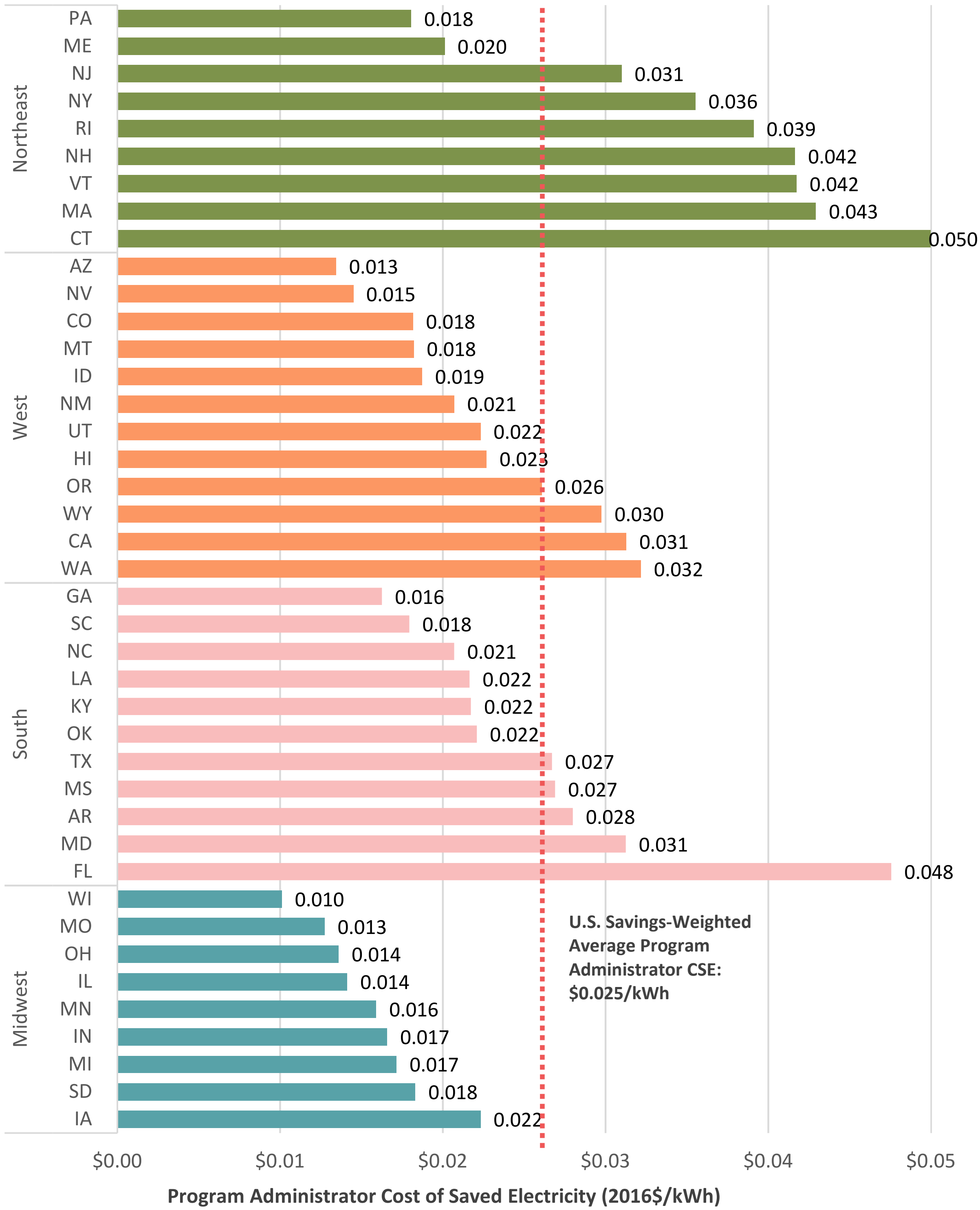


Figure ES-5. Program administrator CSE by state for 2009–2015: savings-weighted averages

A Multi-Program Cost Curve for Electricity Efficiency

We developed an aggregate "cost curve" for electricity efficiency programs implemented between 2009 and 2015. Figure ES-6 provides a composite portrait of the electricity efficiency resource across market sectors (residential and C&I) and program types. Programs are arrayed along the x-axis in ascending order based on their relative CSE. The width of each bar on the x-axis is scaled to represent the lifetime savings of that program type. The values at the top of each bar show the percentage of total lifetime savings for all programs for which savings were claimed between 2009 and 2015.

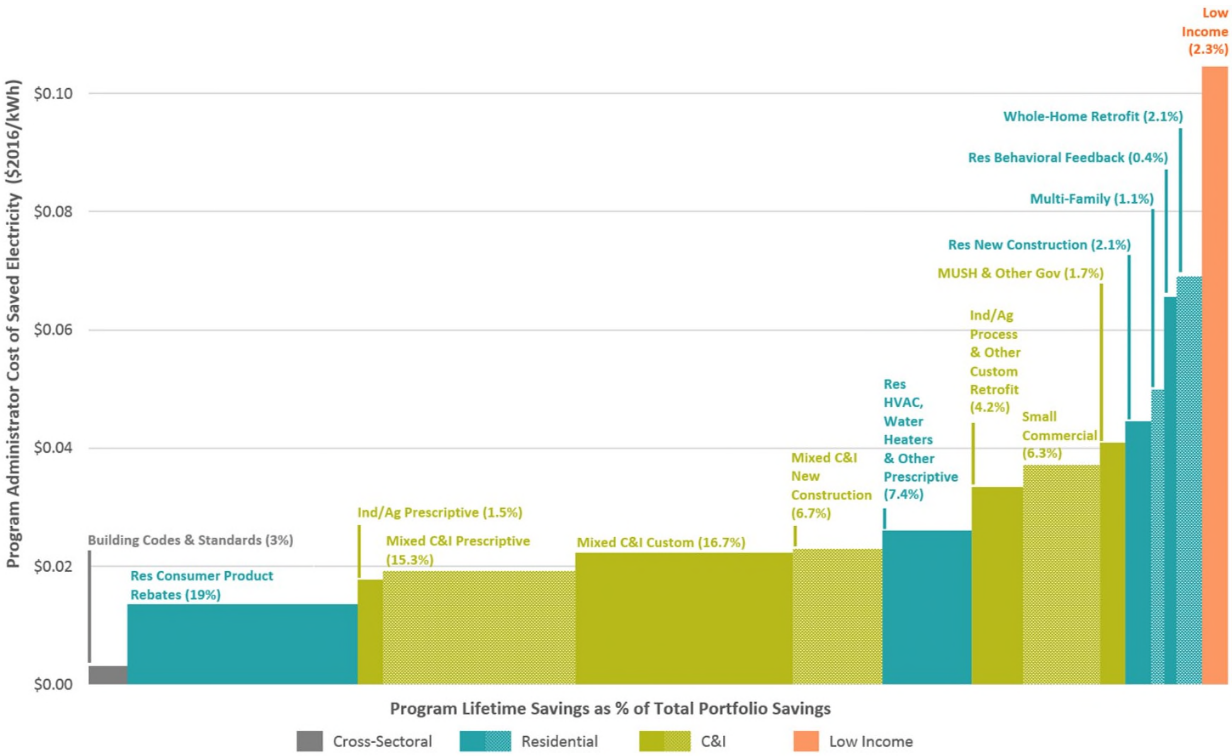


Figure ES-6. Composite cost curve for electricity efficiency programs funded by utility customers (2009-2015)

Utility customer-funded programs aimed at supporting more stringent building energy codes are the least-cost efficiency resource, but these programs are only offered in a few states (e.g., CA, MA). Residential lighting and other consumer product rebate programs provide the most lifetime savings at the lowest cost. Moving up the cost curve are C&I custom and prescriptive programs disaggregated by market sector (e.g., industrial and agricultural customers) and mixed (programs serving a mix of commercial, industrial and agricultural customers).

We draw two major implications from the cost curve. First, residential efficiency portfolios are highly dependent on low-cost savings from rebates for lighting and other residential consumer products. Federal and state energy efficiency standards are substantially raising the energy performance of those products. Further, the performance of light-emitting diodes (LEDs) continues to improve and unit costs continue to decline. As market penetration of LEDs increases, program administrators may have reduced opportunities to acquire low-cost savings through residential lighting programs because an increasing number of consumers may be adopting LED technology irrespective of efficiency programs. If there are significant changes to the costs of residential lighting programs or savings potential decreases, the cost of savings could increase for the overall portfolio.

Second, C&I programs—specifically, rebates for C&I custom retrofits, prescriptive measures and new construction—deliver nearly half of the national portfolio savings on a lifetime basis, and the CSE values for these programs are attractive. The bulk of these savings come from large C&I customers. However, in recent years, more states have allowed large C&I customers to opt out of utility efficiency programs or choose self-direct program options.[3] Where customers can opt out, between 10% and 30% of a utility's load typically no longer participates in the efficiency programs offered. If this trend continues, it will likely shift reliance for savings in the C&I sector onto market sectors dominated by small to mid-size C&I customers, which have higher PA CSE values in our sample and lower savings potential. Thus, a shrinking C&I market for program administrators may put upward pressure on CSE values in the C&I sector and the overall portfolio.

The Total Cost of Saved Electricity

A subset of our sample—27 states—included sufficiently granular data to calculate the Total CSE. The Total CSE for 2009-2015 programs in our sample was ~$0.05/kWh (Figure ES-7). The total CSE for programs that targeted residential customers was $0.039/kWh, while the Total CSE for programs that focus on low-income households was $0.145/kWh. The average value for Total CSE for the C&I sector was $0.055/kWh.

[3] States vary in their criteria for customers eligible to opt out or self-direct. Many states set criteria at greater than 1 megawatt peak demand. In some jurisdictions, industrial customers may choose to opt out of the efficiency programs and may not pay for the costs of energy efficiency programs or receive any of the benefits (e.g., incentives).

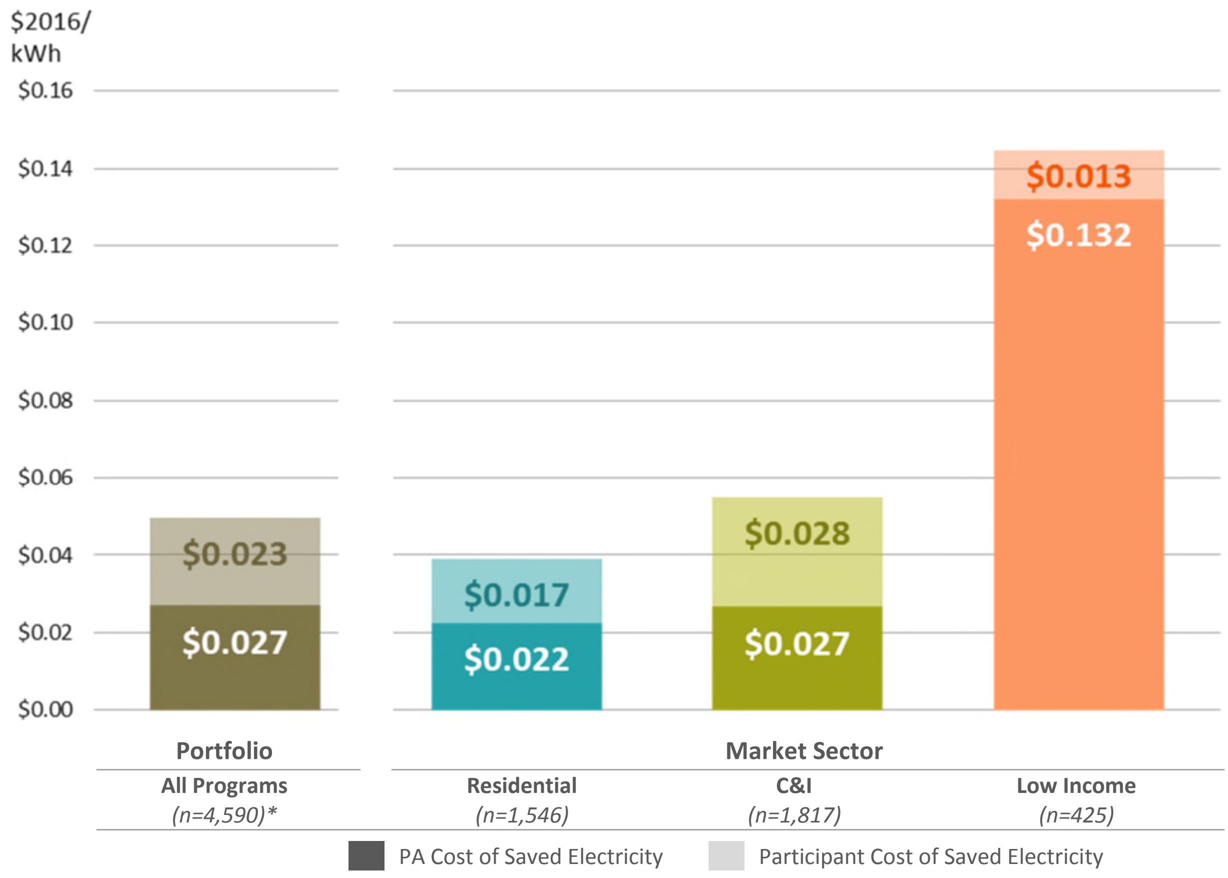


Figure ES-7. Total cost of saved electricity for efficiency programs by sector: national savings-weighted averages[4]

Figure ES-7 presents the Total CSE as stacked bar charts, with the program administrator cost component on the bottom (darker shade) and the participant cost component on the top (lighter shade). From a resource investment perspective, the program administrator cost can be regarded as the cost of leveraging investment by participants. To acquire savings across the full portfolio of programs, program administrators contributed about 54% of total costs while participants contributed about 46%.

[4] Because Total CSE can be calculated for only a subset of our total sample, PA CSE values in this figure are slightly different than those for the full sample.

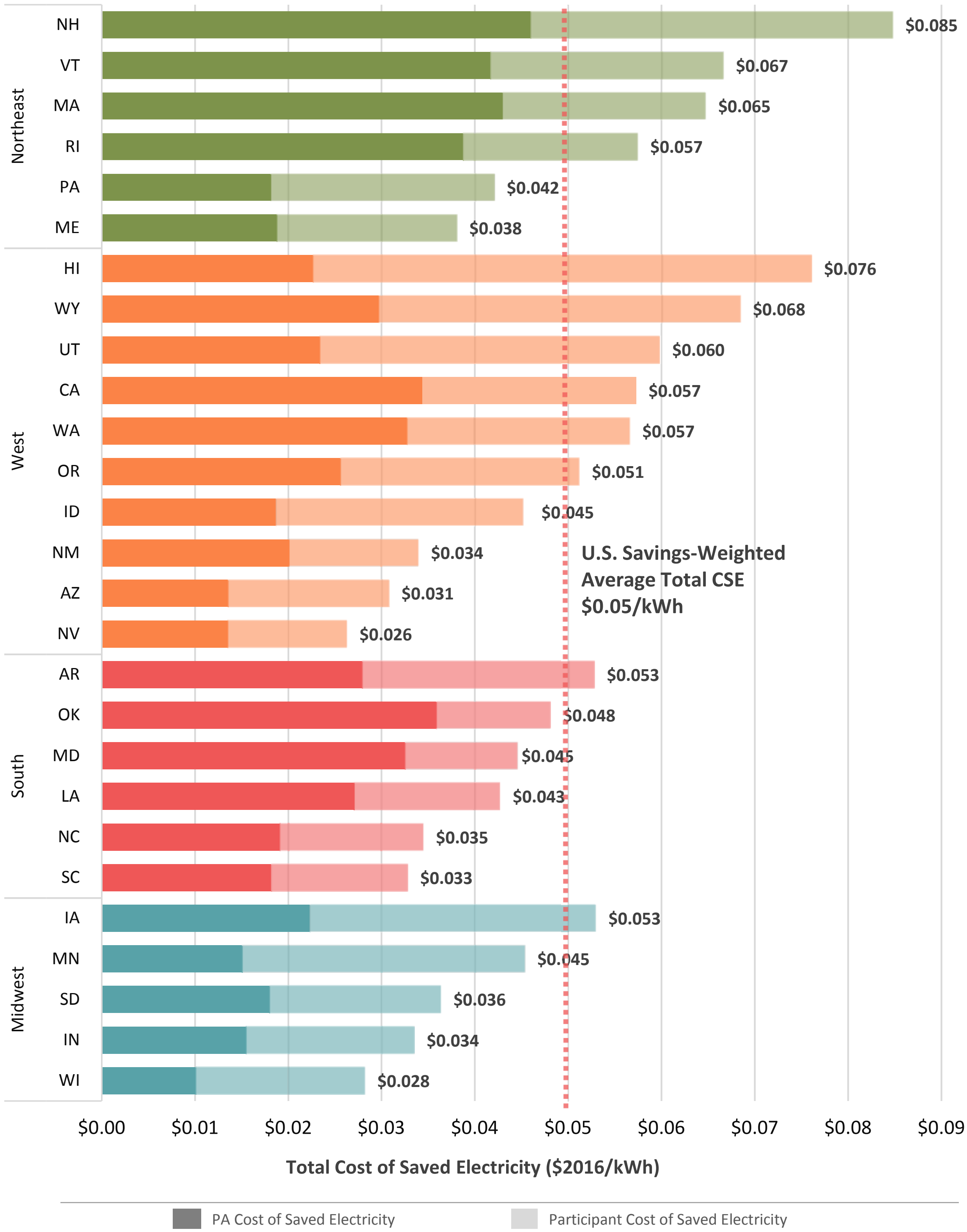


Figure ES-8. Total CSE by state: savings-weighted averages and program administrator (PA) vs. participant costs

The Total CSE varies significantly from region to region and state to state, as illustrated in Figure ES-8. The Total CSE varies by more than a factor of three among states, from a low of ~$0.026/kWh to more than $0.08/kWh. One-third of states in our 27-state sample had a Total CSE less than $0.04/kWh. These states were regionally diverse: three in the West (NM, AZ, NV), three in the Midwest (SD, IN, WI), two in the South (SC, NC) and one in the Northeast (ME). The Total CSE for 15 states in this sample was below the national average of $0.05/kWh. Adjusting for inflation, the Total CSE appears to have increased very little during the last several years in those 27 states.

Progress, Challenges and Future Directions

Over the 2009 to 2015 period, we have witnessed continuation of the expansion in reliance on efficiency programs as a core electricity resource. Program-level reporting of efficiency costs and impacts is increasing and more program administrators are reporting information on customer cost contribution which allows us to calculate the Total CSE.

At the same time, we found that many program administrators do not provide a complete picture of the impacts or costs of efficiency investments at the program level. For example, program average measure lifetimes are essential for calculating the CSE. Yet only 27% of program administrators reported measure lifetime, lifetime savings or both. This data limitation means that we had to impute program average measure lifetime for over half of the program years based on average values from the programs where program administrators reported this information. Public utility commissions may also wish to consider requiring program administrators to report information on participant costs and improve the consistency of estimated lifetimes of installed measures located in similar climate regions across states.

In 2018, we are broadening our analysis of the cost of saved energy to include the cost of saving electricity for public power utilities and the cost of reducing peak electricity demand. We also are conducting a limited update of the cost of saving natural gas. Additional potential areas of exploration include improving our understanding of the cost of saved energy by cost category (e.g., administration vs. incentive costs) and comparing cost performance trends of efficiency and supply-side resources.

Steps such as these will fill in crucial information gaps for efficiency as a cost-effective resource and inform sound decision-making on meeting energy needs reliably and at least cost and risk.

1. Introduction

Energy efficiency in the United States is pursued through a diverse mix of policies and programmatic efforts, which support and supplement private investments in energy efficiency by consumers and businesses. Examples of policy and programmatic efforts include minimum efficiency standards for appliances and equipment promulgated by the U.S. Department of Energy (DOE), state and local building energy codes, tax credits, a national efficiency labeling program (ENERGY STAR®) and efficiency programs that are managed by utilities and other program administrators using utility customer (i.e., ratepayer) funds.

Efficiency programs funded by utility customers target all market segments (residential, commercial, industrial and agriculture) and include financial incentives, technical assistance, education and energy audits. Programs are offered in nearly every state, and 26 states have multiple-year, binding savings targets (ACEEE 2017). Many other states set annual targets. Hundreds of program administrators manage these programs. Program administrators primarily consist of electric and natural gas investor-owned utilities, rural electric cooperatives and publicly-owned electric utilities. State energy agencies and third parties administer utility customer-funded programs in several states.

The cost performance of electricity efficiency programs funded by customers of investor-owned utilities is the focus of this report. The key metric we analyze is how much it costs to save a kilowatt-hour of electricity — ***the cost of saving electricity***.

A broader term, ***the cost of saved energy***, arose from efforts in the 1970s to develop cost performance metrics for energy efficiency programs that could be compared to retail rates and production costs of conventional energy sources (e.g., Sant 1979; Meier 1982, 1984). This broader term encompasses electricity as well as other forms of energy such as natural gas (i.e., the cost of saving a therm). A more comprehensive metric, ***the total cost of saved energy,*** emerged in the early 1990s to account for both the cost to the utility as well as the cost to utility customers participating in efficiency programs (Joskow and Marron 1992; Eto et al. 1994, 1996). Appendix A provides a more detailed account of the development of these metrics. Other researchers have undertaken efforts to quantify the cost of saved energy, most recently Baatz, Gilleo and Barigye (2016), Molina (2014), Arimura et al. (2012), and Takahashi and Nichols (2008 and 2009). These efforts have focused on datasets involving up to 19 states.

Policymakers, regulators, utility resource planners, and program administrators and implementers rely on cost performance metrics, such as the cost of saving electricity, to assess energy savings potential, to design and implement programs in a cost-effective manner, and to help ensure electricity system reliability at the most affordable cost as part of resource adequacy planning and implementation processes. Moreover, declining costs for various supply-side resource alternatives (e.g., wind power, solar photovoltaics, impact of low natural gas prices and increased efficiency of gas-fired generation) have sharpened discussion on the composition and market share of clean energy investments. Spending on electricity efficiency programs funded by utility customers has grown by about 20% since 2011, reaching $5.7 billion in 2016 (CEE 2018). For these reasons, accurate assessments of energy efficiency program costs and performance are an increasingly important policy and regulatory priority.

LBNL launched the Cost of Saved Energy project in 2012 to collect, standardize, and analyze utility customer-funded efficiency program data on a national scale and use this data to help decision-makers assess the cost performance of programmatic efficiency initiatives across geographic regions, states, market sectors and specific types of programs. A related goal was to elevate the state of efficiency program reporting by developing tools and methods (e.g., program typology, standardized definitions for program data, increased transparency) that would facilitate greater consistency and rigor.[5]

In previous reports and technical briefs, we quantified the program administrator cost of saved energy for programs implemented between 2009 and 2013 (Billingsley et al. 2014), the total cost of saved electricity (Hoffman et al. 2015) and trends in the program administrator cost of saved electricity over time (Hoffman et al. 2017). This report marks the most comprehensive effort to date, covering 41 states and drawing from a program sample of 116 administrators between 2009 and 2015 (Appendix A). Our sample is primarily limited to programs that target customers of investor-owned utilities, with a few exceptions.[6]

1.1 Cost of Saved Energy as a Metric

In this report, the key metrics of interest are the *levelized program administrator cost of saved electricity (PA CSE)* and the *levelized total cost of saved electricity (Total CSE)*. The PA CSE enables assessments of efficiency resources from the economic perspective of the utility. The Total CSE captures the full cost—that is, the all-in, composite investment in the efficiency resource by the program administrator and program participants. The cost of saved energy metric is not dependent on variable energy prices or differences in the definition of benefits of efficiency across markets and utility territories.[7]

Resource planners and grid operators often rely on the PA CSE for assessing the prospects for future energy

The Cost of Saved Energy and Cost-Effectiveness Screening

The Utility Cost Test, the Total Resource Cost Test, and the Societal Cost Test are the primary screening tools for comparing the costs and benefits of energy efficiency programs and often inform decisions about whether utility customers should fund a program (NESP 2017). The total cost of saved energy is not intended to define and capture all the benefits of energy efficiency or assign values to them. The total cost of saved energy for the electricity sector answers a simple question: *What is the full cost to save a kilowatt-hour?*

[5] Two technical briefs address reporting tools on the cost of saved energy. All project publications are available at https://emp.lbl.gov/projects/what-it-costs-save-energy.

