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The Total Cost of Saving Electricity through Utility Customer-Funded Energy Efficiency Programs:

Estimates at the National, State, Sector and Program Level

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Overview

This brief presents the most comprehensive estimates to date of the full cost of saving electricity through efficiency programs funded by customers of investor-owned utilities.[1,2] The total cost of the electricity efficiency resource includes the investment by both the program administrator and program participants in saving a kilowatt-hour (kWh). It is a valuable metric that resource planners, regulators and stakeholders can use to assess and compare the relative costs among efficiency programs and between efficiency and energy supply investments.

A previous report (Billingsley et al. 2014) drew upon the Lawrence Berkeley National Laboratory (LBNL) Demand-Side Management (DSM) Program Database[3] to assess the costs to program administrators of saving electricity. For this brief, we updated the database with information from 20 states[4] where one or more program administrators reported sufficient data for analysis of total costs. Based on more than 2,100 program years[5] of data, we compare the total cost versus the program administrator cost of saved electricity at the national and state levels, for market sectors and for the most prevalent program types.

The U.S. average total cost of saved electricity, weighted by energy savings, was $0.046 per kWh for the period 2009 to 2013 for our dataset (see Table 1).

The median value for programs with claimed energy savings across all sectors was $0.069 per kWh. This difference between the average and median reflects the fact that some programs delivered a large share of overall savings at a low total cost.

[1] This brief focuses on the cost of saved electricity; we will explore the total costs of natural gas efficiency programs as more data become available.

[2] Data collected for this analysis came from state regulatory filings or similar documents filed by investor-owned utilities (or third-party program administrators). We did not include data on efficiency programs funded by customers of rural cooperatives, municipal utilities, tribal utilities, or other publicly owned utilities—except in the few instances where those entities contributed to the budgets of third-party program administrators.

[3] The LBNL DSM Program Database is an ongoing collection of spending, savings and other data for utility customer-funded electric and natural gas efficiency programs. The database contains more than 6,000 program years of data, which represents about 1,700 programs across multiple years from 34 states.

[4] Data are from the following states: AR, AZ, CA, HI, IA, ID, MA, MD, ME, MN, NC, NM, OK, OR, PA, RI, SC, UT, VT, and WA.

[5] A *program year* (PY) 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.

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Table 1. Savings-weighted average total cost of saved electricity at the national level by market sector

Sector	Total Cost of Saved Electricity (2012$/kWh)*	Program Administrator Cost of Saved Electricity (2012$/kWh)	Participant Cost of Saved Electricity (2012$/kWh)
All Sectors	$0.046	$0.023	$0.022
Residential	$0.033	$0.019	$0.014
Commercial, Industrial, and Agricultural	$0.055	$0.025	$0.030
Low Income	$0.142	$0.134	$0.008

**Note: Totals may differ from sum of component values due to rounding.*

Program participants paid widely varying shares of the costs of efficiency activities, depending on the design of individual programs (e.g., no direct cost contribution for certain behavioral feedback, direct-install,[6] and low-income programs, and higher participant cost shares for commercial/industrial custom rebate programs).[7,8] Overall, program administrators and participants split the costs of saving electricity almost exactly in half in our program sample, such that total costs were about twice what utilities and other efficiency program administrators on average paid for those energy savings ($0.023/kWh).

We also found that program administrators in fewer than half of states with efficiency programs funded by electric utility customers report total costs and savings. More complete reporting of program-level results would result in a larger study sample and increase representation from regions where efficiency programs are ramping up. Inconsistent data reporting practices also pose challenges. For example, where full costs are reported, differing definitions and interpretations of the components of total costs can make aggregating and comparing data challenging. We identify key data inputs (e.g., lifetime savings, incremental measure costs) for which more consistent reporting would improve insights into efficiency programs, policies and system needs.

Introduction

The cost of saved energy is a useful metric for assessing what efficiency costs across different program types, among program administrators and over time (Billingsley et al. 2014).[9] The cost of saved energy is expressed as dollars or cents per kilowatt-hour of electricity or per therm of natural gas. It is not directly affected by differences in energy prices or other benefits across markets and utility territories.[10] This simplicity makes the cost of saved energy valuable as a standard yardstick across territories and states and different efficiency activities.

The program administrator cost of saved energy enables assessments of efficiency resources from the economic perspective of the utility, and so is useful to program administrators, regulators, and other stakeholders. Resource planners and grid operators often rely on the program administrator cost of saved

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[6] Direct-install programs typically deliver a set of prescribed or pre-approved high-efficiency equipment or measures that are installed under contract to the program administrator and typically do not involve a cost contribution from participants.

[7] We define *participant costs* as the out-of-pocket funds paid by participants for measures and their installation, exclusive of any incentives paid to the customer by the program administrator. Indirect or softer costs, such as customers' transaction cost of investigating energy efficiency investments or waiting at home for a contractor, are not reported and thus are not included.

[8] Custom rebate programs allow customers to propose efficiency measures that are tailored to their facility; the administrator typically reviews and validates modeled or calculated estimates of energy savings and incentives are often capped at a percentage of total project costs (e.g. 50%).

[9] Variation in program design, delivery, market conditions, program maturity, and other factors also may have bearing on differences in the cost of saved energy from one program administrator to the next.

[10] The cost of saved energy can be evaluated for the first year or lifetime of an energy efficiency action, program, or portfolio, and it can be levelized, with the costs spread over the lifetime, as in this brief.

electricity for projecting energy efficiency impacts on load forecasts. For example, the regional transmission 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.

The Cost of Saved Energy and Cost-Effectiveness Screening

The program administrator and total costs of saved energy are neither synonymous with, nor should be confused with, the Program Administrator Cost Test, the Total Resource Cost Test or the Societal Cost Test. These tests are the primary screening tools for comparing the costs and benefits of energy efficiency programs and often decisions about whether utility customers should fund a program. The total cost of saved energy is denominated solely in physical energy savings and 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 does it cost to save a kilowatt-hour?

What program administrators alone pay for efficiency has been the focus of most empirical research to date. The program administrator cost of saved energy is nonetheless subject to criticism that it underestimates the full costs of energy efficiency (Joskow and Marron 1992).[11,12,13] The total cost of saved energy captures the full cost—that is, the full, system-wide investment in the efficiency resource by all parties. The total cost of saved energy provides a way of measuring cost performance and screening programs on a consistent basis that accounts for all costs borne by both the program administrator and participants. In this brief, the primary metric is the *levelized* total cost of saved energy (Equation 1), which is the total cost of the energy saved, spread in equal payments over the economic lifetime of the actions taken through a program (or sector or portfolio), then divided by the annual energy saved.

Equation 1.

$$\textit{Total Cost of Saved Energy} = \frac{\textit{Capital Recovery Factor} * (\textit{Total Program Administrator Costs}^{14} + \textit{Participant Costs}\ (\textit{exclusive of incentives}))}{\textit{Gross Annual Energy Savings}\ (\textit{in kWh})}$$

With the $\textit{Capital Recovery Factor} = [A * (1 + A)^{\wedge B}]/[(1 + A)^{\wedge B} - 1]$
Where:
A = Discount rate
B = Estimated program lifetime in years and calculated as the savings-weighted life of measures or actions promoted by a program

[11] Joskow and Marron reviewed costs and estimated savings for 12 utility commercial lighting efficiency programs and concluded that "computations based on utility expectations could be underestimating the actual societal cost (of efficiency programs) by a factor of two or more on average." Eto et al. (1994, 1996) confirmed that the reported data for those programs understated the total costs for those programs and made efforts to capture as many costs as possible for the same programs. The researchers concluded that, when all costs were accounted for using Joskow and Marron's method, the monetized benefits of those programs exceeded their total costs.

[12] When the program administrator pays the full cost of an energy efficiency action, the program administrator and total costs of saved energy are identical. This circumstance is typical of programs for low-income households and a number of direct-install programs that typically do not involve a cost contribution from participants. The total cost of saved energy, with both the program administrator and participant cost contributions, enables more meaningful comparisons among these many types of efficiency programs than the program administrator cost of saved energy.

[13] For additional information on the various cost performance metrics and the LBNL DSM Program Database, see Billingsley et al. (2014).

[14] Total program administrator costs include all costs of administering, marketing, implementing and evaluating the program, as well as any incentives paid to any party.

We used a 6 percent real discount rate as an approximation of the weighted average cost of capital[15] for an investor-owned electric utility (IOU). We use gross energy savings primarily because net savings are not widely reported. 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.[16] Similarly, since many program administrators do not report evaluated or verified savings, we use claimed savings. To calculate claimed savings, program administrators often multiply per-unit savings estimates for individual measures by the number of measures installed or efficiency actions taken.[17] 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.[18]

The levelized total cost of saved energy treats energy efficiency much like an investment, with costs spread over the lifetime of the efficiency actions. It is comparable to the levelized cost of energy supply (LCOE),[19] which is similarly calculated by spreading generator capital costs over the economic life of the power plant(s). The total cost of saved energy therefore is valuable to resource planners, regulators, and other stakeholders as an initial screening tool for weighing alternative investment options. Utility resource planners can readily use the total cost of saved energy to determine what efficiency resources are the likeliest candidates for consideration in an integrated resource plan. Similarly, efficiency program administrators can use the total cost of saved energy for planning and designing efficiency programs and portfolios, as well as improving program efficacy.

In the next section, we describe our approach for collecting, standardizing and validating the data analyzed. We then highlight several challenges: (1) incomplete reporting of total cost data; (2) varying approaches used by program administrators to define and report participant costs; and (3) certain costs that were excluded from our analysis. We then present the total cost of saved electricity for the period 2009 to 2013 at the national, market sector, program type, and state level.

Data Collection and Analysis Approach

For this study, we identified program administrators that report total costs at the program level and collected program-level cost and impacts data from regulatory reporting, testimony, or similar sources.[20] We found one or more program administrators reporting at this level in 20 states[21] (Figure 1).

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[15] We use a real discount rate because inflation already is accounted for in the use of constant dollars. The 6 percent real discount rate is intended to be a proxy for a nominal rate in the range of 7.5 percent to 9 percent, 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.

[16] See Billingsley et al. (2014) for a discussion of this methodological choice.

[17] For some programs, claimed savings may be based on analysis of utility billing data before and after installation of measures or on results from building simulation models (e.g., new construction programs).

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

[19] The comparison has some limitations. For example, the cost of saved energy usually is calculated at the meter of the end-use customer, while the levelized cost of energy supply is calculated at the busbar of the power plant, which typically does not reflect energy lost in transmission and distribution (i.e., line losses) between the generator and end-use customer. Line losses vary by geography and sector but average about 6 percent nationally, according to surveys by the U.S. Energy Information Administration (http://www.eia.gov/tools/faqs/faq.cfm?id=105&t=3), though other sources report higher values.

[20] See Billingsley et al. (2014) for more discussion on the types and sources of data in the LBNL DSM Program Database, as well as quality assurance and quality control efforts undertaken by LBNL to increase consistency in program data across program administrators.

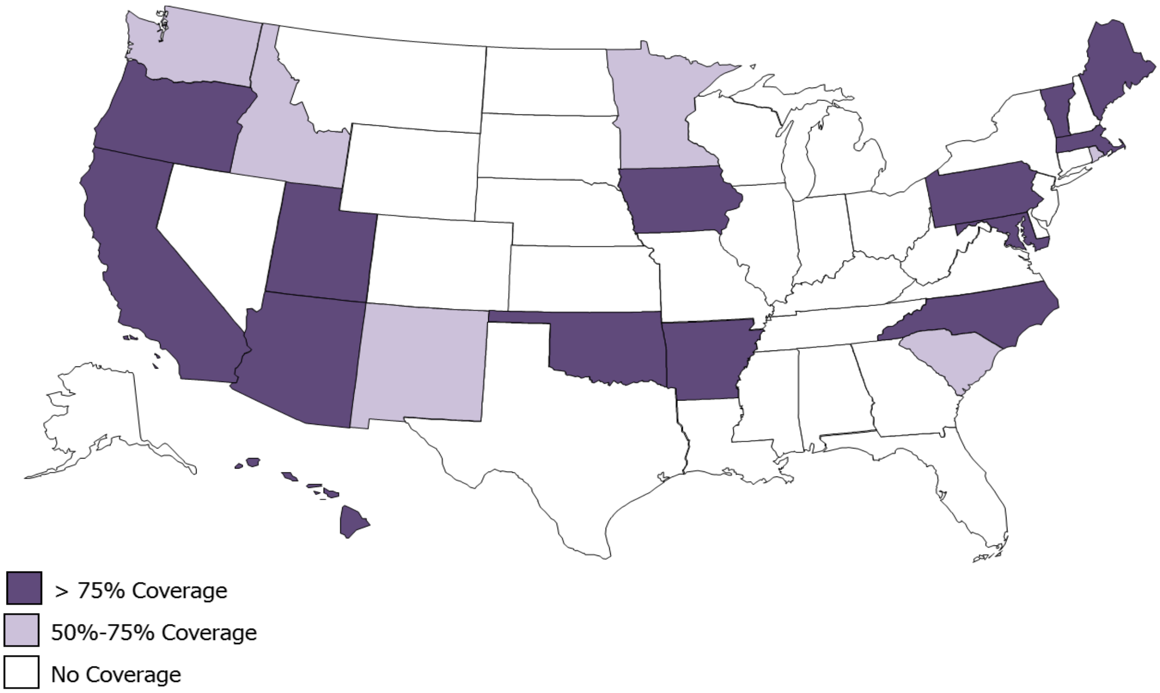

Figure 1. Geographic location of energy efficiency program administrators included in this study
Sources: LBNL DSM Program Database; U.S. Energy Information Administration, Form 861

The states are shaded by the degree of data coverage (i.e., the percent of retail electricity sales of IOUs represented by those program administrators in that state). Dark shading denotes states with data collected from program administrators serving customers of IOUs that account for more than 75 percent of 2012 IOU retail electricity sales in that state; light shading represents states with data collected from program administrators serving customers of IOUs accounting for 50 percent to 75 percent of 2012 IOU retail sales in that state.