[6] The territories and customers targeted by third-party program administrators in several states (e.g., Vermont, Michigan) do include those served by publicly owned utilities. We have undertaken efforts to include more public power programs (e.g., see "Energy Efficiency Reporting Tool for Public Power Utilities" at https://emp.lbl.gov/publications/energy-efficiency-reporting-tool) and are continuing to do so.

[7] Energy prices and approaches used to value the monetary benefits of efficiency have some indirect influence on cost of saved energy values because they provide insight on the potential cost-effectiveness of a given efficiency activity.

savings and projecting the impact of energy efficiency on load forecasts.[8] Utility resource planners (and other stakeholders) use both the PA CSE and the Total CSE to determine what efficiency resources are the likeliest candidates for consideration in an integrated resource plan. Program administrators can use both metrics for planning and designing efficiency programs and portfolios.

Cost of saved energy metrics can provide insight on whether program administrators can meet rising energy savings targets cost-effectively and with what types of programs and technologies. Benchmarking local programs against regional and national estimates of the cost of saved energy also can help improve program performance, especially when costs can be disaggregated (e.g., administration and marketing costs, incentives to customers) to reveal opportunities for streamlining implementation. Assessing how the cost of saved energy changes with respect to funding levels and participation also can indicate whether over time a program or portfolio has potential to scale up in savings. Efficiency industry actors can examine the Total CSE and the magnitude of participant investments to assess markets and business opportunities. Finally, trends in the cost of saved energy over time can provide insight into the prominence and magnitude of efficiency as a resource investment in light of cost trends and relative risks of other resource alternatives.

1.2 Report Objectives and Roadmap

This report provides insight on questions of interest to policymakers, market participants and stakeholders in the power sector and the efficiency industry:

- What has the cost of efficiency been in recent years—by region, state, market sector and program type?
- What programs are supplying the most savings, and what is their relative cost performance?
- How diversified is the efficiency portfolio, and how reliant are program administrators and other industry actors on specific types of programs?
- In what ways is the cost of efficiency changing over time and why are those shifts occurring?
- What share of program administrator costs are devoted to administering programs vs. financial incentives to customers?
- What is the balance of efficiency investment between program administrators and participants, and how is the balance changing over time?

The remainder of this report is organized as follows:

- Chapter 2 describes our approach to data collection, standardization and cost performance metrics, as well as some of the challenges inherent in analyzing efficiency program data.

[8] For example, the independent system operator for New England (ISO-NE) calculates a cost of saved electricity for each program administrator in its territory and uses those values, with adjustments, to translate future efficiency program budgets into savings projections that can be used to refine the ISO-NE's load forecast.

- Chapter 3 offers an overview of program spending and annual and lifetime savings, summarized by market sector and program type.
- Chapter 4 presents the PA CSE for 116 program administrators in 41 states by region, state, market sector and type of program (e.g., whole-home retrofits, residential lighting, behavioral feedback, and commercial and industrial new construction). We examine trends in the program administrator cost of savings between 2009 and 2015. We also construct a cost curve for energy efficiency programs funded by utility customers, with programs ranked by cost performance and magnitude of contribution to lifetime savings acquired.
- Chapter 5 examines the relative magnitude of various cost components as a share of total program administrator costs for five selected program types.
- Chapter 6 reports the Total CSE at the national, regional, and state levels and by market sector and type of program type for 67 program administrators in 27 states. We disaggregate the relative contributions of program administrators and program participants to total costs in order to reflect shifts in the balance of investment in the efficiency resource. We also examine trends in the Total CSE between 2009 and 2015.
- Chapter 7 discusses implications of our work on the prospects for and contribution of voluntary efficiency programs as a resource compared to other resource alternatives, provides our assessment of progress on consistency and transparency of program reporting, and identifies areas for improvement.

2. Data Collection and Analysis Approach

Energy efficiency programs funded by utility customers have evolved over the last three decades on a state-by-state basis. This distributed development has fostered diversity in program oversight, design, administration and evaluation. Thus, information that program administrators provide to state regulators on the costs and impacts of programs may vary in the level of detail and specificity as well as terms and definitions for individual programs.

In this chapter, we summarize data that we compiled at the program level for individual program administrators and compare our sample to national spending on electricity efficiency programs funded by utility customers. We describe our program typology and how we calculate metrics for the cost of saved electricity (CSE), including input values for key variables. We also discuss several challenges associated with collecting and analyzing program cost and impact data and calculating CSE values.

2.1 Electricity Efficiency Program Data: Overview

We compiled data for this study primarily from annual reports filed by program administrators of electricity efficiency programs funded by customers of U.S. investor-owned utilities in 41 states between 2009 and 2015 (see Figure 2-1). Compared to our prior reports, we have added program data for 2014 and 2015 for all 41 states, including five new states (Louisiana, Mississippi, South Dakota, Wisconsin and Wyoming).

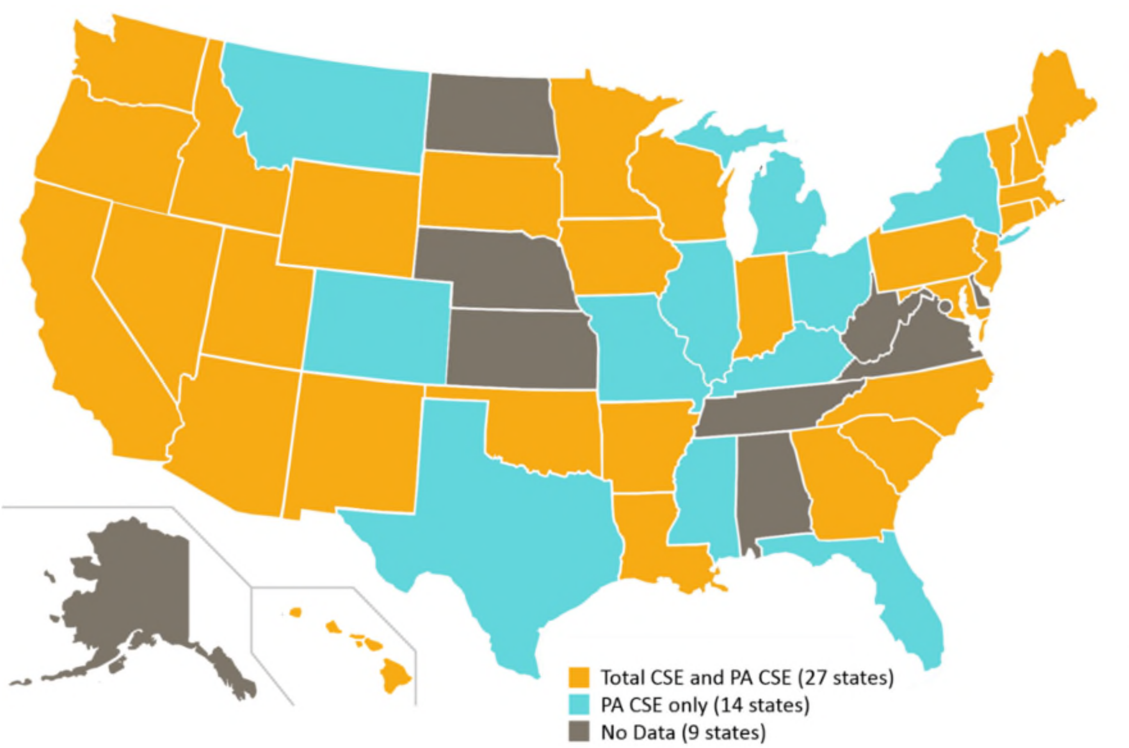


Figure 2-1. States in the LBNL DSM Program Database

At present, the LBNL Demand-Side Management (DSM) Program Database does not generally include data on efficiency programs administered by publicly-owned electric utilities and rural electric cooperatives. A small amount of spending and savings in public- or consumer-owned utility territories is embedded in the data for a few third-party administrators (e.g., Wisconsin Focus on Energy, Efficiency Vermont).

The dataset in this study comprises 8,790 program years.[9] Data fields for each program record (or program year) include the program name, spending information (e.g., budget, actual expenditures, cost breakdown by category), annual and lifetime gross and net energy savings, and participation data (where available) for electricity efficiency programs as reported by 116 program administrators (see Table 2-1).

Table 2-1. Summary of electricity efficiency program data in LBNL DSM Program Database

State	First Year of Data	Last Year of Data	Number of Program Administrators	Number of Program Years
AR	2013	2015	3	99
AZ	2010	2015	3	186
CA	2010	2015	3	1,329
CO	2009	2016	1	304
CT	2009	2015	2	373
FL	2011	2015	5	667
GA	2012	2015	1	64
HI	2009	2015	2	70
IA	2009	2015	2	334
ID	2010	2015	2	149
IL	2008	2014	2	240
IN	2009	2015	5	406
KY	2009	2015	2	131
LA	2014	2015	5	61
MA	2009	2015	5	982
MD	2010	2015	4	403
ME	2009	2015	1	61
MI	2009	2015	2	271
MN	2009	2015	2	382
MO	2013	2015	1	46
MS	2014	2015	2	25
MT	2011	2015	2	57
NC	2009	2015	2	152
NH	2009	2015	3	257

[9] A *program year* is a year's worth of data for each program in the LBNL DSM Program Database. For example, data covering four years of spending and impacts for a particular program represent four program years.

State	First Year of Data	Last Year of Data	Number of Program Administrators	Number of Program Years
NJ	2009	2015	1	114
NM	2010	2015	4	197
NV	2009	2015	2	200
NY	2009	2015	8	552
OH	2009	2015	7	506
OK	2012	2015	3	81
OR	2009	2015	3	42
PA	2009	2015	8	637
RI	2010	2015	1	123
SC	2011	2015	3	168
SD	2014	2015	3	57
TX	2010	2015	10	656
UT	2009	2015	1	72
VT	2009	2015	1	42
WA	2010	2015	2	176
WI	2009	2015	1	101
WY	2009	2014	1	36
			116	***8,790***

We relied primarily on annual DSM or efficiency reports filed by program administrators with state regulatory agencies because they typically include data for a portfolio of programs and are publicly available. In cases when particular data were not readily available in annual reports or were ambiguous, we consulted other reports or solicited information directly from the program administrator or state regulatory staff.[10]

2.2 LBNL Program Database Spending vs. National Spending

The LBNL DSM Program Database represents an increasing share of national electricity efficiency program expenditures (see Figure 2-2). We use the American Council for an Energy-Efficiency Economy (ACEEE) Scorecard report (ACEEE 2017) as the reference for national expenditures. The ACEEE Scorecard includes efficiency expenditures reported by investor-owned utilities as well as publicly owned utilities.[11]

The share of national expenditures on electricity efficiency programs represented in the LBNL database grew from 24% in 2009, when we first began collecting data, to 80% in 2014. Our data for 2015 accounts for about 70% of the spending on these programs as reported by ACEEE. This modest decline

[10] In some cases, we used data from evaluation reports by independent third party evaluators that were included as attachments to the program administrator annual reports.
[11] ACEEE includes energy efficiency expenditure data from publicly owned utilities to the extent that they are reported to the U.S. Energy Information Administration (EIA) or regulatory authorities.

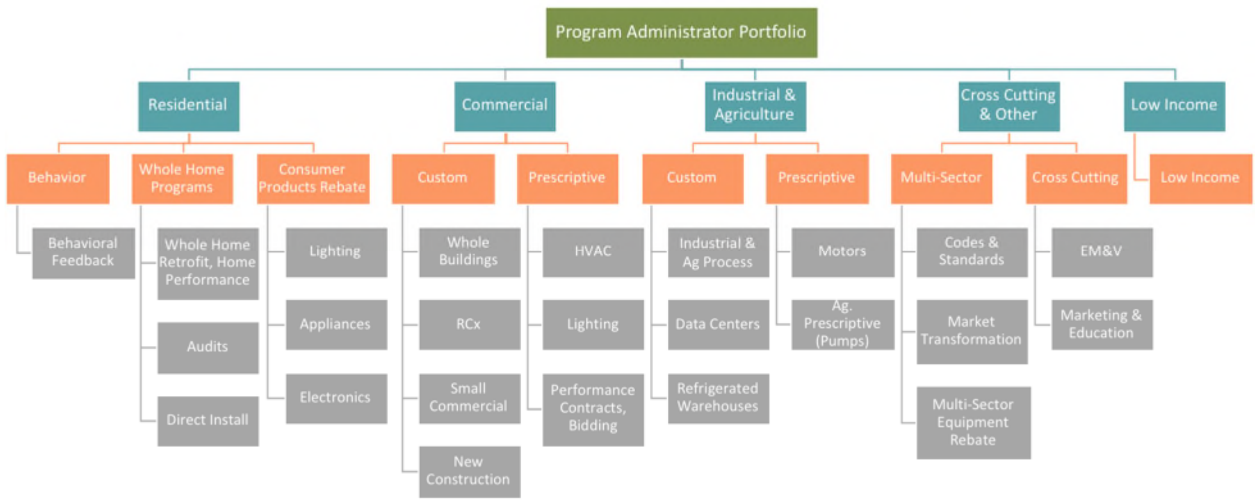
occurred in part because of the lag between when program administrators report their program year results and when we collected data for that state. The increasing share of efficiency program data in the LBNL database is due primarily to the fact that more investor-owned utilities are reporting annual results at the program-level rather than just at the overall portfolio level, consistent with the program typology that we developed (Hoffman et al. 2013). The gaps in our coverage of impacts and spending for utility customer-funded programs are driven by the nine states that do not report this information and the fact that we generally do not have program-level data on efficiency programs administered by publicly-owned electric utilities and rural electric cooperatives.

Figure 2-2. Expenditures on electricity efficiency programs funded by utility customers: LBNL Program Database vs. ACEEE estimate ($ billion)

Source: LBNL Program Database and Berg et al. (2017)

2.3 Program Typology

In order to analyze similar types of efficiency programs, we developed a standard typology that characterizes programs along several dimensions: market sector, technologies, delivery approach, and intervention strategy. Figure 2-3 provides a partial snapshot of the three tiers in the typology: (1) market sector; (2) simplified program categories; and (3) detailed program categories. In total, the typology includes seven sectors, 27 simplified program categories and 62 detailed program categories for energy efficiency (Hoffman et al. 2013).[12] We are able to compare programs in common markets (e.g., commercial custom rebate and commercial prescriptive rebate) and analyze the differences in program designs (e.g., whole home/direct install vs. whole home/audits). Appendix C provides an in-depth discussion of the program typology as well as definitions used by LBNL researchers to classify efficiency programs.



Note: Not all sectors and simplified and detailed program categories are shown in this figure

Figure 2-3. Selected program types in the LBNL program typology

2.4 Cost of Saved Electricity: Definition and Inputs

In Section 1.1, we identified the key metrics of interest in this study—the levelized program administrator CSE and the levelized total CSE—and discussed potential applications of these metrics for policymakers and program administrators. In this section, we provide additional information on key assumptions and input variables used in calculating the CSE values.

The levelized CSE is the cost of achieving electricity savings over the economic lifetime of the actions taken as a result of a program, amortized over that lifetime and discounted back to the year in which the costs are paid and the actions taken. The program administrator CSE accounts for expenditures in planning, administering, designing and implementing programs and providing incentives to market allies and end users to take actions that result in energy savings, as well as the costs of verifying those

[12] LBNL developed this typology in consultation with other organizations (e.g., Consortium for Energy Efficiency, ACEEE).

savings.[13] The total CSE also includes costs incurred by participants (e.g., the consumer purchase cost of energy-efficient appliances, equipment or measures net of any incentives paid by the program, such as rebates).

Equation 1 shows the calculation for the program administrator CSE.

Equation 1:

Program Administrator Cost of Saved Electricity =

$$\frac{\text{Capital Recovery Factor * (Program Administrator Costs)}}{\text{Annual Electricity Savings (in kWh)}}$$

Equation 2 defines the total CSE.

Equation 2:

Total Cost of Saved Electricity =

$$\frac{\text{Capital Recovery Factor * (Program Administrator Costs + Net Participant Costs)}}{\text{Annual Electricity Savings (Gross–kWh)}}$$

where the Capital Recovery Factor (CRF) is

$$CRF = \frac{r(1+r)^N}{(1+r)^N - 1}.$$

and

r = the discount rate

N = estimated program lifetime in years and calculated as the savings-weighted lifetime of measures or actions installed by participating customers in a program.

[13] We included evaluation, measurement and verification (EM&V) costs at the portfolio-level and for specific programs (if reported at the program level). Some ancillary costs associated with investments in energy efficiency are not included because they are either not reported, are not included in program administrator annual reports, or are not included in the standard definition of program administrator or total cost of saved energy. These costs include performance incentives for the program administrator, the time and transaction costs incurred by participants (e.g., analyzing potential efficiency investments, getting the work done) and tax credits.

We used a 6% real discount rate as an approximation of the weighted-average cost of capital for an investor-owned electric utility.[14] We include "net" participant costs to avoid double counting of program incentives so that participant costs are limited to out-of-pocket expenses of the participant.

In calculating CSE values, there are choices with respect to which annual electricity savings values to use (i.e., gross vs. net savings) as well as the basis for savings estimates (e.g., claimed savings, impact evaluation results). Distinctions between so-called "net" and "gross" savings are important elements of analysis of impacts of efficiency programs (NAPEE 2008). Gross savings are defined as the difference in energy consumption with the energy efficiency measures promoted by the program in place versus what consumption would have been without those measures in place. Net savings are defined as the difference in energy consumption with the program in place versus what consumption would have been without the program in place (Violette and Rathbun 2017).[15] We use gross energy savings in calculating the CSE primarily because net savings are not universally reported.[16]

Program administrators primarily use two methods for estimating electricity savings from efficiency programs:

- *Claimed savings* for a program are typically calculated by multiplying the number of efficiency measures installed (or actions taken) by *ex ante* estimates of the per-unit savings. These *ex ante* estimates are often documented in a "technical reference manual" of efficiency measures and actions.[17] *Ex ante* estimates are derived using various methods including building energy simulation models, deemed calculation methods and deemed savings approaches.[18] Most program administrators also typically have an independent evaluator undertake *ex post*

[14] We use a real discount rate because inflation already is accounted for in the use of constant dollars (2016$). Our real discount rate is a proxy for a nominal rate in the range of 7.5% to 9%, typical values for a utility weighted-average cost of capital (WACC). A utility WACC is the average of the cost of payments on the utility's debt (bonds) and its equity (stock), weighted by the relative share of each in the utility's funds available for capital investment. The utility WACC is often used by investor-owned utilities in their economic screening of efficiency programs. Technically, program participants are investing in efficiency using their own discount rate, which is generally higher than a utility cost of capital. A few analysts do take this difference in discount rates into account, although it is not yet standard practice and adds complexity. We have not adopted that approach in this study.

[15] While the definition of net savings varies somewhat across states, this term generally reflects the fact that energy savings from actions taken by participants may not be due specifically to the program itself.

[16] When net savings are reported, inconsistencies in the definition and estimation of net-to-gross ratios add considerably to the uncertainties already embedded in estimates of energy savings. See Billingsley et al. (2014) for a more in-depth discussion of our rationale for utilizing gross savings estimates. If we use "net savings" data for those program years where we have both gross and net savings, we find that the estimated PA CSE would increase by about 23% to $0.031/kWh.

[17] A technical reference manual (TRM) is a term of art that describes a document or database of standardized assumptions and *ex ante* values for determining the savings from well-defined energy efficiency measures installed and operated under defined conditions (Schiller, Goldman and Galawish 2011; Schiller et al 2017). A TRM may include "…the methods, formulas, and default assumptions used for estimating energy savings…from energy efficiency measures and projects" (ERS 2014). In some areas, TRMs are administered and managed on various geographic scales, from regional organizations (e.g., the Regional Technical Forum in the Pacific Northwest) to statewide efforts, maintained by consultants selected by state regulators or program administrators. In other places, individual program administrators maintain less formalized measure lists with deemed savings and measure lifetime estimates for their own use.

[18] Program administrators also differ widely in their assumed baselines—whether the level of energy performance assumed prior to installing a measure or taking another efficiency action is based on common practice, building energy code, or a tiered or dual baseline that changes over the savings lifetime of a measure.

verification that a sample of measures have been installed and are operating properly. Many also use measurements and other forms of verification to ensure the intended savings are actually acquired.

- *Impact evaluation* savings estimates are calculated by measuring energy use of program participants *ex post* and comparing this to counterfactual estimates of what this energy use would have been in the absence of the program. Some states and program administrators attempt to incorporate results from impact evaluations to update the deemed savings estimates in their technical reference manual applied to *ex ante* estimates for future program years.

The savings data in the LBNL database are primarily claimed savings, taken from annual reports filed by efficiency program administrators with state regulators. States and program administrators vary widely in the level of rigor that they apply in estimating these *ex-ante* savings values and the frequency with which they update those assumptions as impact evaluations are completed. In addition, practices vary among states in defining the baseline used to estimate savings. Some program administrators may use existing building codes (or standards) as a baseline in accounting for savings from installation of efficient equipment while other program administrators may use the efficiency of the replaced equipment as a baseline (CEE 2018).

The focus of our analysis is on savings-weighted average and median CSE values. The savings-weighted averages are calculated using costs and savings for all programs over the average lifetime of savings at each level of analysis (e.g., national, state, market sector, program type). The cost term includes all spending, including spending on programs for which no savings are claimed (e.g., residential audits or support programs). Because the averages are savings-weighted, larger programs can have greater influence on the average CSE than smaller programs.

We also report ranges in CSE values for each type of efficiency program, which requires both cost and savings information, by calculating and depicting interquartile ranges—the middle 50% of values (i.e. from the 25th to 75th percentile).[19]

2.5 Program Data Quality, Consistency and Availability: Issue and Challenges

In previous studies, we highlighted several issues related to program data: (1) incomplete or inconsistent data reporting; (2) defining and reporting annual and lifetime savings of efficiency measures; and (3) defining and reporting participant costs (Hoffman et al. 2013; Billingsley et al. 2014; Hoffman et al. 2015). These publications and Appendix D of this report provide a more detailed explanation and discussion of those issues and our approach to addressing them.

[19] All values for a given program, market sector or administrators in a state are included in determining savings-weighted averages and median CSE values.

These issues influence data quality and can confound analysis and compromise the integrity of results. We developed processes and procedures for standardizing data across states in an effort to address and mitigate these issues. For example, several program administrators and states provided us reports that were not publicly available or filled data gaps. However, in a few states, some program administrators either redacted their program spending, savings or both (e.g., VA) or filed no public report (e.g., AL).

When a program administrator reported only net savings, we obtained program-level net-to-gross ratios for the same program to convert the values to gross savings. Where average program lifetimes were not available, we imputed values drawing upon an average value for similar programs.[20] Total cost data present unique challenges for data collection and input. For each annual report collected, LBNL researchers ascertained how the program administrator defined total costs and participant costs and took steps to standardize these values (see Chapter 6 and Appendix C).

We also followed an internal quality control and quality assurance (QAQC) protocol that included flags for aberrant values.[21] Our data entry and QAQC processes helped identify issues that we discussed with program administrators (or regulatory staff). In general, we took all data reported by program administrators as given. The results of LBNL's calculations are therefore highly dependent on values as reported by program administrators.

[20] We had to impute program average measure lifetime for about 59% of the program years using average values from the programs where this information was provided (see section 7.3.2 for more discussion).

[21] Once a researcher completed data entry for a state, a second researcher did extensive spot-checking based on a specified protocol.

3. Electricity Efficiency Programs: Reported Expenditures and Savings

In this chapter, we provide an overview of expenditures and gross savings for electricity efficiency programs implemented between 2009 and 2015 in the LBNL DSM Program Database. This forms the basis for our analysis of the cost of saved electricity.

3.1 Program Administrator Expenditures and Gross Savings for Electricity Efficiency Programs by Market Sector: 2009–2015

The LBNL DSM Program Database includes $26.7 billion (in 2016$) in expenditures for electricity efficiency programs implemented between 2009 and 2015 (see Table 3-1). Commercial and industrial (C&I) programs account for half of that total, while programs that target residential customers and low-income customers account for 31% and 9%, respectively. If we disaggregate results in terms of the share of lifetime gross savings, then programs that target C&I customers account for 61% of reported lifetime savings, while residential and low-income programs account for 32% and 2%, respectively.

Table 3-1. Program expenditures and lifetime gross savings (2009–2015)

Market Sector	Share of Program Administrator Expenditures	Program Administrator Expenditures (Billions 2016$)	Share of Lifetime Gross Savings	Lifetime Gross Savings (GWh)
C&I	50%	13.4	61%	836,241
Residential	31%	8.3	32%	436,770
Low Income	9%	2.2	2%	28,983
Cross Sector/Other	10%	2.7	5%	66,260
Total	**100%**	**26.7**	**100%**	**1,368,254**

3.2 Program Administrator Expenditures and Lifetime Gross Savings by Program Category

It is also useful to review spending and savings trends at the program level. We disaggregate expenditures and estimated gross savings over the program lifetime and report results in the residential and C&I market sectors by simple program category (see Figure 3-1 and Figure 3-2). Among residential customers, programs directed at (1) consumer lighting rebates, (2) whole-home upgrades, and (3) prescriptive rebates for HVAC, hot water and/or building envelope measures (e.g., insulation) accounted for 20%, 24%, and 20% of spending, respectively. These three program types accounted for 64% of expenditures and 76% of lifetime gross savings in the residential sector. Consumer lighting programs were by far the largest contributor to savings in the residential sector, accounting for 45% of residential lifetime savings.

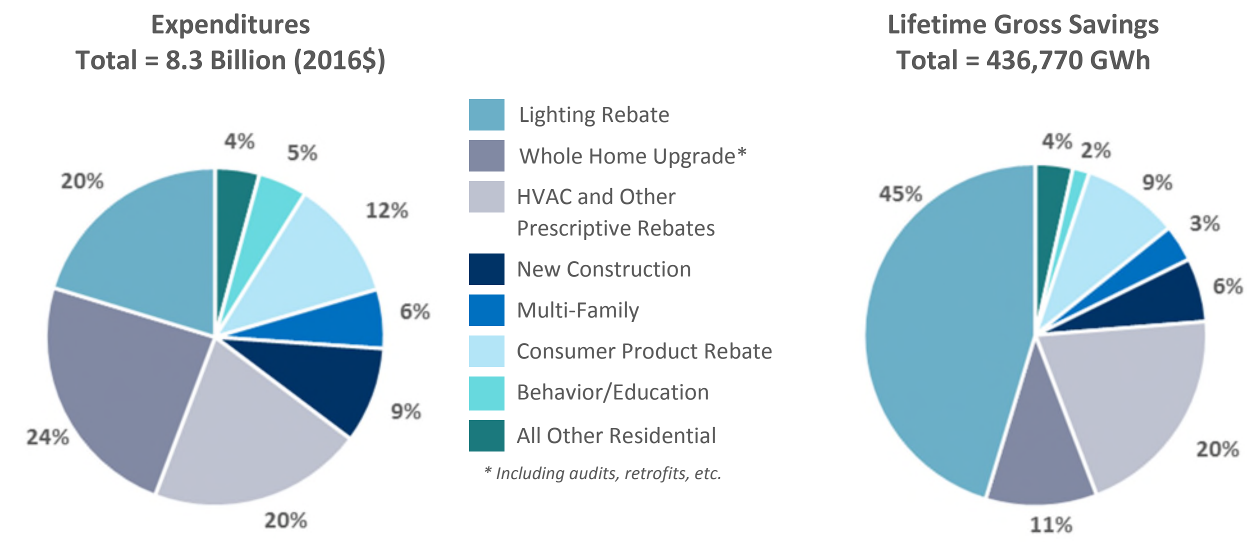


Figure 3-1. Program administrator expenditures and lifetime gross savings for residential electricity efficiency programs (2009-2015)

Small commercial, prescriptive rebate and custom rebate programs accounted for 75% of expenditures in the C&I market (Figure 3-2). These three programs also accounted for 73% of lifetime savings, with custom programs leading savings (37%).

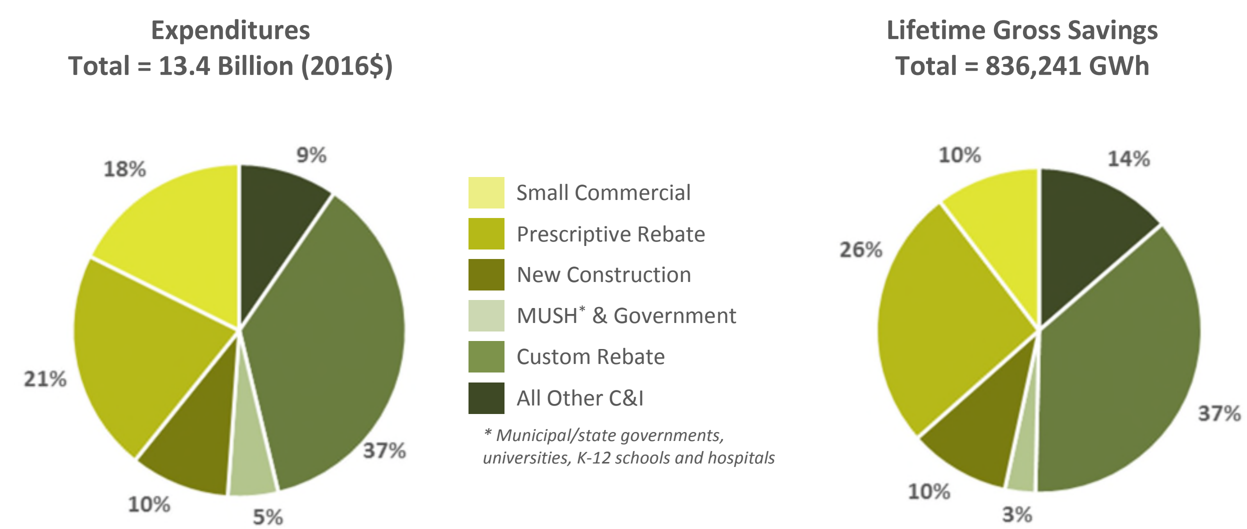


Figure 3-2. Program administrator expenditures and lifetime gross savings for C&I electricity efficiency programs (2009-2015)

4. The Program Administrator Cost of Saved Electricity

In this chapter, we present an overview of the program administrator (PA) cost of saved electricity (CSE) at the national, regional and state levels. LBNL's DSM Program Database includes results from program administrators in 41 states that report impacts and costs at the program level (see Figure 4-1). We then report CSE values by market sector (residential, low income, C&I) and by type of program. At this more disaggregated level, we report medians (e.g., the middle value for a program type among all program administrators), savings-weighted averages and the range of CSE values to provide both the central tendency and variation across our program sample. We then discuss longitudinal trends over time (2009 to 2015) in the PA CSE and present statistical evidence for the validity of the observed trends. Finally, we aggregate spending and savings results and depict them in terms of a program cost curve that shows the costs of acquiring savings through the most common types of efficiency programs offered by the 116 U.S. program administrators in our sample.

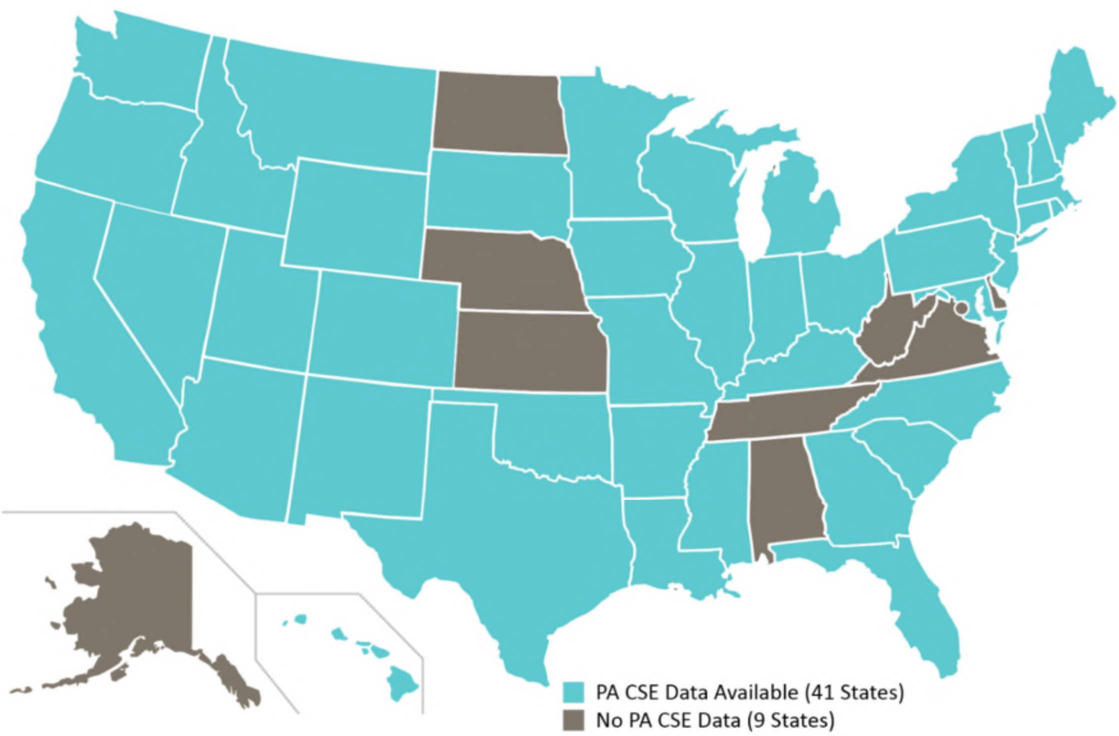


Figure 4-1. States for which PA CSE data are available for electricity efficiency programs in the LBNL DSM Program Database

4.1 National Results

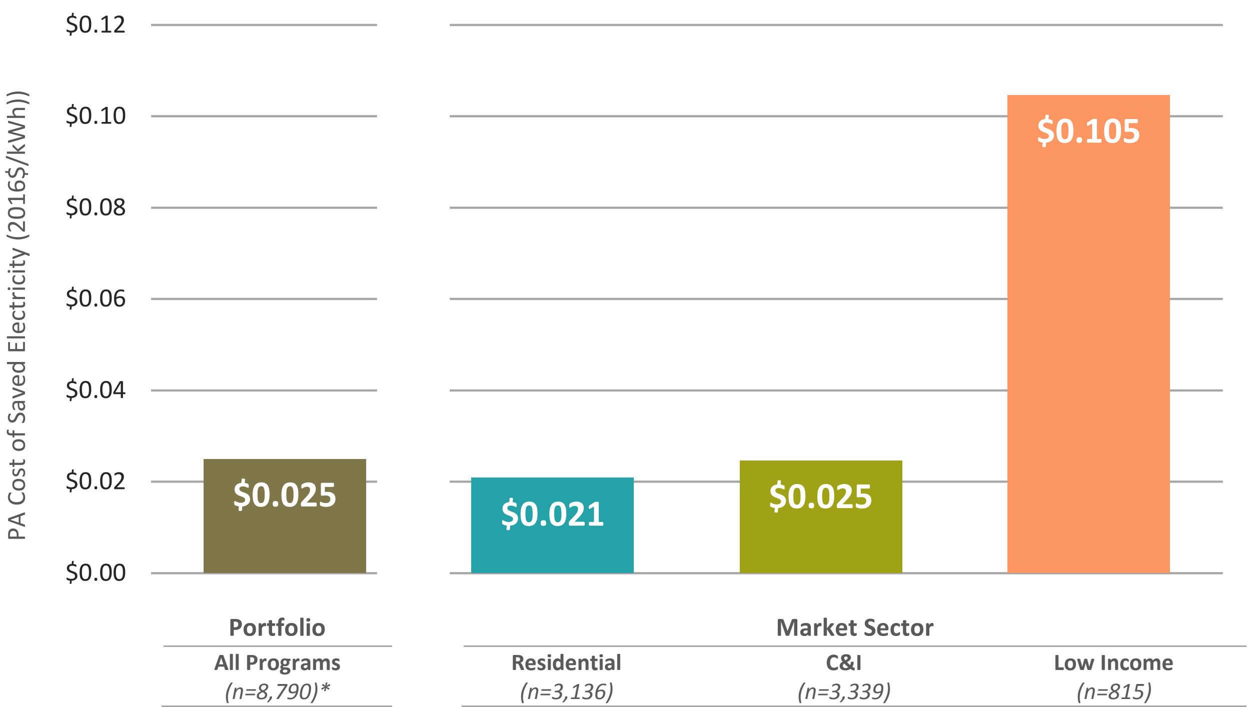
The PA CSE for the national "portfolio" of all programs and related activities is $0.025/kWh in constant 2016 dollars (see Table 4-1 and Figure 4-2).

Table 4-1. Program administrator CSE by market sector: national savings-weighted averages for 2009–2015

Market Sector	Number of Program Years	Average Levelized Cost of Saved Electricity (2016$/kWh)[22]
C&I	*n=3,339*	$0.025
Residential	*n=3,136*	$0.021
Low Income	*n=815*	$0.105
Full Portfolio, All Programs	*n=8,790*[*]	$0.025[**]

[*] The sample size for the full portfolio includes activities for which savings are not claimed but which support the efficiency activities of the program administrator (e.g., planning, research, market assessments, evaluation and measurement).

[**] We do not include additional shareholder incentives that some program administrators may have earned as part of the full portfolio costs because shareholder incentives are not typically reported in annual reports and may be decided in other regulatory proceedings. In our previous analyses, adding a national average shareholder incentive has raised the cost of saved electricity by less than $0.002/kWh.



** The sample size for the full portfolio includes programs for which savings are not claimed but which support the efficiency activities of the program administrator (e.g., planning, research, evaluation and measurement). Costs for these programs are included in our calculation of PA CSE at the portfolio and market sector level.*

Figure 4-2. Program administrator CSE for electricity efficiency programs by market sector: national savings-weighted averages

[22] These values represent the following inflation-adjusted changes in PA CSE values from LBNL's 2014 study using 2009-2011 program data (Billingsley et al. 2014): C&I – 11%, residential – 9%, low-income – 41% and full portfolio (all programs) – 12%.

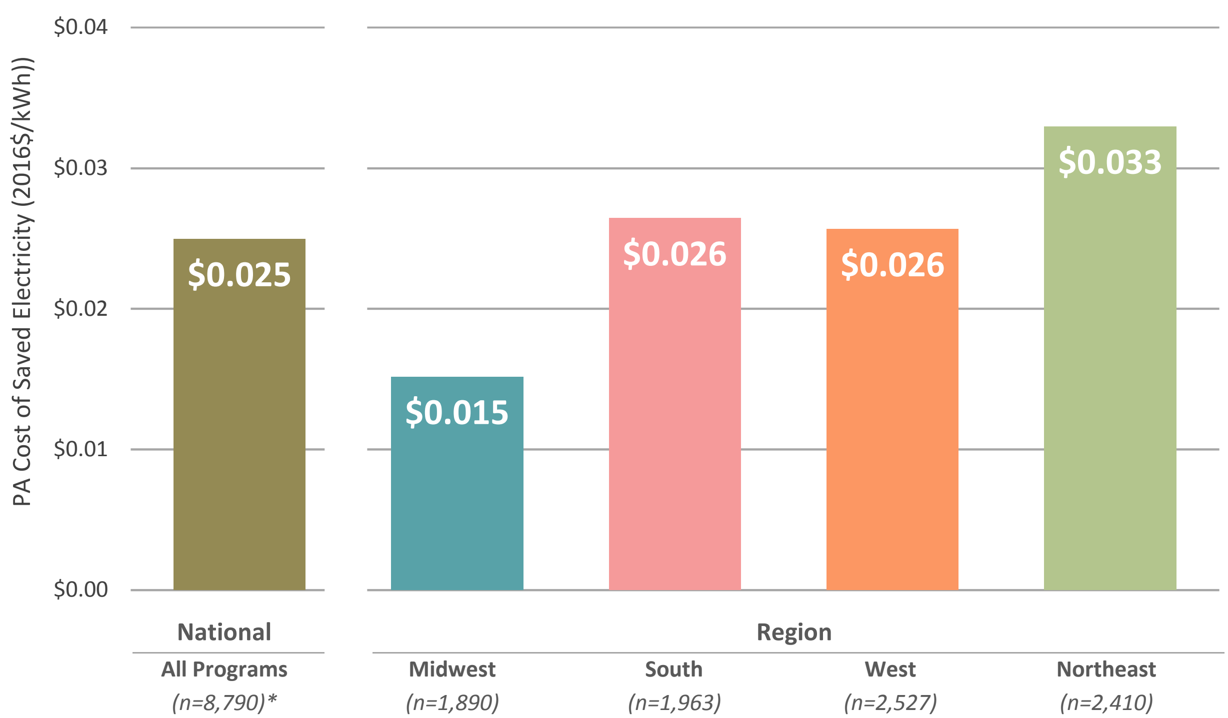
In line with our previous studies (Billingsley et al. 2014), the residential sector continued to provide the lowest cost energy savings during the 2009–2015 period, chiefly through lighting rebate programs.

The PA CSE for low-income programs was about $0.105/kWh. However, programs for low-income households accounted for a modest share of overall savings (2%) and spending (9%). Programs for low-income customers have much lower participant contributions than most other program types and thus require a much higher cost contribution from program administrators than programs for other market sectors. In addition, repair work must be done in many cases before efficiency measures can be installed. Further, low-income programs often have aims beyond energy savings—for example:

- Reduced energy bills
- Improved safety
- Improved health of occupants
- Increased comfort

4.2 Regional Results

The savings-weighted CSE varied widely among U.S. Census regions, ranging from a low of $0.015/kWh in the Midwest to $0.033/kWh in the Northeast (Figure 4-3). The CSE values were comparable in the South and West regions.



** The sample size for the full portfolio includes programs for which savings are not claimed but which support the efficiency activities of the program administrator (e.g., planning, research, evaluation and measurement). Costs for these programs are included in our calculation of PA CSE at the portfolio and market sector level.*

Figure 4-3. Program administrator CSE by U.S. Census region: savings-weighted averages

The average program administrator CSE value ($0.015/kWh) for the Midwest is 40% lower than the national average. A few states in the Midwest region have fairly mature markets for efficient goods and services (MN, IA). However, many Midwest states were ramping up their efficiency programs between 2009 and 2015 and were delivering low-cost savings, particularly with investments in industrial and agricultural efficiency and residential lighting.

4.3 State-Level Results

The program administrator CSE varies significantly at the state level (Figure 4-4).

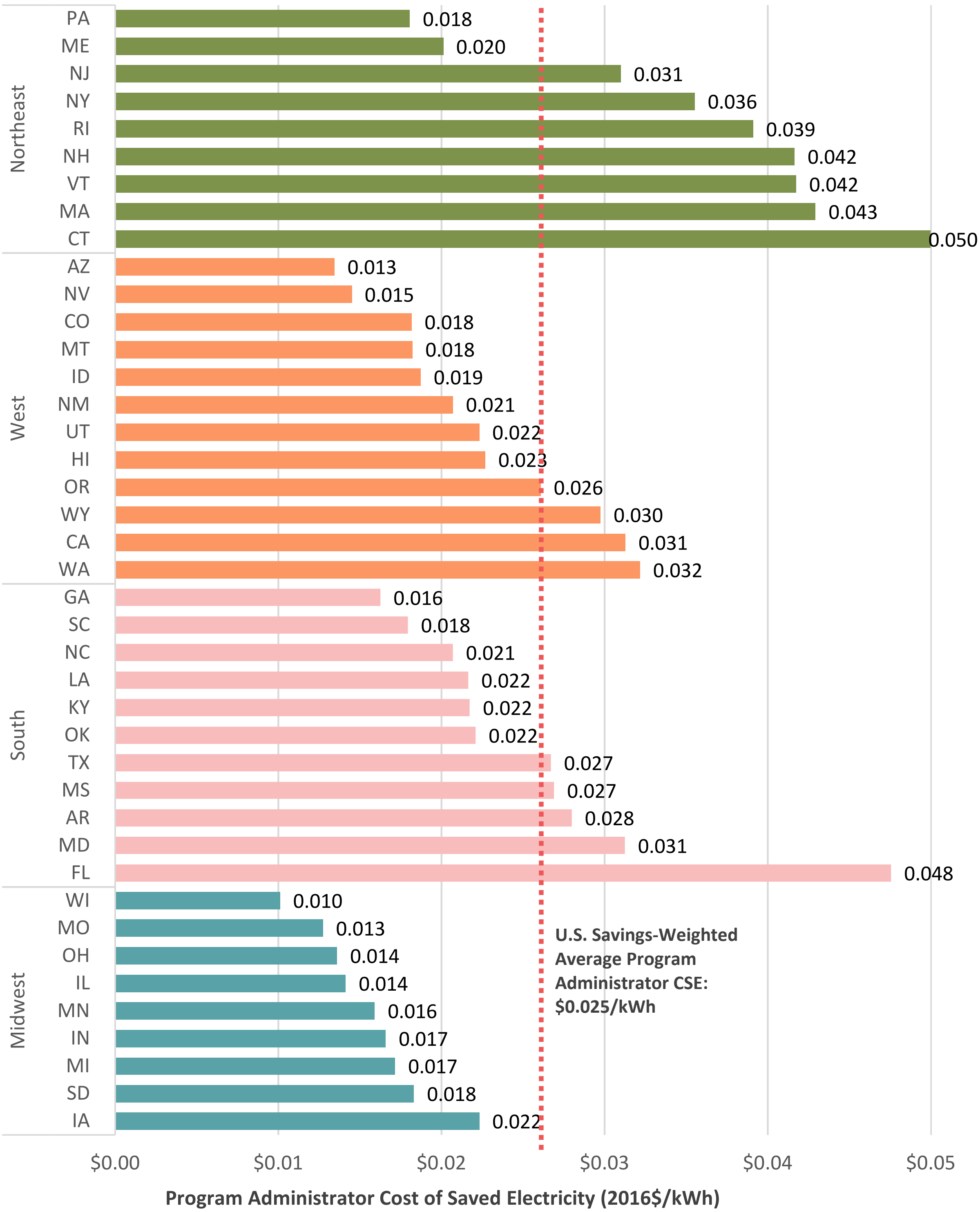


Figure 4-4. Program administrator CSE by state for 2009-2015: savings-weighted averages

We found that 16 states have CSE values that were less than or equal to $0.02/kWh during the 2009-2015 period. These states tended to be concentrated in the Midwest, South and Intermountain West.