We rely almost exclusively on annual reports filed by program administrators because they are the most comprehensive, consolidated repository of efficiency program data. For California, we also drew upon program implementation plans filed by utilities and a program reporting database maintained by the California Public Utilities Commission. For Oregon, the Energy Trust of Oregon provided values directly to LBNL. In several states, we augmented data collection with clarifying questions to the program administrator or regulator, or we requested additional data. We characterized programs by market sector, program implementation type, and technology to enable benchmarking of program results on a more consistent basis and to better define program savings lifetimes, which are a critical input to the cost of saved energy.[22]

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[21] In other states, program administrators only reported efficiency program results at the portfolio level, only reported program administrator costs and savings (and not participant costs), or were not required to file annual reports.

[22] Some program administrators include costs at the portfolio level for specified activities (e.g., statewide brand marketing, regulatory compliance costs) and do not allocate those costs to individual programs. In these cases, we use a method employed by many program administrators, treating each of these activities as a "program" so that all program administrator costs are fully captured and included at the portfolio level. Non-resource programs are typically characterized by sector, except when they are non-sector specific (e.g., emerging technologies programs or work on building codes in an unspecified sector).

In general, we treated all savings and cost data reported by program administrators *as given*. In many cases, we do not have insight into what methods and assumptions underlie the estimation of those values, nor a reliable way to reverse engineer them if desired. The results of LBNL's calculations are therefore highly dependent on values *as reported* by program administrators.

We report the savings-weighted average total cost of saved electricity for the aggregate national portfolio of efficiency programs for which all components of total costs are available, totaling more than 2,100 program years. The weighted average is calculated using *all costs for all programs, levelized over the average lifetime of savings* at the national, state, and sector levels of analysis, including activities for which no savings are claimed.[23] Programs that produce large energy savings have greater influence over the savings-weighted averages than do smaller programs.

We also report savings-weighted averages and median values for the total cost of saved electricity for individual program types. Both costs and savings are required for this calculation, and therefore we derive these values from the ~1,600 program years of data that include both program-level cost and savings information.[24]

Every energy efficiency program is different. Each has its own design and implementation characteristics. While some programs are enormously successful, other programs struggle to get customer participation. Thus, we report the interquartile ranges of the total cost of saved electricity for various types of programs—that is, the middle 50 percent of cost of saved electricity values for each program type or market sector.[25]

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

Data inconsistencies on program spending and savings have been a persistent problem for utility energy efficiency programs (see Hirst and Goldman 1990; Joskow and Marron 1992; Eto et al. 1994). 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's cost of saved electricity.

In this section, we highlight issues that arise specifically in reporting and analyzing the total cost of saved electricity, focusing on issues related to costs incurred by program participants in implementing efficiency projects.

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[23] Many program administrators report costs for certain activities that do not have explicit savings reported. These activities may support a broad array of programs (e.g., portfolio-wide marketing, outreach and planning; financing; residential audits), so savings cannot be assigned to individual programs. We found no obvious consensus method for allocating these costs. We include costs reported for those activities at the portfolio or "all sectors" level for the nation, each sector and each state, but not at the program level. Thus, when analyzing results at the program level, some differences in cost allocation and reporting practices among program administrators persist.
[24] The median is the exact middle value (i.e., 50 percent of values lie above the median and 50 percent below the median) for a set of similarly classified programs.
[25] The highest and lowest 25 percent of total cost of saved energy values for individual programs are not depicted in these figures. However, all program results for a given program type, sector, or state are included in determining savings-weighted averages and median values.

Incomplete Reporting of Data on the Total Cost of Saved Electricity

The data needed to calculate the total cost of saved electricity are typically inputs that program administrators use for cost-effectiveness analyses of their program portfolio, specifically the Total Resource Cost (TRC) or Societal Cost Test (SCT). Twenty-eight states use the TRC test as their primary cost-effectiveness screen[26] for utility customer-funded efficiency programs. Thirteen additional states either require reporting of TRC results or rely upon the SCT as their primary test (Kushler, Nowak and Witte 2012). Thus, as part of efficiency program planning in those 41 states, program administrators must collect or derive all data needed to calculate a total cost of saved electricity at the program level. However, in about half of these states, program administrators do not report program-level total cost data or participant costs to state regulators, or they only report these costs at the portfolio level. In these cases, it is not possible to calculate a program-level total cost of saved electricity. Our study sample is therefore limited to 20 states in which one or more program administrators report total costs (i.e., program administrator costs plus net participant costs) or values from which total costs at the program level can be derived.

Program administrators use different definitions and reporting practices for the components of total costs. LBNL took steps to standardize the cost data and addressed those diverse practices in the following ways:

- **Total costs reported by the program administrator included participant incentives.** Cost data were entered "as is."
- **Total costs reported by the program administrator did not include participant incentives, but incentives were reported elsewhere.** Values for incentives were collected or derived and added to generate total costs.
- **Total costs reported by the program administrator were discounted values.** Values were restored to non-discounted costs and added to the database.
- **Participant costs were available, but total costs were not reported.** Net participant costs (excluding rebates, program-paid installation costs, or discounts for audits) were added to the program administrator cost in order to estimate total cost.

Defining and Reporting Participant Costs

Participant costs are the costs paid by participants who take actions elicited by an efficiency program (e.g., the incremental cost of a high-efficiency refrigerator to the consumer under a refrigerator rebate program).[27]

In an efficiency program, the cost of measures is often split between participating customers and the program administrator that may be providing a financial incentive.[28] The participant cost contribution is

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[26] Such cost-effectiveness screening can be performed at the measure, program, or portfolio level. Which level of screening is binding depends on state policy. Program administrators often perform multiple types of screening to optimize their portfolios, and regulators may require reporting for multiple cost tests.