In some cases, these states tended to be relatively new to energy efficiency, are just ramping up their programs with a heavy focus on lighting, or have program design restrictions that limit savings acquisition (e.g., caps on customer payback periods).

Five states had average CSE values that exceeded $0.04/kWh between 2009 and 2015. Four of these states are located in the Northeast (CT, VT, MA, NH) and have relatively high electricity prices, extensive histories in pursuing energy savings and strong policy commitments (e.g., statutory mandates to acquire all cost-effective energy efficiency or meet specified savings targets). Thus, they tend to have greater market saturation for efficiency measures and have mined more of the lowest cost savings opportunities. Florida had a significantly higher CSE than the regional average. Florida utilities have elevated costs at least partly because they are required to offer free detailed energy audits to customers at considerable expense. For this study period, Florida utilities were not allowed to claim electricity savings for the audits. If we exclude the costs of audit programs offered by Florida's investor-owned utilities, Florida's CSE would be 20% lower, or $0.038/kWh. The CSE for the South would be about 6% lower, matching the national average.

Figure 4-5 shows the relationship between CSE values for 2015 by state compared to electricity savings as a percent of 2015 retail electricity sales in the state. The chart provides one way to assess the relative impact of program administrator efforts. Between 2009 and 2015, 23 states reported program savings that equaled or exceeded 1% of 2015 retail sales. Nine of those states reported savings that exceeded 1.5% of retail sales (CT, AZ, CO, CA, HI, ME, VT, RI, MA), while four states (ME, VT, RI, MA) reported savings that exceeded 2% of retail sales. Figure 4-5 also shows that state-level PA CSE values tend to increase as states achieve more aggressive electricity savings levels (compared to retail sales), although there is significant variation in this relationship across states.

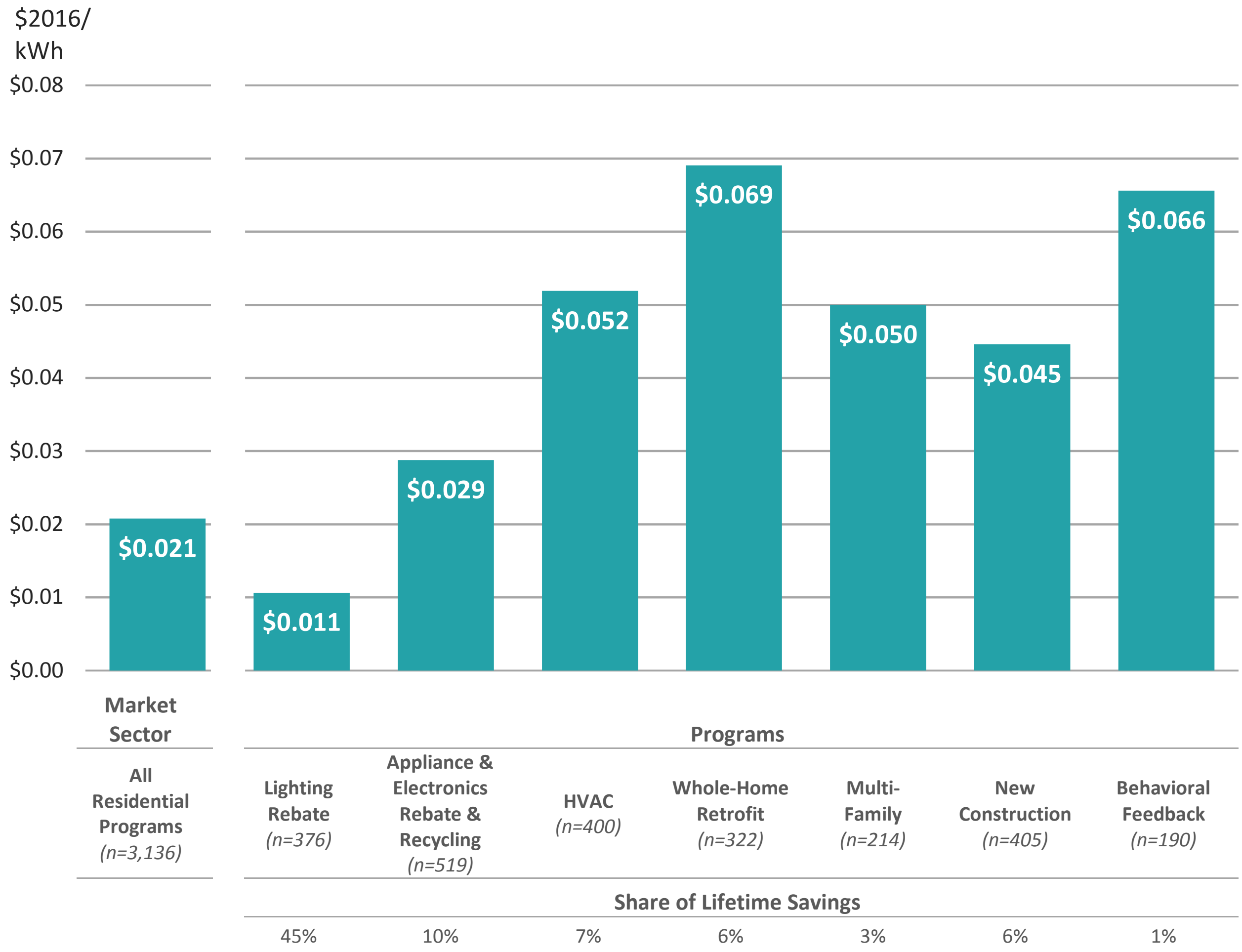
Note: CSE values are for 2015 for all states, except Illinois and Wyoming, where we use 2014 CSE values because program data for 2015 were not available during the collection phase of this study. CSE values for states in this figure do not necessarily match state CSE values in Figure 4-4, which includes the entire 2009-2015 period.

Figure 4-5. 2015 program administrator CSE compared to program savings as a percent of 2015 retail electricity sales: savings-weighted averages by state

4.3.1 Residential Sector

Nationwide, the residential sector, with an average levelized CSE of $0.021/kWh, accounted for much of the lowest cost savings in electricity efficiency portfolios.

We have arranged Figure 4-6 (and Figure 4-8) to reflect the magnitude of each program's contribution to the electricity efficiency resource in the residential market. Thus, we present the residential programs with the largest share of lifetime savings on the left (lighting rebates) to the lowest share of savings on the right (behavioral feedback). The average CSE values for rebate programs were $0.011/kWh for lighting and $0.029/kWh for appliance and consumer electronics and appliance recycling programs.



Note: We used more detailed program categories for several types of programs (e.g., whole home retrofit, HVAC and behavioral feedback) in calculating the PA CSE. Thus, the share of lifetime savings in the residential sector is not the same as shown in Figure 3-1, where we used simple (and broader) program categories.

Figure 4-6. Program administrator CSE for the residential sector and select programs: savings-weighted averages

Lighting rebate programs accounted for 45% of residential lifetime savings acquired in 2009-2015. Consumer product rebates—appliances, consumer electronics and appliance recycling—accounted for 10% of the sector's lifetime savings. Lighting and consumer product rebate programs provide low-cost savings opportunities that reduce the overall cost of efficiency in the residential market. Thus, lighting and consumer product rebate programs often allow program administrators to offer other higher cost, but more comprehensive, programs as part of their residential efficiency portfolios and are an essential element of their compliance strategy for meeting savings targets.

Figure 4-6 also shows that the average cost of efficiency varies widely among residential programs. Between lighting and whole-home retrofit programs[23] is a six-fold difference in the savings-weighted

[23] Whole-home retrofit programs target home energy use with comprehensive strategies to identify and increase

average CSE. This range in cost performance is largely a reflection of differences in program delivery and measure mix. Whole-home retrofit programs typically have a higher cost of savings ($0.069/kWh) because projects are more comprehensive in scope, often including heating and air-conditioning system replacements. In cold climates, air sealing and insulation are common measures. The full cost, not the incremental cost, of these measures is typically used for most cost estimates. These measures also save heating fuel (often natural gas or fuel oil) in addition to electricity, a benefit that is not accounted for in the CSE metric. The cost performance of standalone heating, ventilation and air conditioning (HVAC) programs ($0.052/kWh) also may reflect the relative difficulty of persuading customers to install high-efficiency equipment that has a higher first cost and ensuring those installations maximize energy performance.[24]

Behavioral feedback programs rapidly proliferated among program administrators from 2009 to 2015. These programs use mailed and online messages to customers to persuade them to reduce their consumption by comparing their energy use to that of similar households. These messages, often called "home energy reports," contain tips on saving energy (e.g., turning down the thermostat in the winter when not at home) and can serve as gateways to other residential efficiency programs.

These behavioral feedback programs would appear to be among the costlier sources of residential electricity savings ($0.066/kWh) during our study period for several reasons. First, the largest behavioral feedback programs in our sample, in terms of enrolled customers and aggregate savings, expanded their programs to more residential customers, were located in milder climates and/or were located in territories where efficiency programs have been operating for many years. These programs tended to have higher CSE values and, given their higher aggregate savings in our sample of behavioral feedback programs, they have a strong influence on the savings-weighted average values for this program type. Second, from 2009 to 2013, nearly all program administrators assumed that savings from behavioral feedback programs lasted one year, and we rely on *reported* lifetimes from program administrators. However, a growing number of evaluations suggest that participants' conservation behaviors last longer. One meta-analysis (Khawaja and Stewart 2014) of evaluations of the five longest-running behavior feedback programs recommends using a measure lifetime of 3.9 years. In 2014 and 2015, several program administrators raised the assumed measure lifetime for behavioral feedback to two or three years. If we had assumed that all behavioral feedback programs had an effective useful lifetime of three years, then the savings-weighted average CSE for behavioral feedback programs would have been much lower—$0.028/kWh.

Figure 4-7 shows median, savings-weighted averages and interquartile ranges (denoting the 25th and 75th percentile CSE values) for various types of programs in the residential sector. The median CSE value for the sector was $0.042/kWh. The cost of efficiency was significantly more variable *within* some

efficiency through air sealing, insulation, and heating and air-conditioning equipment improvements, along with more efficient lighting and appliances.

[24] HVAC programs with higher cost of savings often include quality installation training, certification, and inspections to ensure proper duct sealing, refrigerant charge and combustion safety.

residential program types than others.[25] For example, lighting rebate programs delivered savings within a relatively narrow range of cost performance: the CSE value at the 75th percentile is 2.1 times higher than the 25th percentile (Figure 4-7). In contrast, the 75th percentile program value is 3.5 times higher than the 25th percentile value for whole-home retrofit programs. Programs that promote whole-home retrofits often vary significantly in the cost of savings because they require higher initial marketing costs to attract participants, persuade contractors to integrate efficiency into their business models and include strategies to ensure quality installations. These differences in program design and implementation for whole-home retrofit programs tend to increase the spread in the observed PA CSE.

Whole-home retrofit, new construction and HVAC programs all require more capacity-building for program administrators to implement and scale up. Thus, these programs tend to have higher first-year costs which decrease as the number of projects or homes increases with time.

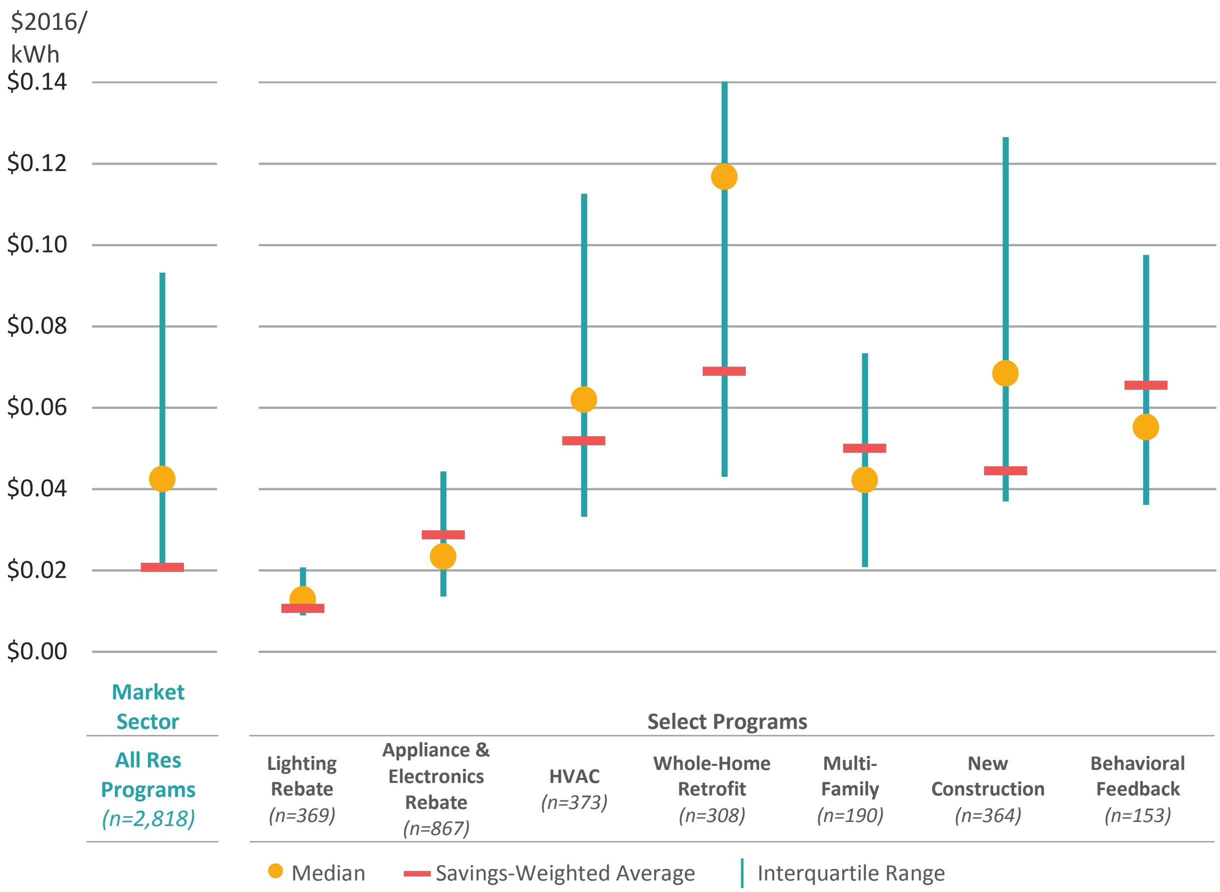


Figure 4-7. Program administrator CSE for the residential sector and select programs: median values and interquartile ranges

25 Variability in some other program types also can be attributed, at least in part, to different program designs and measure mixes—e.g., multi-family programs that focus more on replacing old A/C equipment versus those focusing on replacing lighting in common areas and units.

Opportunities for cost reductions for some of the more costly program types include streamlining of administration and marketing activities, greater economies of scale or both. For example, several residential program types (e.g., whole-home retrofit, new construction) with higher cost of savings show median values that are substantially higher than the savings-weighted averages (Figure 4-7). For program types where savings-weighted average values for CSE are much lower than median CSE values, it may be that more experienced program administrators that have implemented larger programs have moved past initial high costs of small-scale, pilot programs, learned how to streamline costs, or found economies of scale at higher levels of spending or savings acquisition. Similarly, larger program administrators may have the market clout to influence major HVAC system manufacturers and distributors and thus provide efficient and discounted choices for program participants.

Conversely, median costs lower than the savings-weighted average may indicate that larger program administrators are offering programs that include a broader set of measures or measures with deeper savings. For example, in the multi-family market, nearly all program administrators target low-cost efficient lighting in common areas of apartments and condominiums. However, only some program administrators pursue additional savings in the individual units (e.g., lighting, appliances and other plug loads). Similarly, most program administrators initially targeted high-use customers in behavioral feedback programs (and reported higher savings in absolute terms). Some administrators with more aggressive savings targets have now expanded these behavioral programs to include the majority of their residential customers, which in some cases has resulted in lower savings compared to only targeting high-use customers.

4.3.2 Commercial, Industrial and Agricultural Sector and Programs

Electricity efficiency efforts in the C&I sector present a different cost-performance profile than in the residential sector. The average program administrator CSE for the C&I sector was $0.025/kWh (Figure 4-8). Three types of C&I programs—rebates for custom retrofits, prescriptive rebates and new construction—accounted for 74% of the C&I sector's annual and lifetime savings. Average CSE values for these three program types were fairly close to the sector average, ranging between $0.019/kWh and $0.026/kWh.

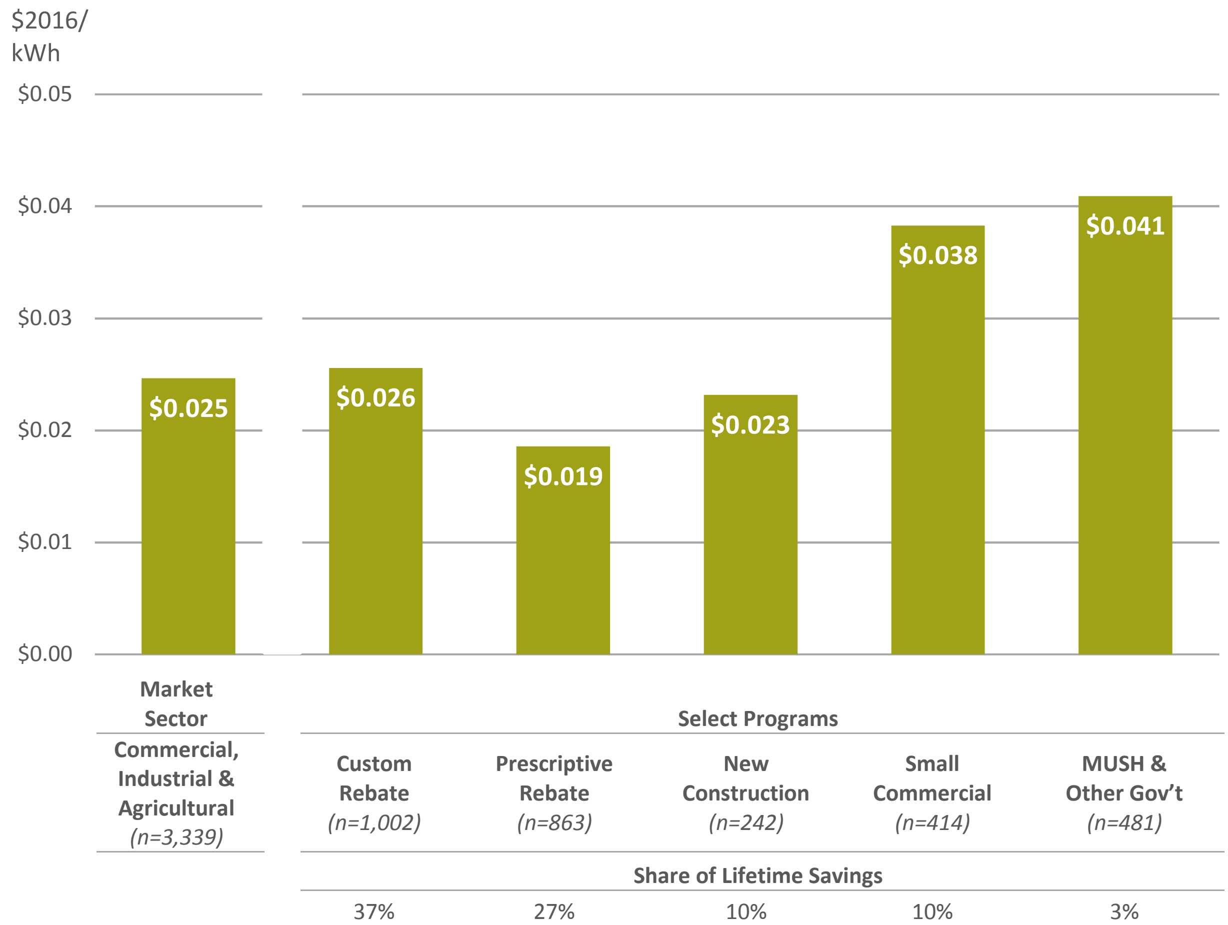


Figure 4-8. Program administrator CSE for the C&I sector and select programs: savings-weighted averages

Commercial/industrial sector programs that offer prescriptive rebates to customers that install high-efficiency lighting, HVAC equipment and controls, refrigeration and motors accounted for 27% of lifetime savings in the C&I sector with a low CSE value of $0.019/kWh. However, unlike the residential sector, a larger share of low- to moderate-cost savings in the C&I sector also came from more comprehensive, multi-measure programs. For example, rebates for custom retrofits accounted for 37% of lifetime savings with an average CSE of $0.026/kWh. Programs that promote more efficient design in new construction contribute 10% to lifetime savings with an average CSE of $0.023/kWh. Programs that specifically target small C&I customers also contributed 10% of the lifetime electricity savings in the C&I sector with an average CSE of $0.038/kWh.[26] Thus, savings are more evenly distributed across different program approaches in the C&I sector, and the average cost of savings only varies by a factor of two across those prevalent program types.

[26] Some program administrators offer distinct programs for small C&I customers (e.g., eligibility requirements related to maximum customer size, different program designs that may include higher rebates or rely on direct install by contractors).

The PA CSE is often less variable overall within the C&I sector compared to the residential sector (see Figure 4-9). Sector-wide, the 75th percentile CSE value is 3.6 times higher than the 25th percentile value in the C&I sector compared to 4.4 times higher in the residential sector. Similarly, for new construction, the CSE interquartile range values vary by a factor of 2.1 in the C&I sector and a factor of 3.4 in the residential sector.

Figure 4-9 also shows that savings-weighted averages for the CSE are slightly lower than the medians for each of the major types of C&I programs (except small commercial). The savings-weighted averages for CSE are close to the median values, suggesting that large and small program administrators are acquiring C&I savings at more or less similar cost for each of those major program types.