[27] Participant costs are important for several reasons. The relative share of measure costs paid by a program administrator versus participants is often considered an indicator of program uptake and can suggest a higher degree of leverage (e.g., less direct incentive spending elicits a larger participant contribution to acquire the same amount of energy savings).

[28] In the Total Resource Cost Test, costs include administrative costs incurred by the program administrator and incremental measure costs. Rebates to participants are viewed as a transfer of funds within the utility system, from all utility customers (as a cost) to those

often shown as net participant costs—i.e., participant costs after customer incentives are taken into account (Equation 2.).

Equation 2.

$$Cost_{Net\ Participant} = Cost_{Incremental\ Measure} - Incentive_{Customer}$$

Some program administrators define incentives narrowly as rebates or other incentives to the end-user or participant. Other states recognize a wider array of costs to induce uptake, such as direct-install costs and "upstream" payments to manufacturers and distributors.

Measure cost is the cost to put an efficiency measure in place, including purchase of the more efficient end-use equipment, installation labor, and materials. Many program administrators define measure costs simply as the incremental cost—that is, the additional increment of cost of the high efficiency measure compared to the cost of a measure of standard energy performance.[29] Other program administrators differentiate measure costs by program type. Incremental measure costs are used for some program types, such as programs that reduce the cost of installing an efficient air conditioner in a new home (rather than a standard, less efficient model) or to replace one that is broken beyond economic repair (replace on burnout) (Equation 3.).

Equation 3.

$$Cost_{Incremental\ Measure} = Cost_{Efficient\ Measure:\ Full} - Cost_{Standard\ Measure:\ Full}$$

$$Cost_{Efficiency\ Measure:\ Full}\ or\ Cost_{Standard\ Measure:\ Full} = Cost_{Equipment} + Cost_{Labor} + Cost_{Transaction}$$

Full measure costs may be used for programs in which participants are encouraged to replace end-use equipment before the end of its useful lifetime. For example, the full measure cost for an efficient motor in a retrofit program might be $1,000 while the incremental cost of that motor compared to a standard efficiency motor might be only $200 for a replace-on-burnout program. The cost difference between using full versus incremental measure costs flows through to the calculation of net participant costs and, in turn, to the total cost of saving electricity.

Participant costs can be determined directly or indirectly:

- **Direct Approach.** Direct participant costs can be tracked by analyzing receipts, invoices or other transaction records of participants, retailers or contractors (see the bottom path of Figure 2), often as a precursor to setting and awarding an incentive to the participant. This practice is often used in commercial and industrial (C&I) custom rebate programs and in whole-home retrofit programs.

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who are program participants (as a benefit), and thus are not regarded as an additional cost to the system. However, in calculating the total cost of saved energy, rebates are considered part of the cost of acquiring the energy savings and thus are included.

[29] The incremental cost of an efficient refrigerator or window is limited to the additional cost associated with its energy-saving features and does not include other desirable features (e.g., a refrigerator's stainless steel finish or the window's attractiveness). Actual adherence to this definition may vary for conceptual or pragmatic reasons. Isolating the increment in costs solely associated with what makes a measure more efficient can be difficult. One accepted method uses statistical regression to separate the efficiency premium from other cost components; this method requires large sample sizes given the number of products and diversity of product features in the market.

Often, the invoiced costs to the participant are costs of the project prior to taking incentives into account. However, determining the accuracy of reported participant costs can be quite challenging. There is a great deal of heterogeneity among C&I custom rebate projects and variability in the level of detail and cost definitions used in participant invoices.[30] In some cases, these differences make it difficult to accurately determine actual project costs or incremental measure costs. The cost for the same measure also may vary by project size (St. John et al. 2014).

- **Indirect Approach.** Program administrators and their consultants usually rely upon point-of-sale data from retailer records but also can tap a variety of other sources (see the top path of Figure 2). Costs not covered by incentives or paid directly by the program administrator are assumed to be participant costs. This approach is common, widespread and used for most measures.[31] Participant invoices may be used for local adjustments to regional or national equipment and labor costs.[32]

Figure 2 illustrates these two approaches and their relationship to net participant costs.

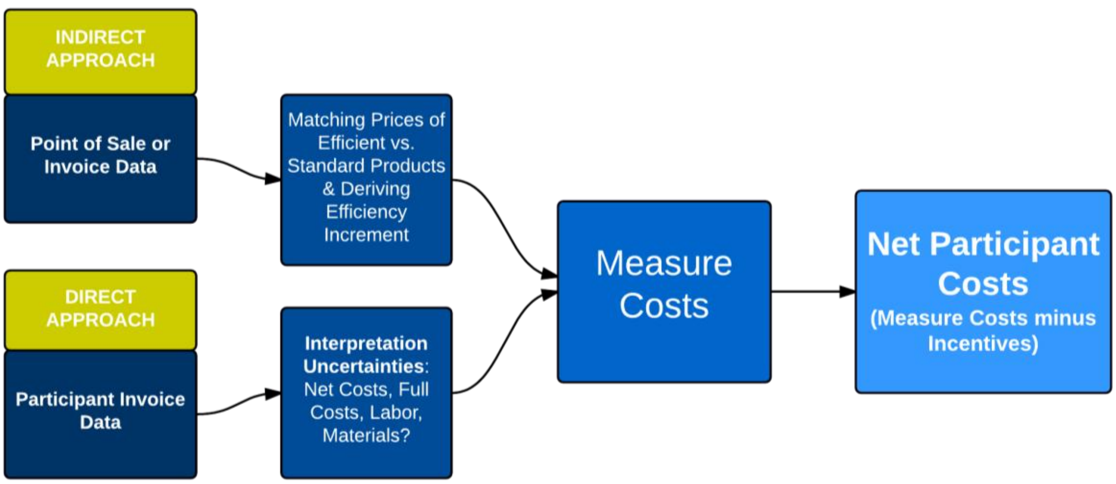

Figure 2. Approaches used by efficiency program administrators to estimate measure and net participant costs

Challenges in Measure Cost Estimation

Acquiring accurate and complete data for determining measure costs can be challenging (Ting 2014; Itron 2014):[33]

- **Comprehensive and reliable measure cost data are often not readily or publicly available.** Utilities and other program administrators would ideally perform and update measure cost studies

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[30] While some participants present itemized invoices, many supply only a single cost number (Teng 2014).

[31] Program administrators may find that state or regional collection and estimation of measure costs is less costly than if conducted by each program administrator alone. These measure costs may be documented in technical reference manuals (TRMs). Thus, two entities may be engaged in the quantification of participant costs when using the indirect approach: the organization that is responsible for estimating measure costs for the TRM and the program administrator that is setting incentive levels.