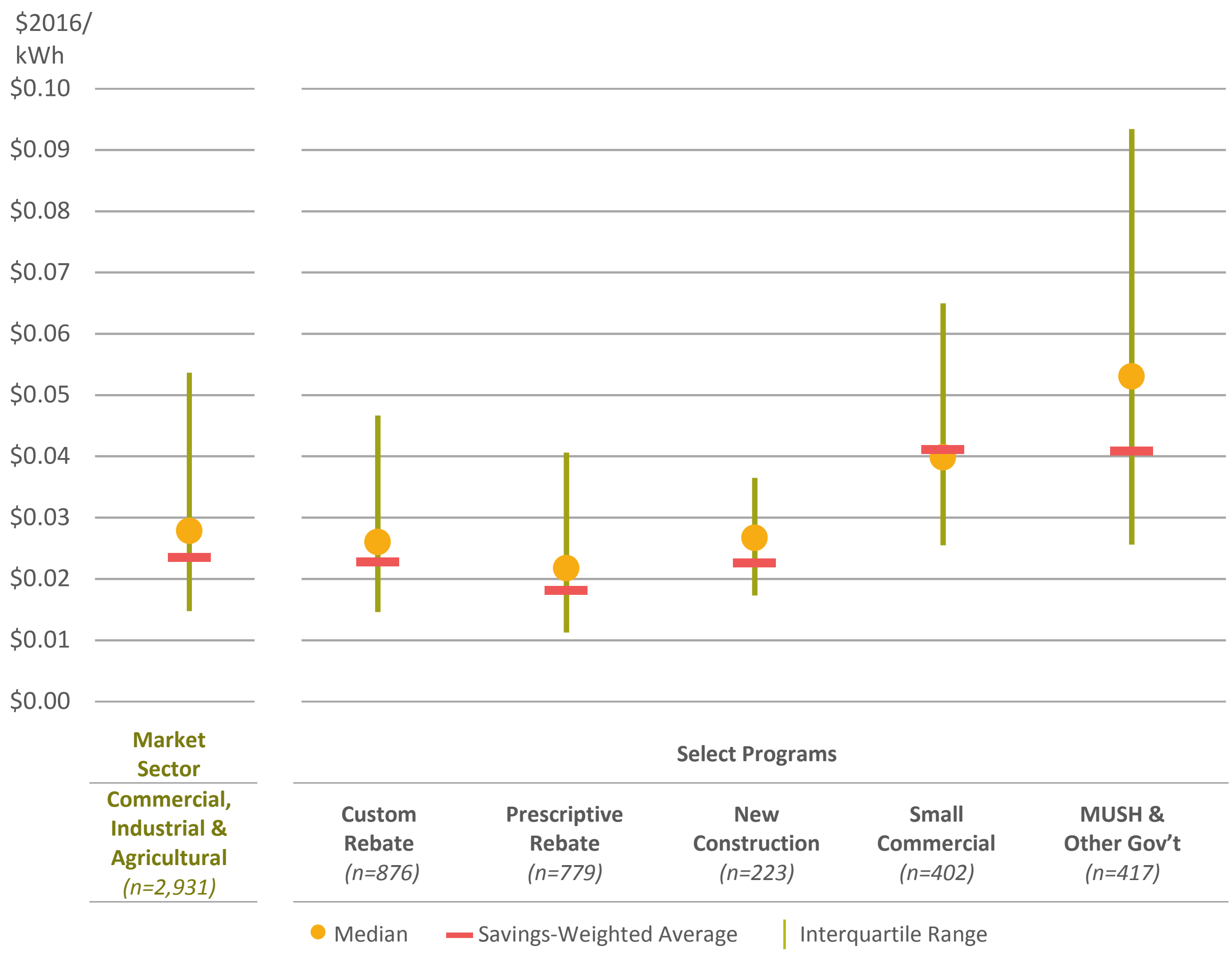


Figure 4-9. Program administrator CSE for the C&I sector and select programs: medians and interquartile ranges

In sum, the savings-weighted average CSE has been somewhat higher in the C&I sector than in the residential sector but less variable among and within the major program types. However, the median CSE value is lower in the C&I sector ($0.028kWh) compared to the residential sector ($0.042/kWh).

4.4 Trends in the Program Administrator Cost of Saved Electricity

We also examined trends in the cost of saved electricity between 2010 and 2015.[27] In our sample of 116 administrators, we have program data for 51 administrators for the entire study period. We focused on this group of 51 program administrators because we can exclude the potential impact of new administrators who may be just ramping up their efficiency programs in recent years.

Table 4-2 shows year-by-year values for the PA CSE for this group on a savings-weighted average basis. The average CSE trends upward over time from $0.022/kWh in 2010, increasing to $0.026/kWh in 2015. This translates into a compound annual growth rate (CAGR) of about 3.5% (accounting for inflation).

Table 4-2. The cost of saved electricity between 2010 and 2015: savings-weighted averages for 51 program administrators

	2010	2011	2012	2013	2014	2015	CAGR for Savings-Weighted Average	Mean CAGR for 51 PAs in Panel
Savings-Weighted PA CSE (2016$/kWh)	$0.022	$0.025	$0.024	$0.025	$0.028	$0.026	3.5%	0.2%

	2010	2011	2012	2013	2014	2015	CAGR for Savings-Weighted Average, by Savings Class	Mean CAGR for PAs in Savings Class
Highest Third Annual Savers	$0.021	$0.026	$0.023	$0.023	$0.027	$0.025	3.5%	3.8%
Middle Third Annual Savers	$0.020	$0.023	$0.021	$0.030	$0.029	$0.028	7.0%	0.2%
Lower Third Annual Savers	$0.032	$0.026	$0.027	$0.029	$0.033	$0.031	-0.6%	-2.8%

In analyzing trends over time in CSE, it is also useful to take a closer look at the pattern of results among program administrators. We segmented the 51 program administrators into three equal groups, by annual energy savings. Annual savings for efficiency programs tends to be correlated with the size of the utility (i.e., its retail load). In aggregate, the savings-weighted PA CSE increased by 3.5% per year for the 51 program administrators. The increase in the savings-weighted value for all 51 program administrators was driven primarily by the 3.5% increase in the PA CSE for the largest program administrators (labeled "Highest Third Annual Savers" in Table 4-2). This top third of administrators accounted for almost two-thirds of annual savings. In contrast, the savings-weighted PA CSE declined slightly (-0.6% per year) for the group of generally smaller and newer program administrators (labeled "Lower Third Annual Savers") that accounted for just 7% of annual savings among the 51 PAs.

[27] A previous LBNL study (Hoffman et al. 2017) examining such trends involved a smaller dataset and shorter timeframe (2009-2013).

However, changes over time in the average PA CSE were less pronounced if we treated CSE values for each program administrator as one data point (i.e., on an unweighted basis). The mean value for the PA CSE for the 51 program administrators increased by only 0.2% per year between 2010 and 2015(Table 4-2; far right column). The average rate of change in the CSE also varied by size of utility (and its annual energy savings). For example, the average PA CSE increased by 3.8% per year among the largest program administrators but changed little (0.2% per year) among the middle group of PAs. For a third group of generally smaller or newer program administrators, the mean cost of saved electricity declined by 2.8% per year, perhaps as they gained experience and economies of scale over the study period(Table 4-2).

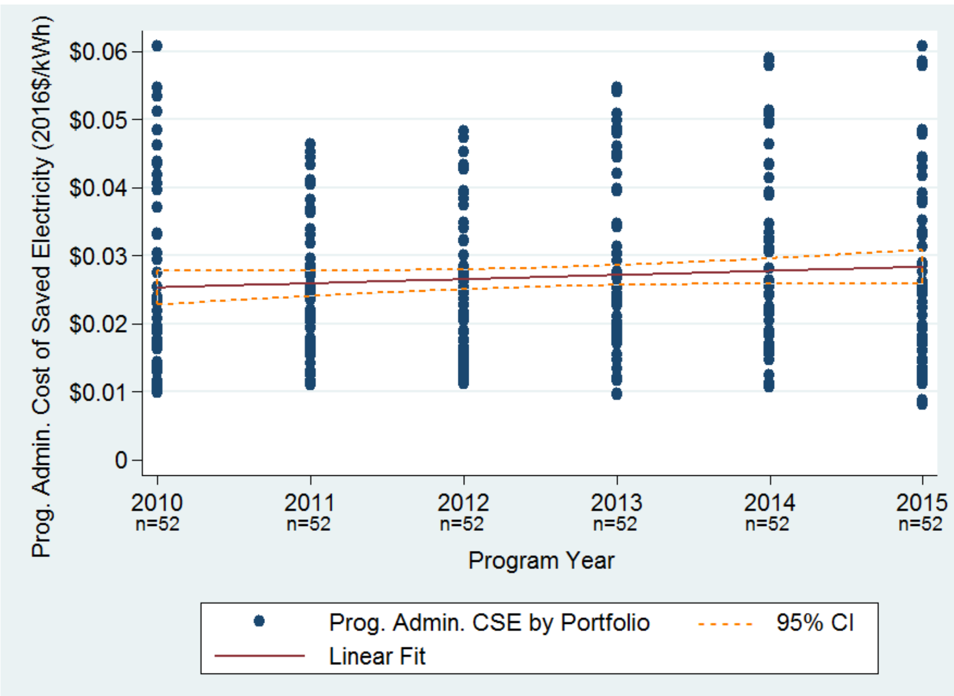


Figure 4-10. Trend in the CSE calculated at the portfolio level for each program administrator (2010-2015)

Figure 4-10 shows the CSE value at the portfolio level in each year for the 51 program administrators, including our statistical analysis (see Appendix E for detailed methodology). The solid line is a linear curve fitted to each year's collection of values. The regression analysis that produces the linear fit in Figure 4-10 treats all data points the same, regardless of the level of savings for each portfolio and program administrator. The curve shows a moderate increase in the CSE over time—about $0.00064/kWh, or 2.6%, per year. That slope is statistically significant at the 95% level. The orange dotted lines on either side reflect the confidence interval; the calculated probability that the actual trend lies within the range bounded by the dotted lines is 95%.

Further work is warranted here to fully understand trends in the CSE at a more disaggregated level—for program types that deliver large shares of the efficiency resource (e.g., residential lighting, C&I custom and prescriptive rebates). The available evidence suggests the CSE is increasing at a modest rate over time as program administrators access savings opportunities more broadly across the building and equipment stock and attempt deep market penetration.

4.5 A Multi-Program Cost Curve for Electricity Efficiency

LBNL's Cost of Saved Energy project collects information on efficiency program spending, savings and average measure lifetime data at the program level in our DSM Program Database. Using this information, we created an aggregate "cost curve" for electricity efficiency programs (see Figure 4-11). This "cost curve" is based on the *actual* efficiency resource during the 2009-2015 period based on program administrators' reporting of program spending and savings.

Figure 4-11 provides insight into the relative contribution of each program type to the efficiency resource at a national level.[28] The y-axis shows the cost of the electricity savings (in $/kWh). Programs are arrayed along the x-axis in ascending order based on their relative CSE. The width of each bar on the x-axis is scaled to represent the lifetime savings of that type of program. The values at the top of each bar show the percentage of total lifetime savings for all programs in the LBNL DSM Database for which savings were claimed during 2009-2015 by program administrators.

We include additional program types in Figure 4-11 compared to Figure 4-6 and Figure 4-8 in order to provide a closer look at the program types that deliver savings at various cost levels, with their corresponding contribution to the aggregate efficiency resource. Programs aimed at supporting more aggressive building energy codes are the least-cost efficiency resource, but these programs are only offered in a few states (e.g., CA, MA).

Residential lighting and other consumer product rebate programs provide the most lifetime savings (19% of total savings) at the lowest cost, followed by C&I custom and prescriptive programs disaggregated by market sector (such as industrial/agricultural customers) and mixed (which includes commercial, industrial and agricultural customers). Many types of C&I programs deliver savings at roughly similar cost, whereas programs in the residential sector show more of a dichotomy between low-cost, high-savings programs that target single measures (e.g., compact fluorescent lamps or light-emitting diodes) and higher cost programs that are aimed at more comprehensive, multi-measure approaches to home energy savings. Figure 4-11 captures these cost-performance characteristics in the two sectors.

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[28] "Supply" curves for efficiency measures are a common tool used to estimate the remaining technical, economic, and/or achievable potential for energy efficiency, typically for a single utility territory, state or region (shown on the x-axis). Efforts to develop a national supply curve for energy efficiency have also utilized this approach, portraying the efficiency resource as a composite of measures at a combination of savings potential and cost (McKinsey 2007). We have used this supply curve concept—displaying efficiency measures (or programs) in order of ascending cost and showing the relative magnitude of savings potential (or program activity) to create a "cost curve" for efficiency programs implemented between 2009 and 2015. In future work, we may extend this approach to regions and states.

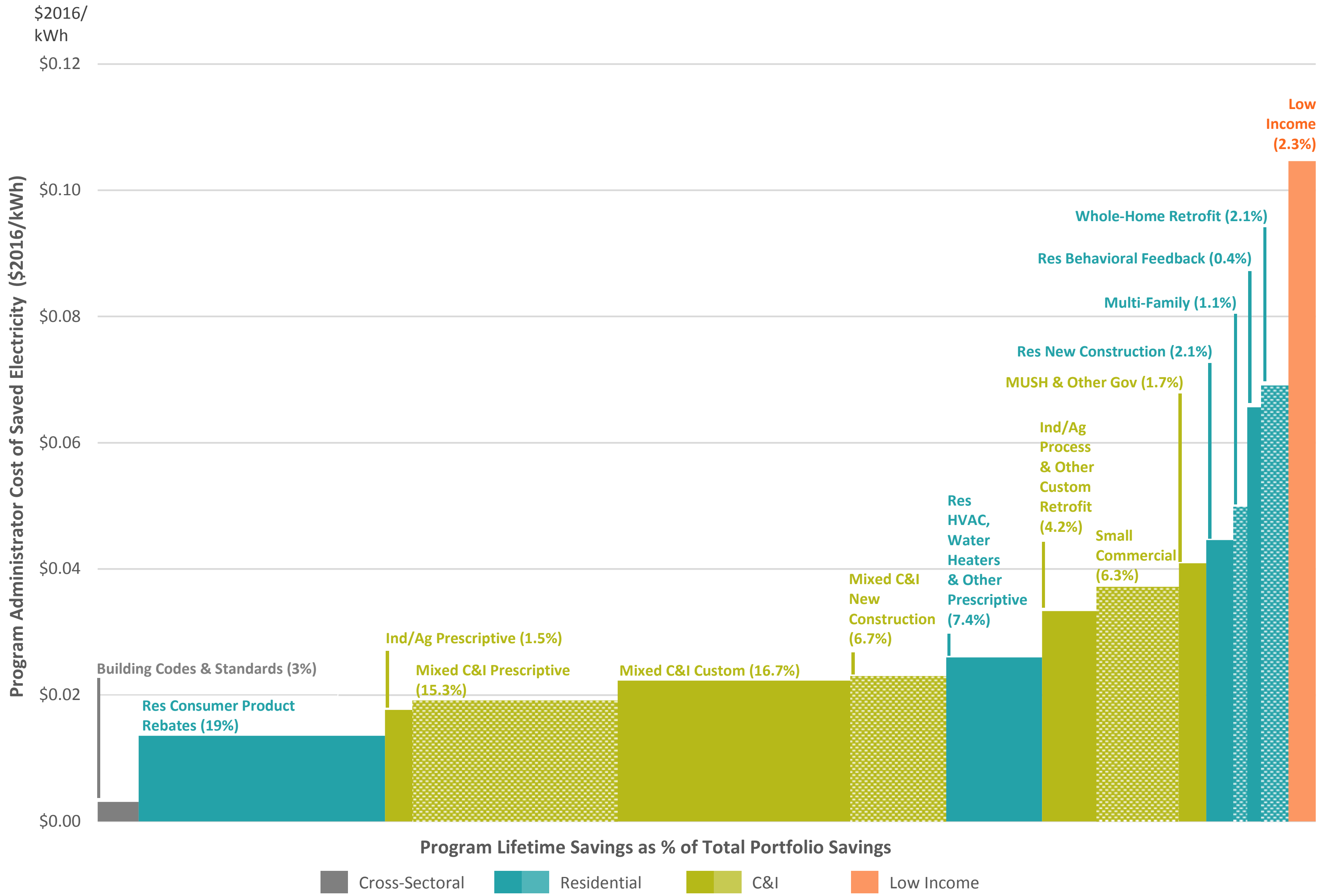

Figure 4-11. A composite cost curve for electricity efficiency programs funded by utility customers (2009-2015)

5. Disaggregating Program Administrator Costs by Cost Category

5.1 Overview

In this chapter, we conduct an exploratory analysis of the relationship between program design, administration and marketing costs of electricity efficiency programs, and the overall costs of these programs (including incentives or rebates provided to customers). In order to inform decisions regarding program design, a key long-term objective of this line of research is to understand the extent to which programs with high administration and marketing costs also tend to have higher CSE values. We examine and discuss the share of administration and marketing costs compared to overall program administrator costs at the market sector level (residential vs. C&I sector) and for several selected program types.

We view these initial results as exploratory because sample sizes are small for some program types and because program administrators use different approaches to account for and report administration and marketing costs. We have made an effort to report program-level administrative costs in a comparable and consistent fashion. In the future, as sample size increases and more granular, disaggregated and consistent program cost data become available, this information could inform a more in-depth review of the relationship between administration and marketing costs and the overall CSE.

5.2 Approach

Our review of electricity efficiency program data reported by program administrators reveals three basic approaches their reporting of administration and marketing costs:

(1) *Disaggregated program-level:* All costs are broken out and reported on a program basis including administrative costs; financial incentives paid to customers or contractors; marketing, education and outreach costs; costs incurred for evaluation, measurement and verification activities and other costs.

(2) *Partial disaggregated program-level:* Some (but not all) program costs are disaggregated and reported on a program basis.

(3) *Some administrative costs reported at market sector or portfolio level:* Some administrative costs are treated as "common costs" (e.g., certain costs associated with offering a portfolio of programs such as planning, designing and marketing of the overall efficiency portfolio) and are reported at the market sector or portfolio level.

Our analysis focused on those program administrators that reported incentives paid to customers in specific programs.[29] The sample size for our analysis included about 3,780 program years in which administrators reported financial incentives (e.g., rebates) in their cost data.

[29] We excluded program data for administrators that did not report incentive costs because it is not possible to disaggregate administrative costs versus financial incentives (e.g., rebates) paid to customers.

We report the share of administration and marketing costs for electricity efficiency programs (i.e., the sum of administrative; marketing, education and outreach; and other costs) divided by all costs incurred by the program administrator (administration and marketing costs, financial incentives to customers, evaluation, measurement and verification (EM&V) and other costs).[30] The percentage indicates the share of administration and marketing costs compared to overall costs incurred by program administrators.[31]

5.3 Administration and marketing costs at the market sector level

Eighty-five program administrators reported sufficient information for calculating administration and marketing costs at the market sector level (residential and C&I sectors) between 2009 and 2015. We treated each program administrator's annual residential or C&I ratio of administration and marketing costs to program administrator cost as one data point. We typically have about four years of data per program administrator, which provides a sample size of approximately 640 data points altogether for the two sectors.

Figure 5-1 shows median values, interquartile ranges and average values for the ratio of administration and marketing costs to overall costs incurred by program administrators in this sample. Electricity efficiency programs targeted at C&I customers spent less of their total budget on administrative costs compared to programs targeted at residential customers. The median and average values for the share of administration and marketing costs were 25% to 27% in the C&I sector compared to 33% in the residential sector. However, in this sub-sample, despite spending a lower share on administration and marketing costs, the PA CSE was somewhat higher for C&I programs compared to residential programs ($0.024/kWh vs. $0.020/kWh). We also observe significant variation in reported administration and marketing costs at the market sector level, with an interquartile range that varied between 20% to 45% in the residential sector and 14% to 38% in the C&I sector.

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30 EM&V costs were not included as part of administration and marketing costs because they were often not reported at the program level.

31 The inverse of the percentage represents the share of program administrator costs paid as incentives or rebates to customers. In some cases, it also includes EM&V costs, depending on whether the program administrator reports those costs at the program or portfolio level.

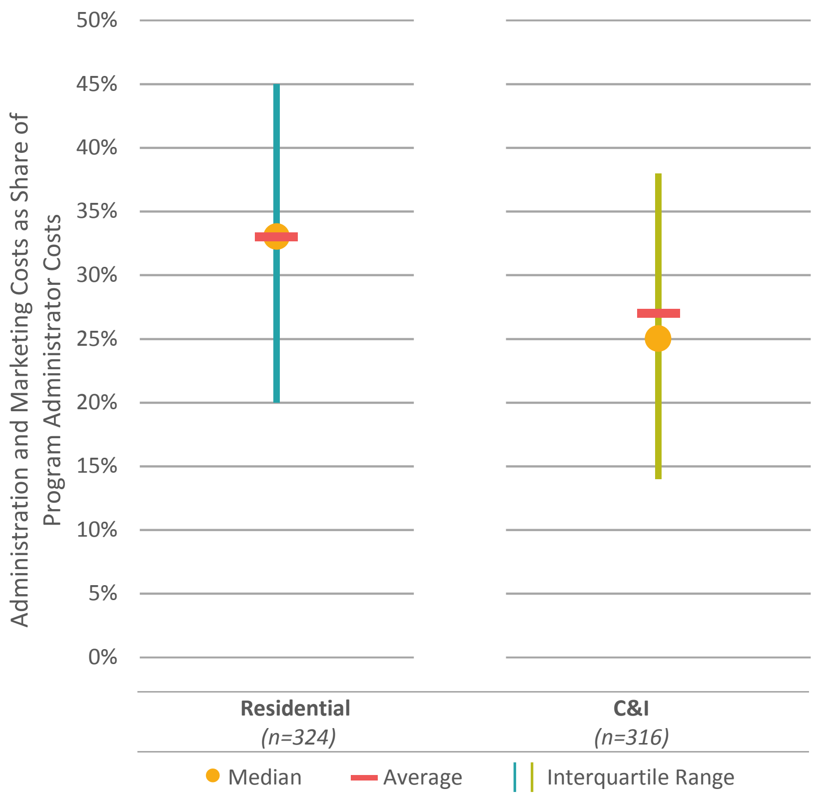

Figure 5-1. Market sector analysis comparing administrative cost to overall program administrator cost

5.4 Program level results

We compiled data for five selected electricity efficiency programs that included disaggregated information on administration and marketing costs along with reporting of financial incentives (or rebates) to customers.[32] We then calculated the ratio of administration and marketing costs to program administrator's overall costs for five selected programs:

- residential whole-home retrofits;
- residential high-efficiency consumer products;
- residential high-efficiency lighting;
- C&I prescriptive rebate programs; and
- C&I custom programs.

[32] We also included programs from two California utilities (Pacific Gas & Electric and San Diego Gas & Electric) that reported financial incentives for both electricity and gas customers. In future research, we will try to separate incentives provided by dual-fuel utilities for electricity versus gas efficiency measures and programs.

Sample size ranges from about 120 to 200 program years of data for the three residential programs to about 280 to 380 program years of data for the C&I prescriptive and custom rebate programs respectively.

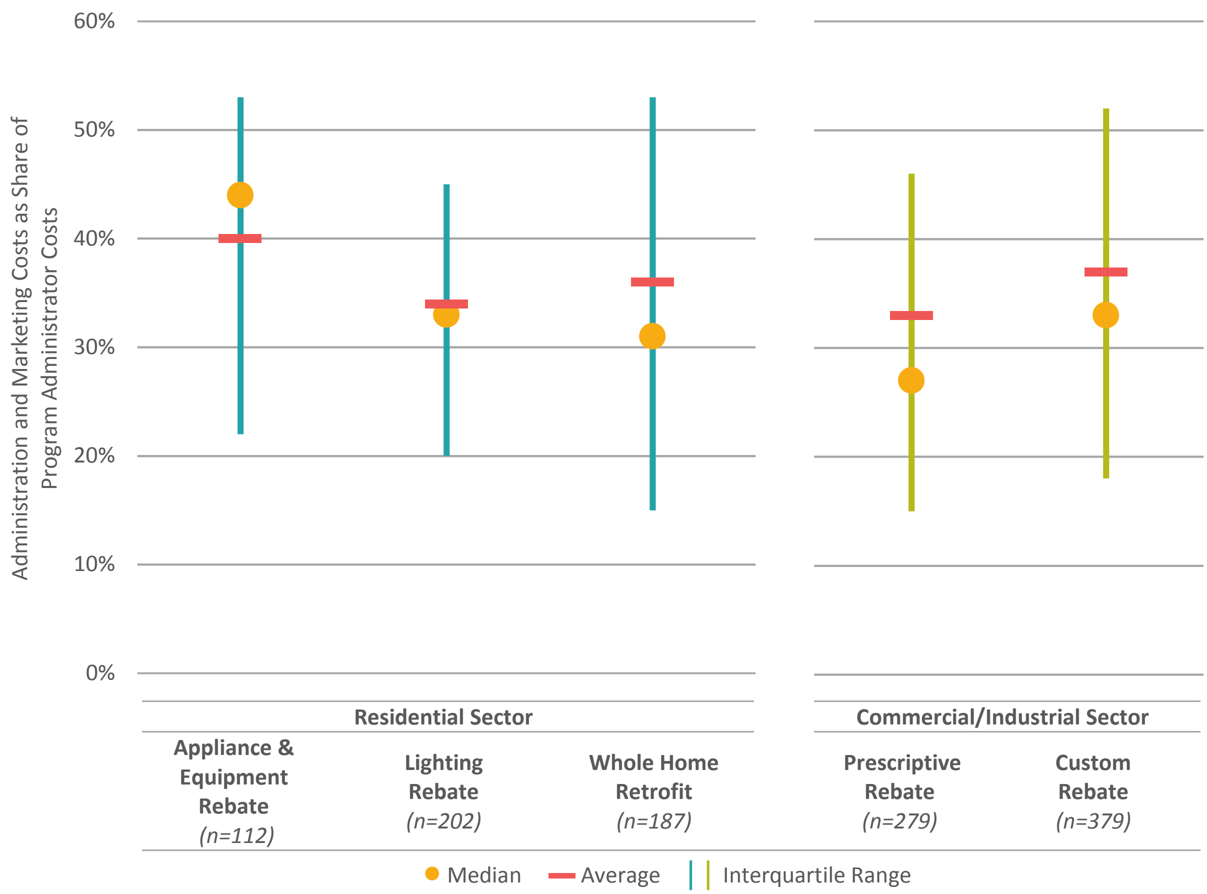

Figure 5-2. Program-level analysis comparing administration and marketing costs to overall program administrator costs

Median and average values for the ratio of administration and marketing costs to overall program administrator costs ranged between 33% and 36% for residential lighting rebates and whole-home retrofit programs and exceeded 40% for residential appliance and equipment rebate programs (see Figure 5-2). The interquartile range in administration and marketing costs for whole-home retrofit programs (15% to 53%) and C&I custom rebate programs (18% to 52%) was larger than for the other three program types. Median and average values were somewhat lower for C&I prescriptive rebate programs (27% to 33%).

Median and average values for the ratio of administration and marketing costs to overall program administrator costs ranged between 33% and 37% for the C&I custom rebate programs. We took a closer look at this sample of programs and created a discrete dataset that included only the top 25% of programs in terms of their spending. We calculated average and median values for this subset of custom rebate programs. Median and average values for the ratio of administration and marketing costs to overall program costs were 22% and 25%, respectively (see Table 5-1)—about 10% to 12% lower than for the entire sample of custom rebate programs. These results suggest that as custom rebate programs increase in size (e.g., spending), there may be some economies of scale in their administration and marketing costs, or significant differences in program design (e.g., larger custom rebate programs may provide higher incentives to customers) or both.

Table 5-1. C&I custom rebate programs: administration and marketing costs as a share of overall program administrator costs

Program Type	Number of Program Administrators	Program Years of Data	Median	Average
Custom rebate programs	67	335	33%	37%
Larger custom rebate programs (top 25% of spending)	28	84	22%	25%

5.5 Next Steps

This is the first year that LBNL has analyzed the composition of program administrator costs in broad categories and its potential impact on the cost of saved energy. The results of this initial market sector and program-level analysis must be interpreted with caution due to the small sample sizes.

Our initial findings show that the ratio of administration and marketing costs to overall program administrator costs tends to be somewhat lower in the C&I sector compared to the residential sector.

Our exploratory program-level analysis indicates two preliminary findings: (1) programs in which administration and marketing costs account for a higher share of overall program administrator costs may not result in a higher cost of saved energy (as demonstrated by our analysis of residential consumer product programs); and (2) lower ratios of administration and marketing costs to program administrator costs may not result in low cost of saved energy (e.g., whole-home and residential lighting programs). However, the programs studied with the lowest cost of saved energy in our small sample, C&I programs, do have the lowest ratio of administration and marketing costs to overall program administrator costs.

Looking forward, additional analysis on the impact of administration and marketing costs could focus on an analysis of cost breakdowns based on the *total cost* of electricity efficiency programs (e.g., including participant costs).

6. The Total Cost of Saved Electricity

In this chapter, we present an overview of the total cost of saved electricity (Total CSE) at the national, regional and state level. The Total CSE is the all-in investment in the efficiency resource, including program administrator and participant costs. We first describe the sample of program administrators in the 27 states that currently report total costs at the program level (Figure 6-1). We then discuss challenges in defining and reporting Total CSE data, given data availability and consistency issues. We report Total CSE values by market sector (residential sector and commercial, industrial and agricultural sector) and type of program. At this more disaggregated level, we report median and savings-weighted average CSE values as well as the interquartile range of Total CSE values to present both the central tendency and variation across our program sample. We then discuss trends over time in the Total CSE and present results of our statistical analysis.

6.1 Data Reporting and Sample Size

Earlier analyses of the Total CSE (Friedrich, Eldridge and York 2009; Billingsley et al. 2014; Molina 2015; Hoffman et al. 2015) were based on data collections ranging from seven to 20 states and datasets generally ending before 2013.

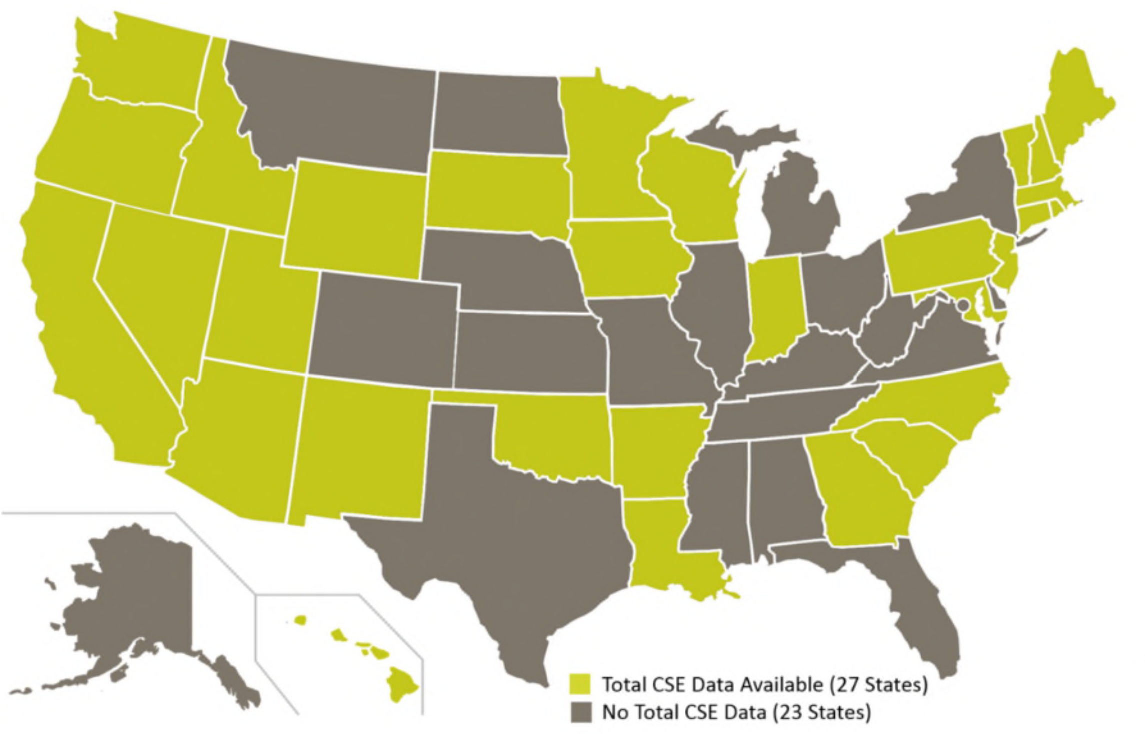

Figure 6-1. Program administrators report Total CSE at the program level in 27 states

The sample size for this analysis of Total CSE is 4,590 program years provided by 67 program administrators in 27 states that currently require reporting of total costs at the program level. For comparison, our sample of program data for the program administrator CSE is 8,790 program years provided by 116 administrators in 41 states (see Chapter 4).[33]

6.2 Defining and Reporting Total Cost of Saved Electricity: Issues and Challenges

Inconsistencies in reporting energy efficiency program costs and impacts have been a persistent challenge for utility energy efficiency programs (see Hirst and Goldman 1990; Joskow and Marron 1992; Eto et al. 1994). A previous LBNL report (Billingsley et al. 2014) described varying practices of program administrators in reporting costs and savings, differences in definitions of input values (e.g., net savings, cost categories reported by program administrators), issues that arise in defining gross and net savings, and varying estimates of key input values (e.g., measure lifetime), and illustrated how these differences can affect the program administrator CSE. Hoffman et al. (2015) highlighted issues related to definition, estimation and reporting that are unique to total costs. Program administrators use different definitions and reporting practices for the components of total costs and also face considerable challenges in estimation, particular for measure costs and participant costs (see Appendix D for a summary of these issues).

In collecting Total CSE data, LBNL encountered four general treatments of the data and its reporting:

- *Case 1: The program administrator reported total costs which included administrative costs, incentives or rebates provided to program participants and an estimate of net participant costs.* In this case, cost data were entered "as is."
- *Case 2: The program administrator reported total costs as used in its Total Resource Cost test and did not include participant incentives. Those incentives were provided elsewhere in annual reports (e.g., in program cost breakdowns).* In this case, we obtained or derived values for incentives to participants and added them to generate actual total costs.
- *Case 3: The program administrator reported discounted values.* We restored values to non-discounted values.
- *Case 4: The program administrator did not report total costs but separately provided information on costs paid by participants.* We added information on net participant costs (e.g., excluding rebates, program-paid installation costs or discounts for audits) to reported program administrator costs to generate total costs, using annual DSM reports and information provided by program administrators upon request.

We attempted to standardize the program and participant cost data where possible.

[33] Thus, calculated values for the program administrator cost component of the Total CSE differ slightly from those in Chapter 4.

6.3 National Results

The Total CSE for 2009-2015 programs in our sample is ~$0.05/kWh (Figure 6-2). The Total CSE for programs that targeted residential customers is $0.039/kWh, while the Total CSE for programs that focused on low-income customers is $0.145/kWh. The average value for Total CSE for the commercial, industrial and agricultural sector (C&I) is $0.055/kWh.

Figure 6-2 shows the Total CSE as a stacked bar chart with the program administrator cost component on the bottom (darker shade) and the participant cost component on the top (lighter shade).

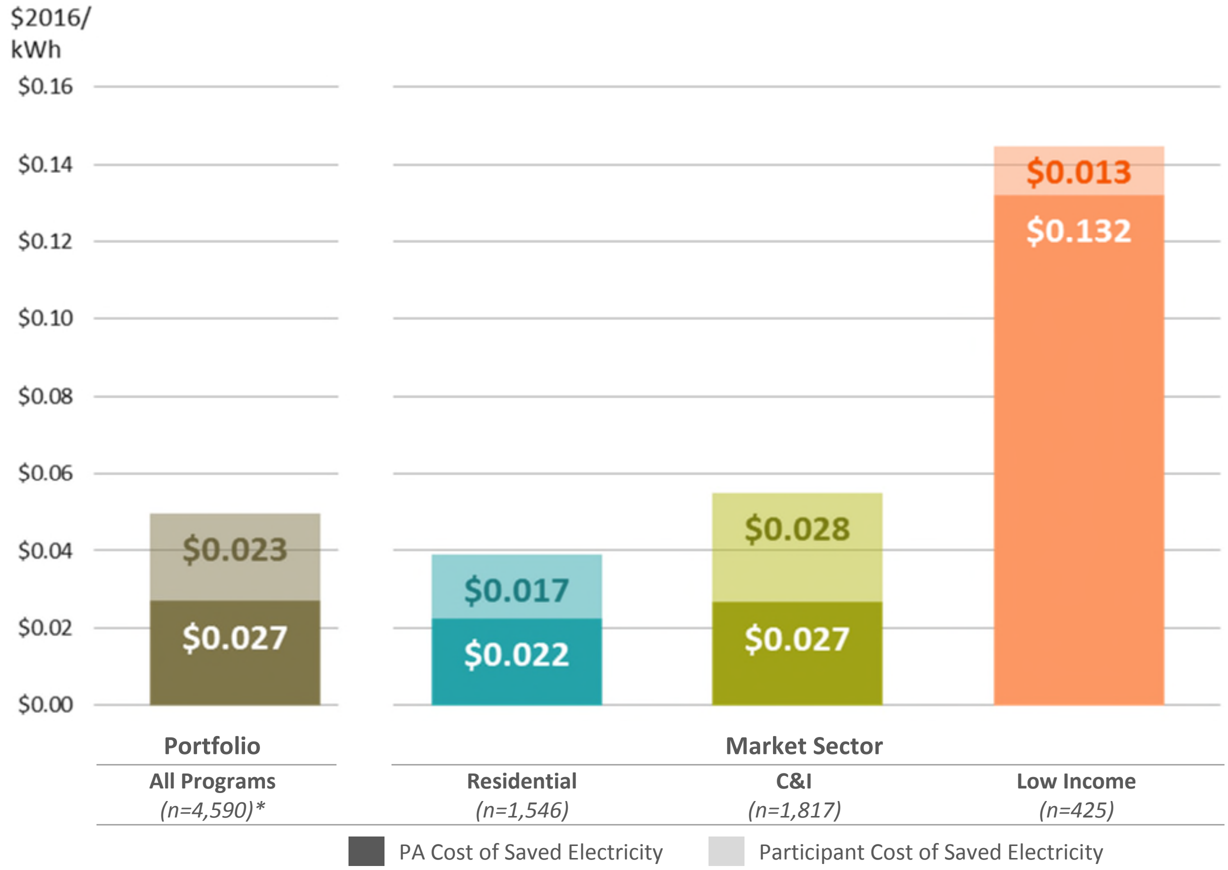

Figure 6-2. Total CSE for electricity efficiency programs by sector: national savings-weighted averages

From a resource investment perspective, the program administrator cost can be regarded as the cost of leveraging investment by participants. To acquire savings across the full portfolio of programs, the program administrator contributed about 54% of total costs while participants contributed about 46%.[34] The current breakdown suggests that program administrators paid a slightly higher share of total

[34] The program administrator cost component of Total CSE in Figure 6-2 is slightly higher than is reported in Chapter 4. A likely explanation is that for the 27 states that report total costs, there is heavier representation from states that have pursued energy efficiency for many years. These states tend to offer a more comprehensive set of programs, which often translates into a higher savings-weighted average PA CSE compared to the 41 states in our full dataset.

costs to attract participants (54%) compared to ~51% for a previous LBNL study for the 2009-2013 period (Hoffman et al. 2015).

Table 6-1. The Total CSE for energy efficiency programs by sector: national savings-weighted averages

Market	# Program Years	Total CSE (2016$/kWh)	Program Administrator CSE (2016$/kWh)	Participant CSE (2016$/ kWh)
Commercial, Industrial & Agricultural	*n=1,819*	$0.055	$0.027	$0.028
Residential	*n=1,550*	$0.039	$0.022	$0.017
Low Income	*n=425*	$0.145	$0.132	$0.013
Full Portfolio, All Programs	*n=4,596**	$0.049	$0.027	$0.023

** The sample size for the full portfolio includes programs that do not claim savings but which nonetheless support the efficiency activities of the program administrator (e.g., planning, research, evaluation, measurement and verification). Costs for these programs are included in the "Portfolio-All Programs" value. The totals may not precisely match the sum of the component values because of rounding.*

6.4 Regional Results

In Figure 6-3, we show the Total CSE in the four Census regions. Two distinct Total CSE profiles emerge from this regional breakdown: (1) the South and Midwest regions at $0.042 to $0.045/kWh, respectively, where many program administrators are ramping up their efficiency efforts and gaining experience and (2) the Northeast and West regions at ~$0.052 to 0.053/kWh respectively, where many experienced program administrators have been designing and managing energy efficiency programs for several decades and have higher avoided costs or retail rates which may allow them to justify higher spending on efficiency programs.

The national Total CSE average of $0.05/kWh is closer to the values for the West and Northeast regions. Those regions include program administrators with larger portfolio-level savings that have more influence in the calculation of the savings-weighted average Total CSE for our national sample.

As Figure 6-3 shows, the Midwest region relied more heavily on participant cost contributions than other regions. The region's share of program administrator to total costs was 39% for the 2009-2015 study period, and participant costs to total costs was 61%. By contrast, program administrator costs accounted for 45% of total costs and participant costs were ~55% of total costs in the West and Northeast regions. In the South, the program administrator share was 65% of Total CSE, and the participant cost contribution was about 35% of Total CSE.

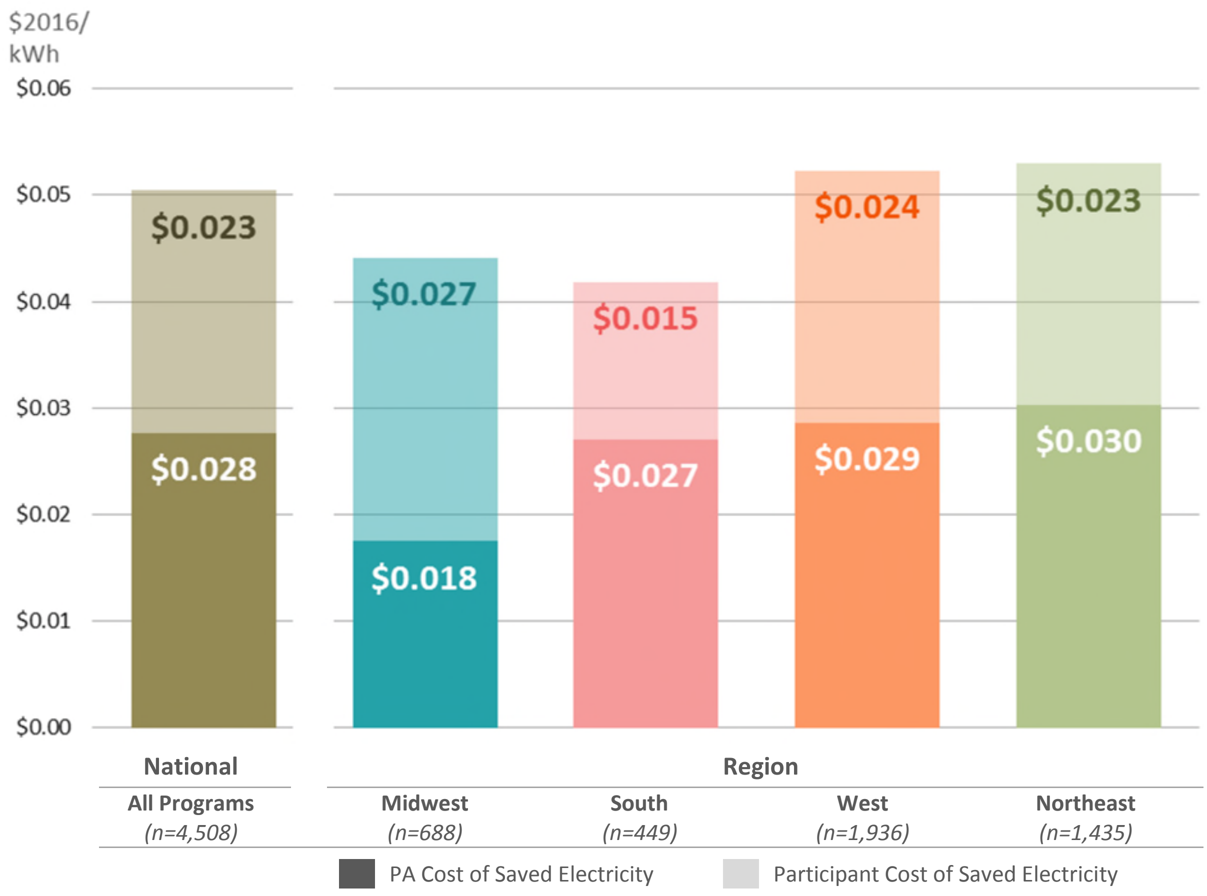

Figure 6-3. Total CSE by U.S. Census region: PA vs. participant costs (savings-weighted averages)

6.5 State-Level Results

The Total CSE varied by more than a factor of three among states, from a low of ~$0.026/kWh to more than $0.08/kWh (see Figure 6-4). Nine of 27 states had a Total CSE less than $0.04/kWh. These states were regionally diverse: three in the West (NM, AZ, NV), three in the Midwest (SD, IN, WI); two in the South (SC, NC), and one in the Northeast (ME). Fifteen of 27 states had a Total CSE under the national average of $0.05/kWh. Among states with the highest Total CSE values (greater than $0.06/kWh), three states are in the Northeast region (NH, VT, MA); Wyoming and Hawaii also are in this group.

In line with the regional results, the relative share of Total CSE paid by program administrators versus participants also varied significantly among states (see Figure 6-4).