[32] Program administrators obtain or estimate measure costs through a variety of sources, such as databases that track program rebates and projects, onsite collection at local/regional retailers and distributors, contractor price sheets, online retailers, interviews with contractors or other market actors, and the program administrator's own judgment (NW Regional Technical Forum Guidelines for the Estimation of Incremental Measure Costs and Benefits 2013; CPUC 2010-2012 WO017 Ex Ante Measure Cost Study Draft Report 2014).

[33] Of all values used in establishing cost effectiveness of energy efficiency programs, measure costs receive the least emphasis and research investment (St. John et al. 2014).

periodically. Measure-level cost studies often are based on statistical regression analyses of market data, yet they can be perceived as difficult or costly and thus are often performed or updated infrequently. Borrowing from other jurisdictions is a common practice (Ting 2014; St. John et al. 2014; LBNL research).

- **Translating the prices of many product brands and models into costs of generic efficient "measures" and products can be difficult.** Determining energy savings impacts of products can be performed by grouping the technologies according to their energy performance criteria—e.g., SEER, AFUE, R-value.[34] Product costs must be assessed at a more granular level, since there is more variation in individual products and their costs than in their energy performance. This requires that sample sizes of measure cost studies be on the order of hundreds or thousands.
- **Measure costs vary across time and geography.** Measure cost studies are a snapshot in time and place. For example, in commercial prescriptive programs, St. John et al. (2014) found that regional differences can have a significant impact on average costs for specific measures, with regional costs for a given measure varying 7 percent to 51 percent from the national average. Average costs for the same measure varied by up to 24 percent over just a few years. Borrowing of measure cost values from other jurisdictions is common, although it is not clear that adjusting those values by time and place is as common.[35]
- **Measure costs vary based on the sales channel, the nature of the sales transaction, and the scale of the purchase.**

Other Costs Excluded from the Analysis

A number of other costs should in theory be included in the total cost of saved energy, but these types of costs generally are not included as a matter of practice or are not available at the time that program administrators submit their annual reports. Examples include:

- **Lost Revenue Recovery and Performance Incentives for the Program Administrator.** Recovery of "lost revenues" and performance incentives for utility shareholders or other program administrators are often regarded as a component in the total cost of saved energy. However, the awarding of lost revenue recovery and performance incentives tends to substantially lag annual program reporting.

Non-Energy Benefits

Investments in high-efficiency products and equipment often result in benefits to customers beyond energy savings. For example, a home with better insulation and higher-efficiency windows is more comfortable. The cost of saved electricity does not include the enhanced comfort of homeowners who retrofit their homes, the water saved with energy-efficient clothes washers, or the adverse health impacts that are mitigated by reducing emissions from fossil-fuel power plants. Values for most of these non-energy benefits also are rarely reported as program-level outcomes and thus are not readily available.

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[34] Seasonal Energy Efficiency Ratio (SEER) is the ratio of output cooling energy in British thermal units (Btus) to the input electric energy consumed in watt-hours. Annual Fuel Utilization Efficiency (AFUE) is a thermal efficiency of combustion equipment. R-value is a measure of thermal resistance typically used in building insulation.

[35] Escalation rates can be applied to correct for temporal changes, and different calibrations for installation labor, materials, and contractor markup can be applied to adjust by geography or market.

Thus, LBNL did not include these costs in our calculation of the total cost of saved electricity.[36]

- **Participant Transaction Costs.** Program participants typically incur costs in analyzing potential efficiency investments and getting the work done. For example, homeowners may have to take time off from work to meet contractors and have measures installed. Businesses must devote time to securing budgets, getting and reviewing contractor bids, obtaining financing, and interacting with program staff and contractors. Industrial facilities may slow or stop production to make efficiency improvements. These costs are rarely included in regulatory reporting as a matter of practice and as a practical matter. However, it can be difficult to establish a counterfactual: Would the time and attention invested have been different for purchase and installation of less efficient insulation, lighting, or equipment?
- **Tax Credits.** Four states in our sample (OR, SC, NM, OK) offer some form of tax credits, most commonly for new construction. These forms of tax relief result in reductions in a government's treasury akin to a societal cost.[37] Information is not readily available on whether efficiency program participants claimed a tax credit, nor is it clear that accounting for tax credits would change the total cost of saved electricity so we did not account for tax credits in this analysis.

Results: The Total Cost of Saved Electricity

The National and Sector-Level Total Cost of Saved Electricity

The total cost of saved electricity, weighted by the reported energy saved, was $0.046 per kWh across all sectors and programs in our 2009–2013 data collection (see leftmost bar in Figure 3).[38] For comparison, the American Council for an Energy Efficient Economy (Molina 2014) reported a savings-weighted average of $0.054 per kWh (in 2011 dollars) for a smaller sample of program administrators in seven states.[39]

Figure 3 shows the level of participant spending leveraged by program administrator spending. The average total cost of saved electricity was about twice the program administrator cost of saved electricity ($0.023/kWh) in our 2009–2013 dataset.

The average total cost for all residential sector programs was $0.033 per kWh (see Figure 3), about 40 percent lower than the average cost of saved electricity in the commercial, industrial and agricultural sector ($0.055 per kWh). Programs in the C&I sector nonetheless had a larger influence over the savings-weighted average than residential programs because of greater energy savings (51 percent vs. 38 percent of total savings).

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[36] See footnote 39, however, for an estimate of what the total cost of saved electricity would be if performance incentives were included.

[37] At the federal level, tax credits often are forecasted and reported as a form of expenditure.

[38] We also calculated the cost of saved electricity using a lower discount rate (3 percent real) that could be a proxy for a societal discount rate. At this lower rate, the savings-weighted average total cost of saved electricity is $0.038/kWh for all programs in our sample.

[39] Differences in assumptions and key inputs account for some of the difference in results. For example, Molina et al. (2014) used a slightly lower discount rate (5 percent vs. 6 percent real), included performance incentives for program administrators, reported all costs in 2011 dollars, and used net rather than gross energy savings. LBNL did not include performance incentives because they usually are not available at the time that spending and savings are reported. If a 12% estimated national average for performance incentives (Hayes et al 2011) were applied to all program years for the program administrators in this analysis that receive performance incentives, the U.S. average total cost of saved electricity would be $0.048/kWh. If we adjusted our analysis to account for all of ACEEE's methodological differences for our sample of programs, then the levelized total cost of saved energy would increase to $0.051/kWh (compared to our estimate of $0.046/kWh).

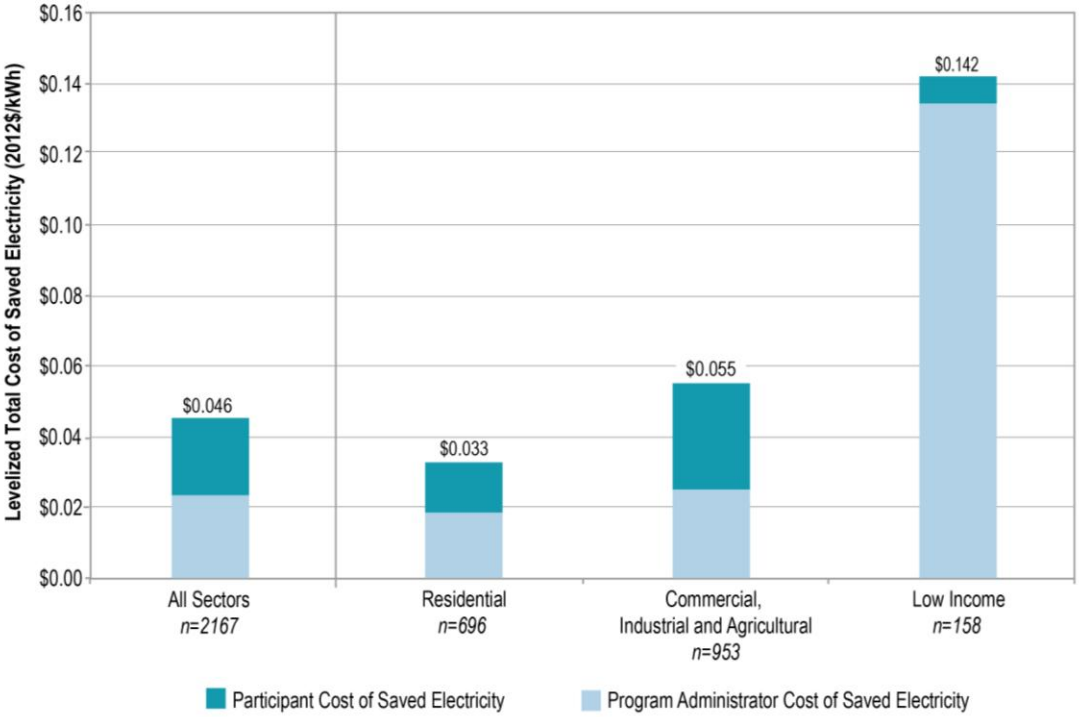

Figure 3.Total cost of saved electricity for all market sectors. The total cost consists of program administrator and participant costs.

Low-income programs had a significantly higher cost per unit of energy saved with an average of about $0.142 per kWh. Low-income programs had only a modest impact on the savings-weighted average value for all sectors, however, because they only accounted for about 1 percent of total savings for our sample of programs. For this reason, we focus our discussion on other types of programs. But we note that, in many states, program administrators are required to look beyond strict cost-effectiveness criteria for low-income programs and consider other policy objectives (e.g., equitable access to efficiency programs among all customer classes, safety and health issues), which influence the cost, design and relative size of low-income programs.

The cost contribution from participating low-income customers tends to be modest in these programs (~10 percent of project cost), with program administrators most often paying the full cost of comprehensive retrofits of older, lower-quality housing, in which basic repairs may be a prerequisite for efficiency improvements.[40]

The Total Cost of Saved Electricity for Efficiency Programs with Claimed Savings

Thus far, we have reported average values for all programs in our dataset, using all savings and spending, regardless of whether a specific program or expenditure is associated with a claim of energy savings. We take this approach to ensure that all costs are counted, even those not directly tied to saving electricity. From here onward, however, all reported values are reported solely for programs with a claim of energy savings.

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[40] During the 2008 to 2010 recession, program administrators in a number of states raised the income eligibility of their low-income programs or added offerings to serve households on the margins of poverty guidelines. In some cases, program administrators asked for a modest contribution from these customers. For our sample of low-income programs, costs incurred by participating low-income customers were about $0.014/kWh.

The total cost of saved energy ranged fairly widely in all sectors (Figure 4). The third quartile value across all sectors was 250 percent higher than the first quartile value, with particularly wide ranges among low-income and residential programs. The breadth of these ranges is a product of many factors, including but not limited to the contexts in which the programs operate, diversity in measure mixes and program designs, and the program administrators' assumptions regarding measure lifetimes and unit savings.

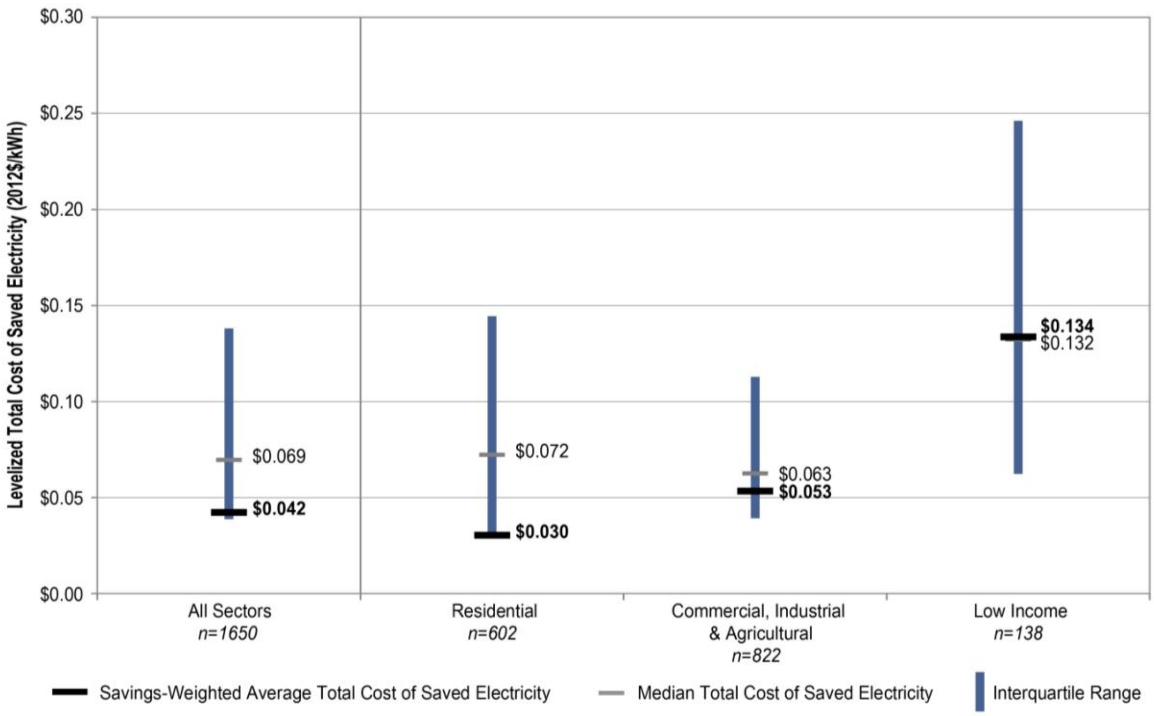

Figure 4. Savings-weighted average, median and interquartile range of total cost of saved electricity values for all sectors. Only programs with claimed savings are included.