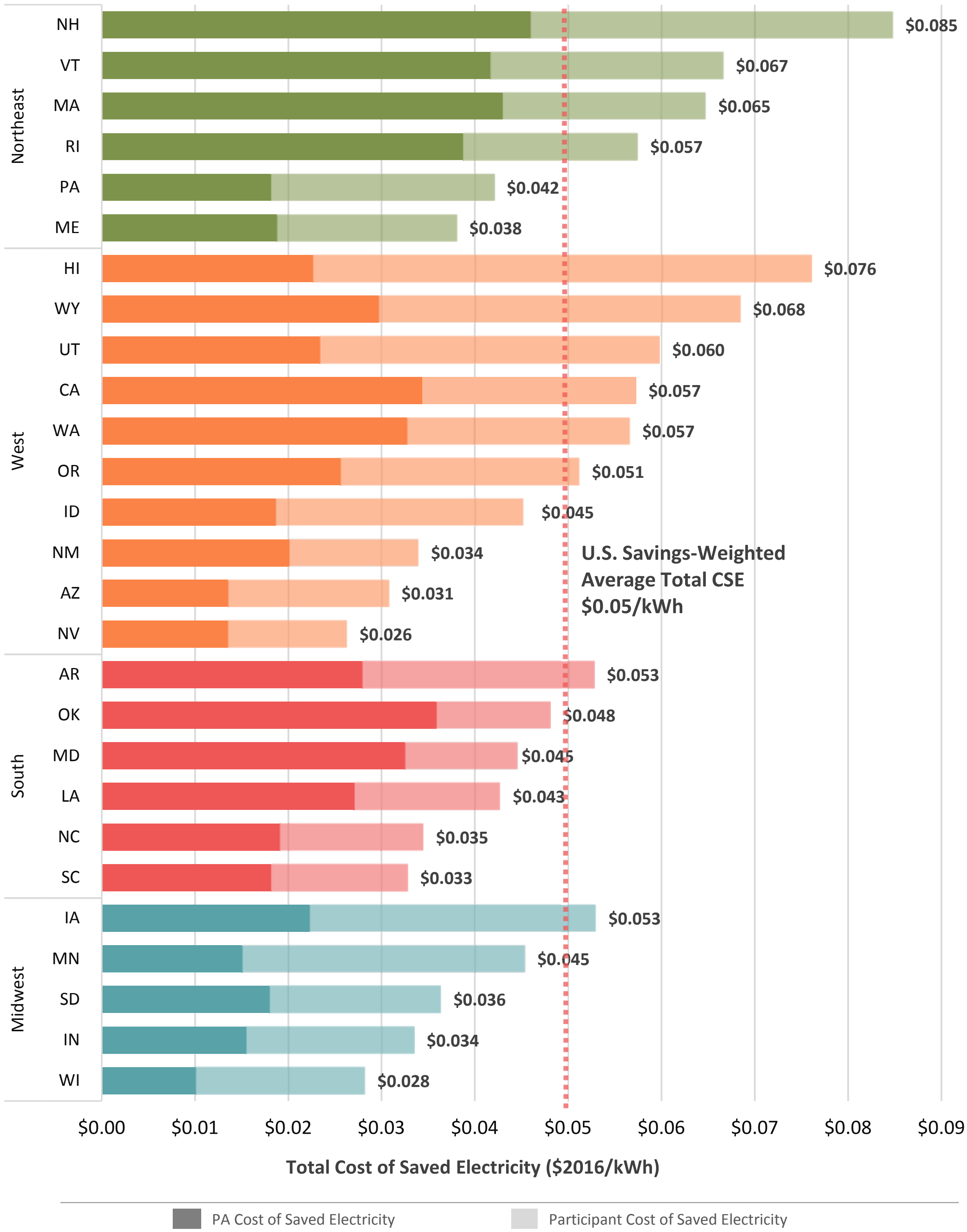

Figure 6-4. Total CSE by state: PA vs. participant costs (savings-weighted averages)

6.6 Residential Sector and Programs

The residential sector had the lowest sector-level Total CSE during the study period at $0.039/kWh (see Figure 6-5). The low Total CSE ($0.027/kWh) for lighting programs drove these sector results, as lighting programs accounted for about 45% of the lifetime gross savings in the residential sector. All other residential programs had significantly higher average values for the Total CSE, ranging from $0.074/kWh for multi-family programs to $0.139/kWh for HVAC programs. Because HVAC and whole-home retrofit programs promote equipment system replacements and other long-lived measures, they typically leverage significant cost contributions from participants.

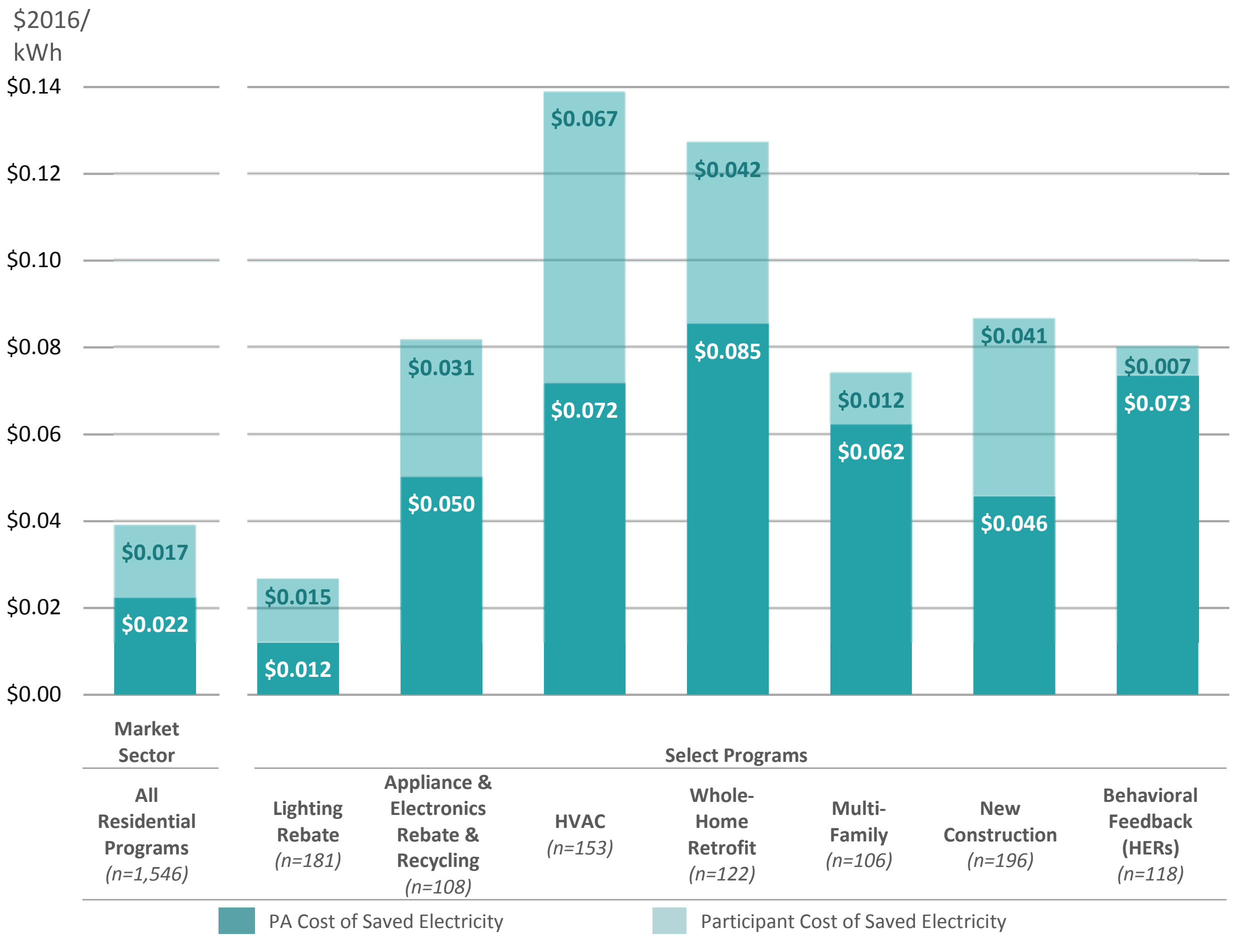

Figure 6-5. Total CSE for the residential sector and select programs: PA vs. participant costs (savings-weighted averages)

In the residential sector as a whole, program administrators on average are paying 57% of the Total CSE compared to 43% from program participants.[35] Participants tended to pay more of the Total CSE in

[35] The Total CSE for many program types is based on the sum of the program administration cost and the PA and participant shares of the *incremental* measure costs associated with installation of more efficient equipment, appliances, or lighting. Participants may view the measure cost as the total price of the measure, not just the participant's share of the increment of cost associated with securing the energy savings over a product with standard performance.

residential lighting programs, about 55% on average. HVAC programs tended to split the cost of savings evenly with participants. But program administrators paid most of the total cost of savings in other major types of residential programs: 61% for appliance and consumer electronics rebate programs, 67% for whole-home retrofits and 83% for multi-family retrofit programs.[36]

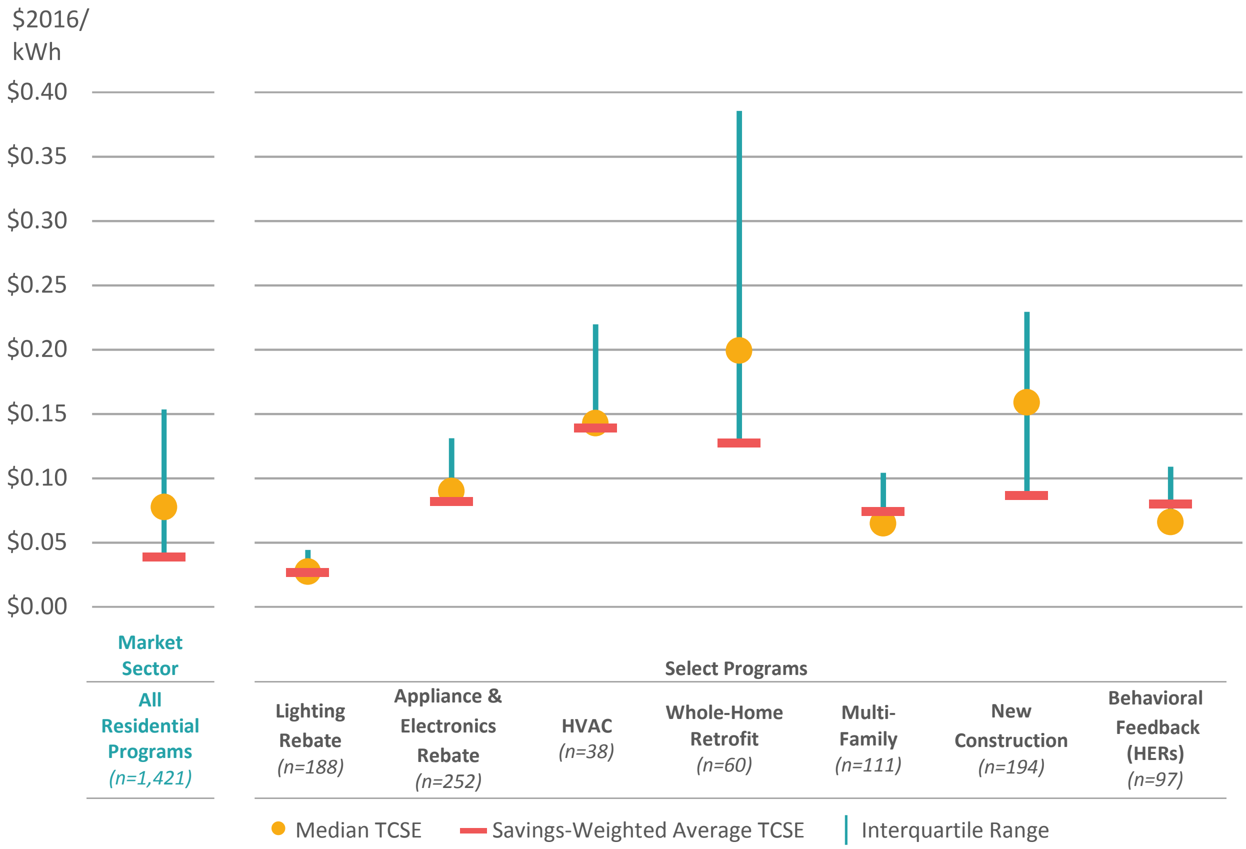

Figure 6-6. Total CSE for the residential sector and select programs: medians, savings-weighted averages and interquartile ranges

Figure 6-6 shows the median values, savings-weighted averages and interquartile ranges of Total CSE for major types of residential sector programs. While the savings-weighted average for the residential sector was lowest among the market sectors, the median Total CSE value was higher than the national and C&I median values. The median CSE value was also higher for several types of programs (e.g., whole-home retrofit, new construction) within the residential sector than the savings-weighted average CSE value. The gap between the median values and savings-weighted averages for these program types may indicate some opportunity for cost reductions with greater scale of savings and longer experience.

[36] The large PA share of the Total CSE for behavioral feedback programs is a function of the program design. Program administrators generally pay a third-party implementer to design and generate periodic messages to customers that compare their energy usage to similar households and recommend ways to reduce energy waste. Participants typically incur no upfront costs. However, a small number of behavior-based programs are hybrids that combine behavioral feedback messaging with onsite audits or other activities that require some participant cost share.

The range in the Total CSE was narrowest in lighting, appliances and consumer product rebate, multi-family and behavioral feedback programs. Whole-home retrofit, new construction and HVAC programs tend to have wider ranges, at least partly driven by more challenging markets and differences in program design and delivery. For example, HVAC programs can include system replacements as well as system tune-ups.

6.7 Commercial, Industrial and Agricultural Sector and Programs

The average Total CSE for the C&I sector is $0.055/kWh (see Figure 6-7), about 41% higher than the average Total CSE in the residential sector. The C&I sector average reflects the cost performance of multiple paths to savings—rebates for prescriptive measures such as lighting and HVAC controls, multi-measure programs promoting custom retrofits, and more efficient new C&I facilities. Together, these three program types accounted for 76% of lifetime savings for the C&I sector, while the difference in average Total CSE values was within $0.01/kWh between the three types of programs. Across the most common C&I programs, average Total CSE values ranged from a low of $0.045/kWh for new construction programs to $0.091/kWh for programs that target municipal/state government, university, K-12 schools and hospital customers (e.g., MUSH market).

Figure 6-7. Total CSE for the C&I sector and select programs: PA vs. participant costs (savings-weighted averages)

Cost contributions between program administrators and participants for C&I programs generally reflected different trends than most residential programs. For the 2009-2015 period, participants in C&I programs were still paying slightly more than program administrators for each unit of electricity savings (52% of total costs from participants and 48% of total costs from program administrators). The C&I programs that generate the most savings—rebates for custom retrofits (37% of sector lifetime savings) and prescriptive rebate programs (26% of sector lifetime savings)—leveraged more investment from participants (about 56%) than from program administrators (44%) (see Figure 6-7).

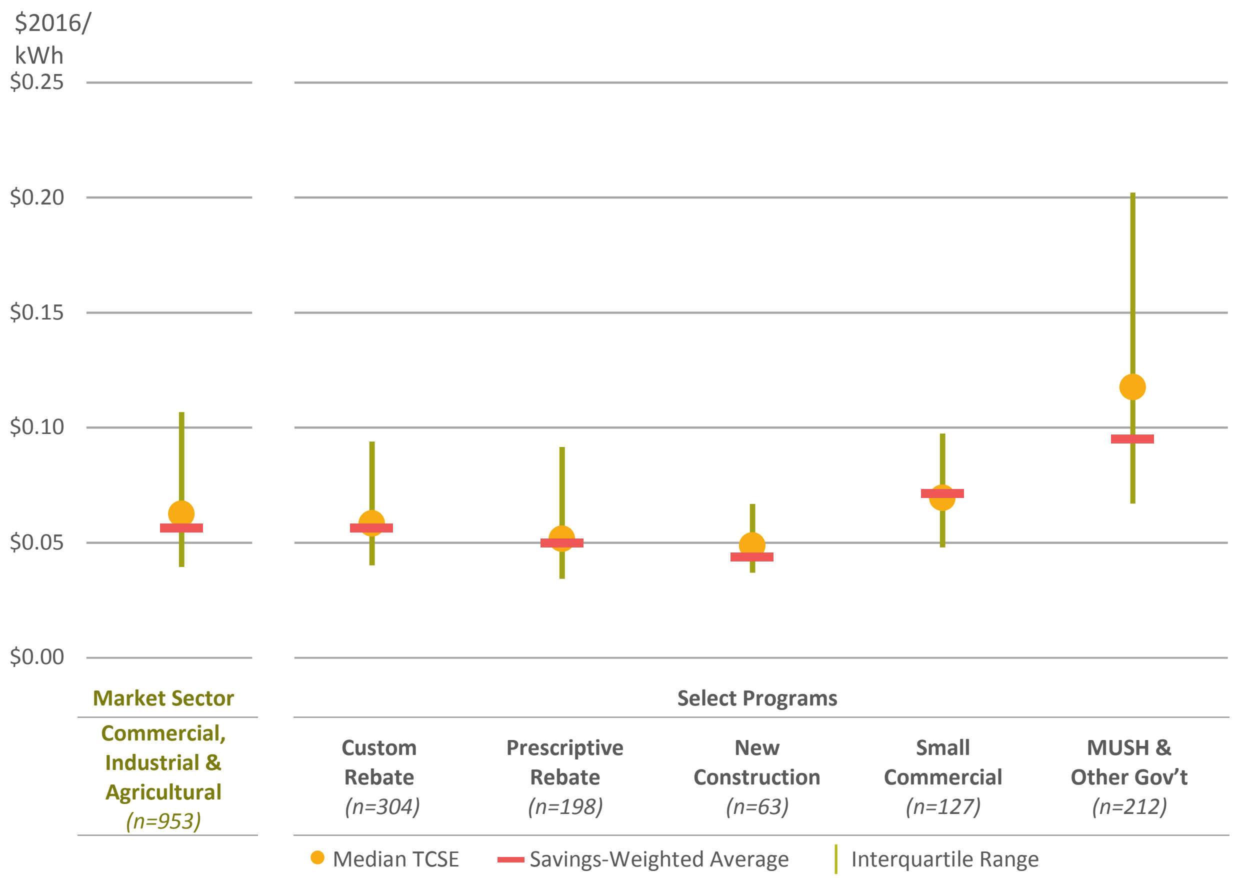

Figure 6-8. Total CSE for the C&I sector and select programs: medians, savings-weighted averages and interquartile ranges

The median values for total CSE were quite close to the savings-weighted averages for most C&I programs, except for programs that target government and institutional customers (see Figure 6-8).

6.8 Trends in the Total Cost of Saved Electricity, 2009-2015

Several studies have examined trends over time in the PA CSE (Billingsley et al. 2014; Molina 2014; Takahashi et al. 2015; Hoffman et al. 2016). However, trends in the Total CSE have not received much attention despite the importance of understanding changes over time in the full cost of the efficiency resource.

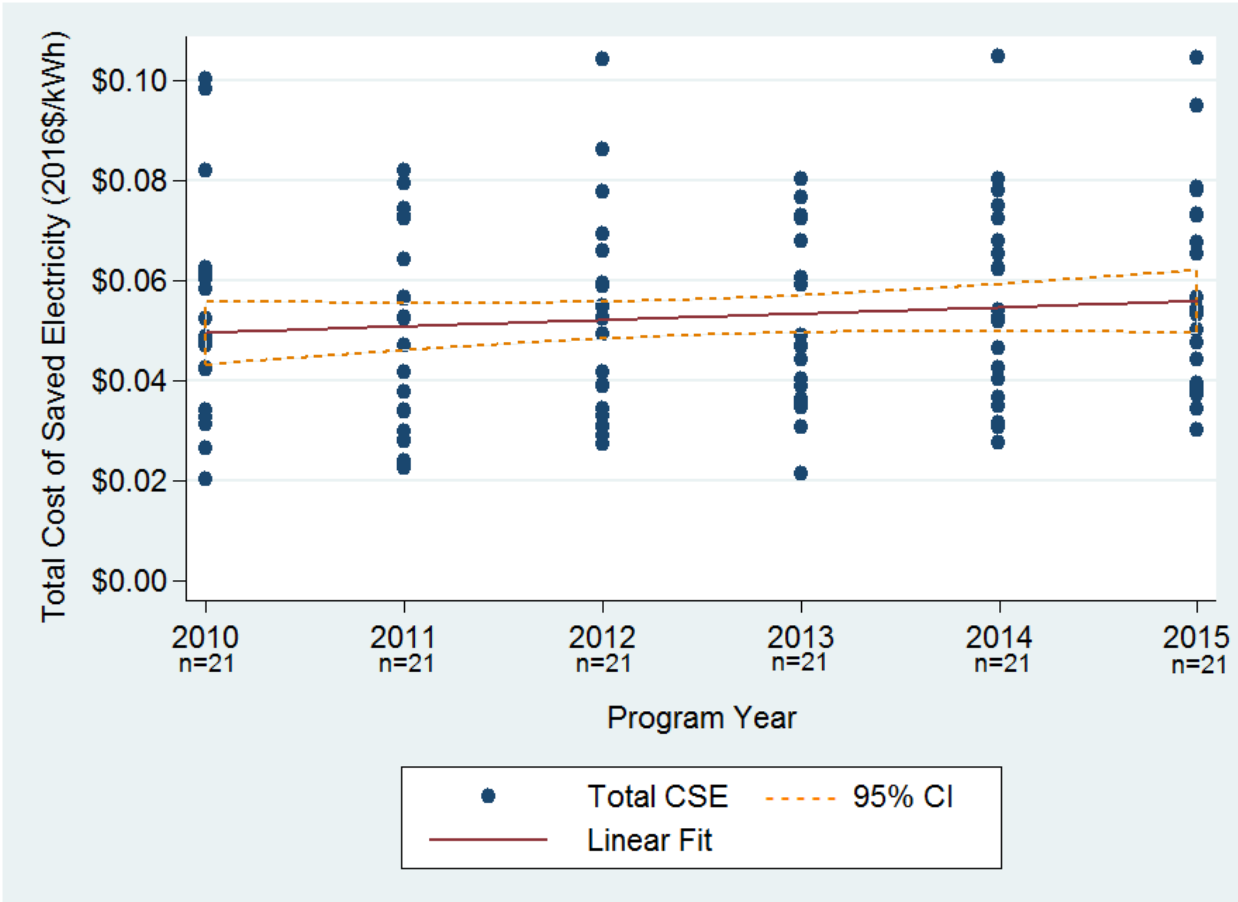

Figure 6-9. Trend in total CSE by program administrator (2010-2015)

Figure 6-9 shows the total CSE at the portfolio level for each program administrator, year by year. In this regression analysis, we limited the sample to the 21 program administrators for which total CSE values were available for all years between 2010 and 2015 in order to explore whether, on average, a program administrator's total costs tended to increase or decrease over the 2010-2015 period.[37]

The solid line is a linear curve fitted to each year's values. The dashes delineate the confidence interval within which the actual trend curve is 95% likely to be found. The slope of the top red line indicates the rate of growth in the *Total CSE*—slightly less than $0.0015/kWh per year or about 3% of the period average. For comparison, Figure 6-10 depicts both the total and program administrator cost of savings for 21 program administrators in the 2010-2015 period.

[37] A balanced panel means that the sample includes the same group of program administrators for all years. Such a sample helps isolate changes in the Total CSE largely attributable to time and removes the influence of additional program administrators in states added to the dataset in recent years. We excluded 2009 program data because it would have significantly reduced our sample size of program administrators with data available in all years.

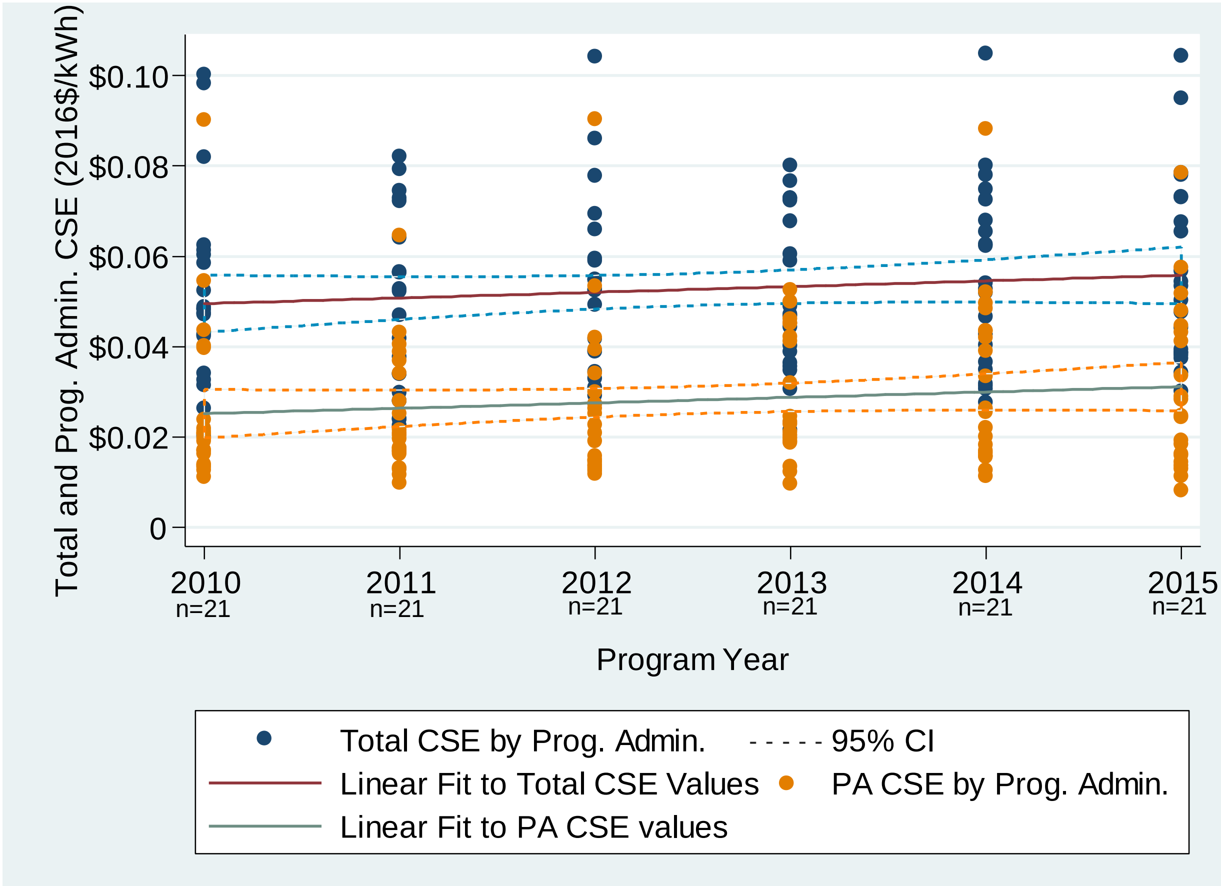

Figure 6-10. Trend in program administrator and total CSE by program administrator (2010-2015)

The rate of increase indicated in Figure 6-10 for the *program administrator portion of the Total CSE* (the slope of the top solid line) is about $0.0013/kWh or a little more than 4% per year. The rate of increase for both Total CSE and PA CSE were significant at the 95% level. Our results suggest that the Total CSE has been increasing at a modest rate, driven by somewhat faster growth in the program administrator cost of savings.

7. Summary and Discussion of Next Steps

In this chapter, we discuss possible implications of our results on the future evolution of energy efficiency resource portfolios. We also offer our assessment of progress and remaining challenges for improving the consistency, quality and transparency of information provided by efficiency program administrators on the costs and impacts of efficiency programs since we began the Cost of Saved Energy project in 2012. Finally, we offer our thoughts on future directions and next steps in characterizing the costs and savings (energy consumption and peak demand) impacts of efficiency programs.

7.1 Implications of CSE Results on the Evolution of Energy Efficiency Resource Portfolios

In this study, we found that the PA CSE for the national "portfolio" of all programs averaged $0.025/kWh on a savings-weighted basis between 2009 and 2015, while the Total CSE averaged $0.05/kWh. We found significant variation in these CSE values by region (the Midwest and South tended to have lower CSE values than the West and Northeast) and by state.

We also analyzed trends in the PA CSE over time for a subset of 51 program administrators for which we had complete program data from 2010 to 2015. In aggregate, the savings-weighted PA CSE increased by 3.5% per year for the 51 utilities. However, changes over time in the average PA CSE was less pronounced if we treated CSE values for each program administrator as one data point (i.e., on an unweighted basis). The mean value for the PA CSE for the 51 program administrators increased by only 0.2% per year between 2010 and 2015 (see Table 4-2).

In analyzing trends over time in CSE, it is also useful to take a closer look at the pattern of results among administrators. We segmented the 51 program administrators into three equal groups, by their annual savings. Annual savings for efficiency programs tends to be correlated with the size of the utility (e.g., its retail load). The average PA CSE increased by 3.8% per year among the largest program administrators, who typically were offering programs in more mature markets for efficiency services. In contrast, the average CSE decreased by 2.8% per year for the group of smaller (and generally less experienced) program administrators. The cost of savings for a third group of middling savers stayed largely flat (see Table 4-2).

The unique level of detail in the LBNL DSM Program Database enables calculation of CSE values at the program level—average, median and ranges—for many types of efficiency programs. This more disaggregated analysis can provide insights on key issues that may influence the mix, cost and performance of energy efficiency resource portfolios going forward.

For the first time, we developed a national "cost curve" for existing electricity efficiency programs (see Figure 4-11). This cost curve provides a composite portrait of the efficiency resource across market sectors (residential and C&I) and program types. It lends a broader context for our findings on cost performance at the market sector and program levels. As Figure 4-11 shows, low-cost savings from rebates on residential consumer products—especially lighting—have the effect of reducing the cost estimates for the efficiency portfolio as a whole, accounting for 45% of lifetime savings in the residential sector and 19% of lifetime savings of the entire national portfolio, with a program administrator CSE value of only $0.011/kWh (see Figure 4-6).

The continued cost-effectiveness of the aggregate portfolio of efficiency programs—and thus the magnitude of the efficiency resource and where those savings can be acquired—depends to a significant degree on continued low cost and substantial savings from residential consumer products. Technological changes can enhance lifetime savings on a per measure basis. For example, light-emitting diode (LED) lamps have longer measure lifetimes than incandescent and halogen bulbs and compact fluorescent lights (CFL). As market penetration of LEDs increases, program administrators may have reduced opportunities to acquire low-cost savings through lighting programs because an increasing number of consumers may be adopting LED technology irrespective of voluntary programs and the replacement cycle for LED lights may be less frequent (MAEEAC 2018).

Moreover, a new phase of federal lighting standards takes effect in 2020,[38] when residential general service lamps[39] other than linear fluorescents will have to deliver 45 lumens per watt. These lighting standards are likely to change the baseline against which savings are calculated. No current incandescent bulbs can meet the standard. Most CFLs can meet the standard, and some will become the baseline performance standard for the residential lighting market. The savings differential between CFLs compared to incandescent bulbs is substantially greater than for LEDs compared to CFLs. Thus, the magnitude of prospective savings may decline for lighting programs, which seek to promote next generation technologies or serve hard to reach markets. At the same time, the performance of LEDs continues to improve, and unit costs continue to decline. The relative pace of these changes in market dynamics and technologies is not clear. If there are significant changes to the costs of residential lighting programs or savings potential decreases, however, the cost of savings could increase for the overall efficiency portfolio.

C&I programs—rebates for C&I custom retrofits, prescriptive measures and new construction—deliver nearly 50% of the national portfolio savings on a lifetime basis. These programs have CSE values that are attractive ($0.02–0.03/kWh) to program administrators. The bulk of these savings come from large C&I customers. However, in recent years, more states have allowed large C&I customers to opt out of

[38] The 45 lumen-per-watt standard for a slightly narrower definition of general service lamps took effect in California on January 1, 2018.
[39] General service lamps are lamps for the most common applications. Exemptions are quite limited and include appliance bulbs, black lights, exit lights, infrared lights and traffic signal lights.

utility efficiency programs or choose self-direct program options.[40] This phenomenon often leads to situations where 10% to 30% of a utility's load (particularly in the Midwest) is no longer eligible to participate in the efficiency programs offered by the administrator. If this trend toward allowing large customers to opt out continues (or expands to more states), it will likely shift reliance for savings in the C&I sector onto market sectors dominated by small to mid-size C&I customers. Programs that target small C&I customers[41] tend to have higher program administrator CSE values in our sample ($0.038/kWh) than programs that target large C&I customers, as well as lower savings potential. Thus, a shrinking C&I market for program administrators may put upward pressure on CSE values in the C&I sector and the overall portfolio.

Behavioral feedback programs have proliferated widely among and within jurisdictions. A number of program administrators expanded these programs from pilots to large scale roll-outs during the latter years of our study period. The programs reliably deliver annual savings of 1% to 2%, often rely on robust evaluation methods (e.g., randomized control trials with treatment and control groups), and typically are critical elements of compliance for program administrators that face annual savings targets. However, behavioral feedback programs have not yet demonstrated their potential as a low-cost, longer-lasting efficiency resource, in part because some program administrators and many state regulators remain skeptical that savings from normative messaging in particular (i.e., home energy reports) last beyond a year. A mounting body of evidence indicates those savings do decay after messaging completely stops (Cadmus 2015, Allcott and Rogers 2014). However, the research to date suggests those decay rates are modest (e.g., 10% to 20% per annum), such that most savings last beyond the second year, and a significant share lasts three or four years. These studies warrant close attention by state regulators because they have the potential to significantly improve the cost performance of behavioral feedback programs. For example, in our sample, program administrator CSE values improved from $0.066/kWh assuming a one-year effective useful lifetime to $0.02–0.03/kWh if we assume savings persist for three years. It is incumbent for program evaluators to continue to test and quantify the persistence of behavioral feedback savings as part of rigorous EM&V activities.

7.2 Deconstructing Program Administrator and Total CSE metrics

This study examined the cost components of energy efficiency to a greater degree than in previous work. We examined the breakdown in program costs for the first time in this study and found significant differences by market sector and among different types of programs (see Chapter 5). For example, the median and average values for the share of administration and marketing costs to overall PA costs are 25% and 27%, respectively, in the C&I sector compared to 33% and 33% in the residential

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[40] States vary in their criteria for customers eligible to opt out or self-direct; many states set criteria at greater than 1 MW peak demand. In some states, qualifying industrial (and other large) customers can "self-direct" fees toward energy efficiency investments in their own facilities, instead of paying into an aggregated pool of funds that the utility collects to fund all efficiency programs. Under a self-direct paradigm, industrial customers can choose to pay the fees to the utility or spend the fees in their own facilities to achieve energy savings. In some jurisdictions, industrial customers are allowed to opt out of paying for energy efficiency altogether.

[41] The small commercial subsector is classified as a "hard-to-reach" market by some program administrators and state public utility commissions.

sector.[42] On average, some programs cost more to administer than others (e.g., 33% to 36% for residential lighting and whole-home retrofits and more than 40% for consumer product rebates). In addition, we found that administration and marketing costs were quite variable across some program types, with interquartile (25th to 75th percentile) ranges often varying by a factor of three for the share of administration and marketing costs to overall program administrator costs (e.g., 18% to 52% for C&I custom rebate programs). Extending our understanding of these costs to more program types and identifying more opportunities for operational efficiencies will require a larger sample and more disaggregated reporting of program cost data.

Our study of Total CSE also provides insights on the costs incurred by program administrators versus participants. We find that these cost contributions vary significantly across program types and regions. For example, program administrators accounted for a higher share of total CSE in the South (65% of total costs), while participant cost contributions were higher in the Midwest region (61% of total costs). These results underscore previous findings: different types of efficiency opportunities and kinds of customers face different market barriers and require targeted implementation strategies.

The growing sample of programs in the LBNL DSM Program Database that includes information on total costs now enables tracking of changes in the Total CSE over time. Across all program administrators, total costs are largely flat or increasing at a low rate. Disaggregating total costs indicates that the participant cost of savings is flat or declining, while program administrator costs appear to be rising, particularly among C&I programs.

7.3 Program Data Collection and Reporting: Progress and Challenges

Program administrator annual reports are typically the product of state regulatory requirements or traditional practices that have evolved over time. In this study, we compiled and analyzed 8,790 program-years of data and discovered a wide spectrum in the level of detail and completeness in annual program reporting.

7.3.1 Progress

First, we now have program-level data for 116 program administrators in 41 states and have added 10 states since our initial CSE study (Billingsley et al. 2014). Similarly, we now have Total CSE data for 27 states and added seven states since our last analysis of this metric (Hoffman et al. 2015). Nearly all states offer energy efficiency programs funded by utility customers. Program-level reporting of efficiency costs and impacts is increasing and granularity and quality of reporting are improving.

Second, we significantly increased the sample size of programs and program administrators for which we are able to calculate the Total CSE (52% of programs and 54% of program administrators in the LBNL

[42] Administrative costs include actual spending by the PA on costs associated with planning, designing, and implementing an energy efficiency program. These costs pay for the salaries, training, and equipping of internal PA staff to administer and implement a program or oversee the work of an outside (contracted) implementer.

DSM Program Database). Our earlier study on the Total CSE found that participant cost information was reported for only about 38% of the program years in our database (Hoffman et al. 2015).

Third, we found that more program administrators are reporting detailed information on program costs by cost category. For example, we conducted exploratory analysis of five selected efficiency programs (see Chapter 5) and found that program administrators reported disaggregated information on administration and marketing costs for 42% to 58% of the program years for these five types of programs. This detailed cost information will allow us to further explore issues related to the level of administration and marketing costs for different types of programs and its impact on the CSE.

7.3.2 Challenges

Annual reports from many program administrators still do not provide a complete picture of the impacts or costs of efficiency investments at the program level. Although these reports may meet state regulatory requirements, significant room for improvement persists in the consistency, completeness and transparency of program-level reporting.

Program-average measure lifetimes

Program average measure lifetimes are essential for calculating the CSE (and for estimating lifetime savings from first-year savings). Yet only 27% of program administrators (32 of 116) reported measure lifetime, lifetime savings or both. These administrators tended to manage larger program portfolios, as their programs represented about 41% of the program years in the database. This data limitation means that we had to impute program average measure lifetime for over half of the program years based on average values from the programs where program administrators reported this information.

Moreover, for similar types of programs, we discovered that program average lifetimes vary significantly. It is logical for program average lifetimes to vary if programs have different mixes of measures or different applications (Hoffman et al. 2015).[43] It is not uncommon for the interquartile range (25th to 75th percentile values) for program lifetime to vary by five years, and we observe a 10- to 15-year spread in minimum and maximum values for similar programs (see Appendix D; Figure D-1). However, these factors cannot entirely explain the significant observed variability in lifetimes for similar programs. Variability in measure lifetimes—and therefore in the average measure lifetimes for programs—is a critical issue if program administrators are going to benchmark their results against national practices. All else equal, program administrators that report longer measure lifetimes will have lower CSE values compared to those that report shorter measure lifetimes. Differences in assumed program average lifetime have a significant impact on CSE values. Thus, additional efforts are warranted to improve the consistency of estimated lifetimes of installed measures for program

[43] For example, a custom C&I rebate program may include hundreds of different measures. The effective useful lifetimes (EULs) of those measures are defined by more than strictly the technical lifetime or mean time to failure. How and where a measure is installed, and how it is used, are significant influences on measure lifetime. Similarly, practices differ among states in surveying and accounting for the impact of renovation, remodels, and rehabilitation activity on the lifetime of measures installed by customers.

administrators located in similar climate regions, including proposing default values and guidelines for treating and accounting for market activities (e.g., remodels, renovation).

Participant costs

We also think it is important for program administrators to report information on participant cost contributions in order to calculate total CSE values. Most states use information on participant cost contributions or incremental measure costs in their cost-effectiveness screening of programs, but only 27 states have provided this information in annual reports filed by program administrators. Moreover, reporting practices for net participant costs (participant costs after customer incentives are taken into account) vary across states, and approaches used (e.g., direct or indirect calculations) depend in part on the type of program and the approach taken to estimate incremental measure costs. Challenges in measure cost estimation include the following:

1. Comprehensive and reliable measure cost data are often not readily available or publicly available.
2. Measure costs vary based on the sales channel, the nature of the sales transaction and the scale of the purchase.
3. Measure costs vary across time and geography.[44]

This is an area where increased transparency of program administrator practices in accounting for participant costs and estimating measure costs would facilitate comparisons and more accurate and consistent estimates of participant (and total) costs.

Energy savings: gross and net

Program administrators in some states report just gross savings or net savings; others report both. Gross savings are those associated with the program participants' efficiency actions, irrespective of the cause of those actions. Net savings (for both program participants and nonparticipants) are those attributed to a program. The proper use of net and gross savings in CSE calculations is a subject of debate (SEE Action 2012). Diverse definitions of net savings further complicate standardization and analysis. Some program administrators integrate a realization rate[45] into calculation of their net-to-gross ratios; others apply that factor independently. The estimation of program participants who would have taken the desired efficiency actions in the absence of the program (i.e., free riders) often does not include partial or deferred free-ridership (i.e., those who would engage in some, but not all, of the desired efficiency actions or may engage in those actions in the future).

[44] Some jurisdictions, particularly California and the Northeast, place a high priority on accurately accounting for measure costs (and therefore participant costs) through periodic and exhaustive measure-cost studies.
[45] A realization rate is typically an adjustment in savings to account for differences between the program administrator's original tally of measure installations and per-unit savings and what is validated or verified in some fashion by an evaluator. That verification may include checking a sample of projects or a more comprehensive accounting that includes post-installation savings measurements.

Most program administrators do not include spillover—reductions in energy consumption, demand or both caused by the presence of an energy efficiency program, beyond the program-related gross savings of the participants and without financial or technical assistance from the program.[46] Some administrators include only participant spillover (i.e., participants not targeted by the program who nonetheless take the desired action as part of the program); others also include nonparticipant spillover (i.e., customers who do not take program incentives or otherwise participate in a program but nonetheless take the action promoted by the program). Most program administrators do not take account of market effects outside of free-ridership and spillover. Most importantly for our efforts to facilitate more consistent and standardized program reporting, program administrators do not supply information in their annual reports on exactly what definitions and practices they use to estimate net savings.

These factors serve to confound data standardization and analysis. Because of this lack of consistency in net savings data, our CSE studies to date present CSE-based values using gross savings. However, we can do a back of the envelope comparison of the potential impacts of using net savings values, ignoring inconsistencies and limitations in the consistency of net savings data. We can compare claimed net savings with claimed gross savings for the program years for which we have both values, which is about one-third of our 2009-2015 data sample. If we apply and impute the estimated net/gross ratio from this sub-sample to the entire sample of program data, the estimated program administrator CSE for 2009-2015 using net savings data would be $0.031/kWh, 23% higher than gross PA CSE savings.

The impact of calculating CSE using net savings versus gross savings is clearly substantial. State utility regulators and stakeholders in many states regard net savings as a useful metric to assess program impacts. Thus, LBNL will continue to collect net savings data and work to standardize that data for analysis and calculation of a program administrator CSE based upon net savings in a future study.

It is also important to monitor and track how quickly program administrators reflect changes to existing standards (lighting and equipment/appliance standards) and building codes in their assumptions regarding baseline conditions and the impact that these new baseline conditions have on estimates of gross savings. Practices and guidelines regarding appropriate baselines (e.g. existing codes and standards, current market practices or existing usage) for estimating savings from installed measures in various applications vary somewhat across states.

Efficiency program data: data quality, consistency, transparency and availability challenges

Historically, information on energy efficiency program spending and impacts has been publicly available in most states. However, we were not able to collect program-level data in a few states because they chose to redact such information (e.g., VA) or simply did not report basic information on program costs and savings (e.g., AL).[47] With program-level data now publicly available in 41 states, the rationales for redacting or withholding basic spending and savings data are not apparent.

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46 See http://www.neep.org/emv-forum-glossary-terms-and-acronyms.

47 The parent companies for some of those utilities report program data in other states, without redaction.

As a practical matter, the quality and quantity of data reported by program administrators is an important factor in assessing energy efficiency as a resource in the utility sector. The need for more consistent and comprehensive reporting—and for greater rigor in estimation of measure costs, savings and lifetimes—has increased with the magnitude of investment in, and reliance on, energy efficiency in the resource mix. In states that have a long history of pursuing energy efficiency, protocols for EM&V activities are often fairly strong. Estimates of annual and lifetime savings and costs are continuously updated as new information comes to light about high efficiency technologies and their market applications. Program administrators, regulators and stakeholders in those states have a firmer grasp on what is known and still to be learned about the magnitude and cost of savings being acquired compared to states that have not run efficiency programs as long.

We would expect that states with longstanding efficiency programs or that have been ramping up their efforts would require rigorous EM&V activities and more comprehensive reporting to ensure that efficiency initiatives are delivering as promised and as cost-effectively as possible. With some noteworthy exceptions,[48] we observe that most states that are relatively new to energy efficiency or still ambivalent in policy commitment tend to use cost and savings assumptions that are less transparent or less grounded in studies of local applications and conditions. Those states also tend to have highly aggregated and opaque reporting of spending and savings (e.g., program costs are not broken down by PA vs. participant costs or by cost category, the assumed savings lifetime is not always evident). These practices tend to reinforce misperceptions that demand-side resources are less understood than supply-side resources. Thus, we encourage further efforts to improve consistency, quality and transparency in program administrator reporting of this information.

In our initial Cost of Saved Energy study (Billingsley et al. 2014), we urged state regulators and program administrators to focus additional attention on efficiency program reporting and offered the following:

> We believe that there is a direct connection between the maturation of energy efficiency as a utility and national resource and increased consistency in periodic reporting of efficiency program costs and impacts. Additional rigor, completeness, standard terms and consensus on at least essential elements of reporting could pay significant dividends for program administrators and increase confidence among policymakers and other stakeholders.

Those same sentiments hold four years later. Informed policy debate and market development begin with quality information. The resources devoted to energy efficiency initiatives and the return on those investments should be readily apparent to those who pay the program costs, those who debate the merits of programs and those whose businesses depend on those programs. Those needs are especially pertinent in states where efficiency is a nascent or developing resource and reporting lags national norms in consistency, rigor and completeness.

[48] Arkansas requires utilities to file thorough reports on energy efficiency programs.

7.4 Future Directions

Potential future directions for analysis of the cost of saved energy and the factors that influence the cost include the following:

- *Broaden scope to include public power utilities:* Building on prior efforts, in 2018–19 we will collect data on the cost of saving electricity for public power utilities and publish a technical brief on our findings.
- *Develop metrics to report on peak demand impacts:* There is increasing interest by utilities, regional grid operators, policymakers and regulators in the time-varying impacts of energy efficiency measures and programs. In 2018–19 we will contribute toward understanding the impact of electricity efficiency measures in reducing peak demand, building on work in 2017 and 2018.[49]
- *Update cost of saving natural gas:* Our initial report on the cost of saved energy (Billingsley et al. 2014) included both electricity and natural gas programs, based on data from 2009–2011. In 2018–19, we will undertake a limited update of the cost of saving natural gas focusing on large and dual-fuel programs.
- *Estimate CSE values based on net savings:* State utility regulators and stakeholders in many states regard net savings as a useful metric to assess program impacts. It is important to review state and utility practices for estimating net savings and to explore ways to standardize that data for analysis and development of metrics for the cost of net savings.
- *Improve understanding of CSE by cost category:* It would be useful to look more deeply into cost breakdowns so utilities, other program administrators, regulators and stakeholders can benchmark the relative share of administrative costs, incentive costs and participant costs to improve program design and delivery.
- *Compare cost performance trends of efficiency and supply-side resources:* An examination of the cost performance trends among energy efficiency and supply-side resources could help utilities and grid operators better anticipate changes in the future resource mix.

Steps such as these will fill in crucial information gaps for energy efficiency toward meeting electricity system needs reliably and at least cost and risk.

[49] See, for example, https://emp.lbl.gov/publications/time-varying-value-electric-energy and https://emp.lbl.gov/publications/time-varying-value-energy-efficiency.

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