The median value of the total cost of saved electricity for programs in all sectors was much higher than the savings weighted average, at $0.069 per kWh. This difference reflects the fact that some programs that account for a large share of the overall savings in our sample have low total costs of saved electricity values, thus keeping the overall savings-weighted average low compared to the middle value of the dataset.

Efficiency Programs in the Residential Sector

The comparatively low cost of savings in the residential sector was influenced significantly by one type of program (Figure 5).[41] Consumer product rebates include programs that provide incentives for lighting, appliances and consumer electronics. These programs were a key driver for the relatively low cost of saved electricity in the residential sector, delivering energy savings in 2009–2013 at an average of $0.021 per kWh (Figure 5). Of these programs, lighting rebate programs had the largest influence on cost performance for the residential sector overall. They accounted for nearly 60 percent of the savings in the residential sector, with a savings-weighted average total cost of $0.018 per kWh. Historically, compact fluorescent lighting programs have accounted for a large share of savings and helped bolster the cost effectiveness of the rest of the portfolio. Excluding residential lighting-only rebate programs—an extremely unlikely but illustrative scenario—the total savings-weighted cost of saved electricity would have been $0.055/kWh for the residential sector (~ 70 percent higher) and $0.054 per kWh for all sectors (nearly 20 percent higher).

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[41] See Billingsley et al. (2014) for details on the multi-level typology used to characterize programs nationally.

Residential prescriptive programs typically provide incentives for more efficient heating, ventilation and air conditioning (HVAC) systems; water heaters; and shell improvements (e.g., additional insulation, high-efficiency windows). Their savings-weighted average cost of saved electricity is $0.054 per kWh. Multi-family retrofit and whole-home retrofit programs tend to promote more comprehensive retrofits (i.e., several different measures are installed) and are more costly on average ($0.071 and $0.094 per kWh, respectively). Residential new construction programs tend to have high cost of saved electricity values on average ($0.111 per kWh), in part because building efficiency standards have captured some of the lower-cost efficiency opportunities.[42]

The relative cost contributions provided by program participants also varies widely for different types of residential programs. For example, participants usually incur no costs in behavioral feedback programs but contribute more to multi-family retrofit programs (28 percent of total costs), whole-home retrofit programs (36 percent), and prescriptive programs (59 percent) (see Figure 5).

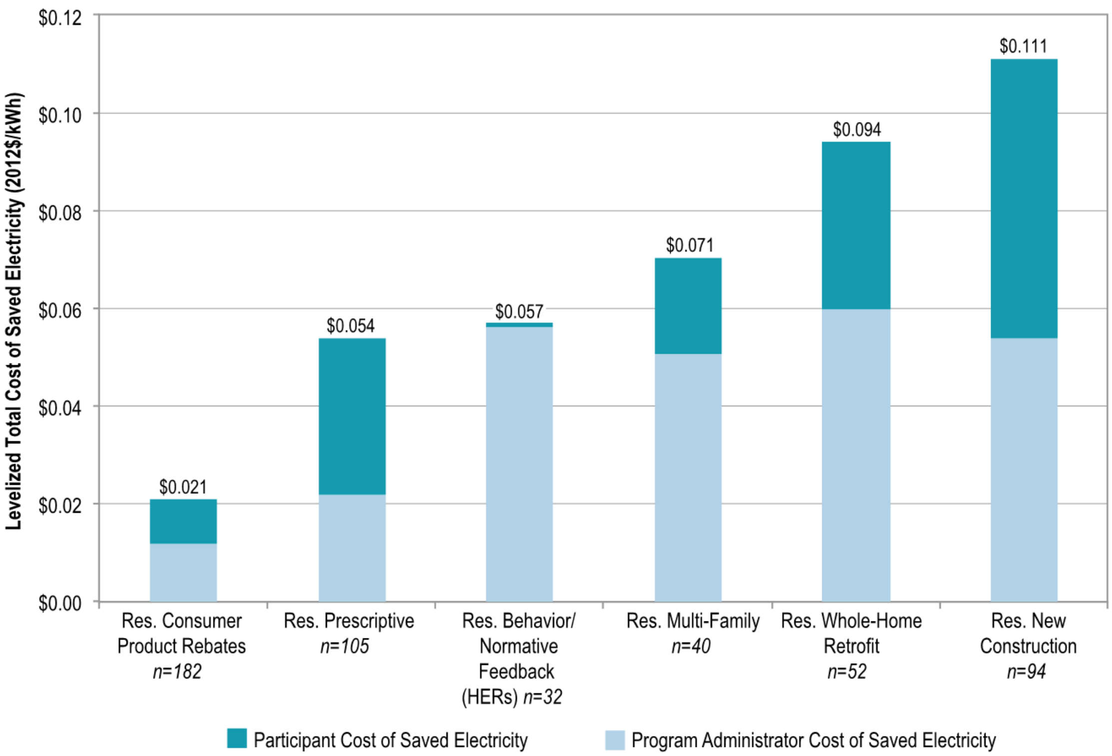

Figure 5. Total cost of saved electricity for various types of residential programs. The total cost consists of program administrator and participant costs.

It is also important to understand the range in performance among types of programs. Figure 6 shows median values and the interquartile range in the cost of saved electricity values. The interquartile ranges vary by a factor of three to five among residential program types. The large range for whole-home retrofit and new home construction programs may reflect variability in the mix of measures, program maturity, knowledge and state of the market, and program design. For example, many of the whole-home retrofit programs (i.e., home energy upgrade) are relatively new programs, and thus may have significant start-up

[42] In assessing the effectiveness of new construction programs, program administrators and policymakers should also consider market barriers (e.g., split incentives) and "lost opportunity" costs (e.g., from a societal perspective, it still may be less expensive to construct a high efficiency building initially, rather than retrofitting that building later).

costs or be early in developing the necessary relationships with local contractors. Some new construction programs attempt to drive higher energy performance throughout the home, while other new construction programs are limited primarily to promoting certain high-efficiency equipment or appliances.

Behavioral feedback, or "home energy report," programs are increasingly common.[43] The savings-weighted average total cost was $0.057 per kWh for these programs in our 2009–2013 dataset. These 32 programs (excluding pilots and other programs for which no savings are claimed) have an interquartile range of $0.038 to $0.092 per kWh. By way of comparison, for three programs sponsored for multiple years by U.S. utilities, Allcott and Rogers (2014) reported a range of $0.032 to $0.044 per kWh.

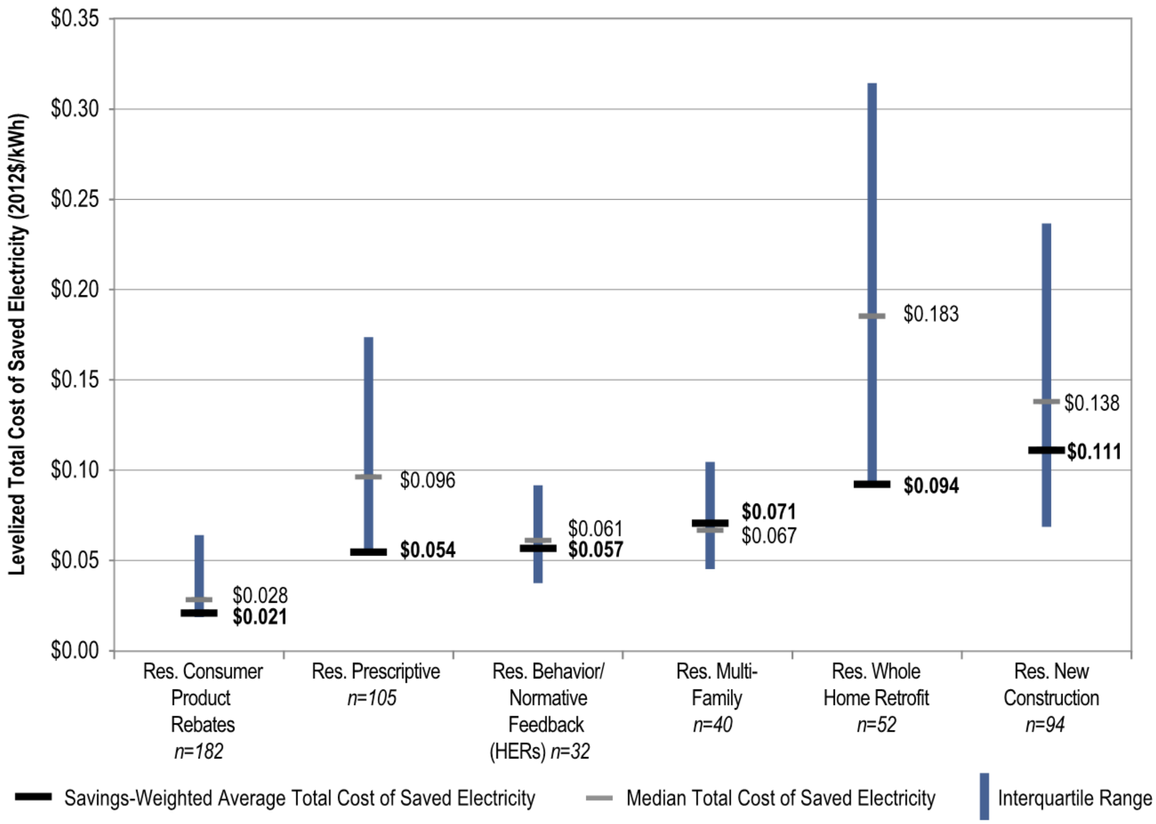

Figure 6. Savings-weighted average, median and interquartile range for the total cost of saved electricity for various residential program types

Several factors may account for differences in these results for behavior feedback programs. First, we report our results as a savings-weighted average for a larger sample of programs. In addition, some large behavior feedback programs in our sample (in terms of enrolled customers and aggregate savings) targeted broader groups of residential customers, were located in milder climates, were located in territories where efficiency programs have been operating for many years, or all of these. These programs have higher cost of saved electricity values and, having produced large savings relative to other behavioral feedback programs, have a strong influence on the savings-weighted average values. Second, most savings from behavioral feedback programs come from changes in customer behavior (e.g., turning out unneeded lights), with some savings resulting from installing more efficient lights or equipment that is discounted or rebated by other

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[43] These programs send periodic reports that provide the household with a comparison of its energy use relative to similar households and offer customized energy-saving tips (e.g., resetting the thermostat). Programs may also provide information on financial incentives for purchase of high-efficiency equipment.

programs. To avoid double-counting savings, some program administrators allocate those savings to the other programs, which tends to increase the cost of saved electricity for the behavioral feedback program.

The duration and persistence of savings are key factors influencing the total cost of saved energy. In our dataset, all program administrators estimated savings for behavioral feedback programs are based upon the assumption that the savings from actions taken by customers would last about one year.[44] A recent meta-analysis (Khawaja and Stewart 2014) of studies of the five longest-running behavior feedback programs recommends using a measure lifetime of 3.9 years. Using that value, the savings-weighted average total cost of saved electricity for behavioral feedback programs with claimed savings would have been $0.017 per kWh, compared to the $0.057 per kWh average based on a one-year measure life. Behavioral feedback programs did not have much influence on our overall results for total cost of saved electricity because they only account for about 6 percent of total residential savings in our 2009–2013 dataset.

Commercial, Industrial and Agricultural Sector Efficiency Programs

Non-residential programs that have claimed savings have an average total cost of $0.053 per kWh, with average values for most program types in a narrow band between $0.042 per kWh and $0.063 per kWh (Figure 7). The most common program types are *prescriptive* and *custom rebate* programs, with total costs averaging $0.045 and $0.052, respectively. Each of these two program types accounts for about one-third of non-residential claimed savings.

Programs that target energy savings opportunities in the government and institutional sector had a higher cost of saved electricity on average ($0.085 per kWh). Some program administrators have implemented programs that specifically target the so-called "MUSH"[45] market that includes state and local government facilities, universities and colleges, K-12 schools and hospitals. In the 2009–2013 period, California utilities offered more than 80 of these programs, most of them collaborations with local governments. These California programs account for more than half of the savings in the MUSH category. If these programs were removed from the analysis, the savings-weighted cost of saved electricity for government and institutional programs would have been $0.048 per kWh, closer in cost performance to the non-residential sector overall ($0.053 kWh).

On average, programs that target non-residential customers appear to leverage more participant investment compared to residential sector programs, with program administrators paying on average 46 percent of total costs and participants paying 54 percent. In custom and prescriptive rebate programs, on average, program administrators and participants split total costs 41 percent/59 percent and 42 percent/58 percent, respectively.

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[44] Program administrators used a measure life of one year for these behavioral programs because it was a condition of regulatory approval for a pilot or because the programs were new.
[45] MUSH is an acronym for Municipalities, Universities, Schools and Hospitals.

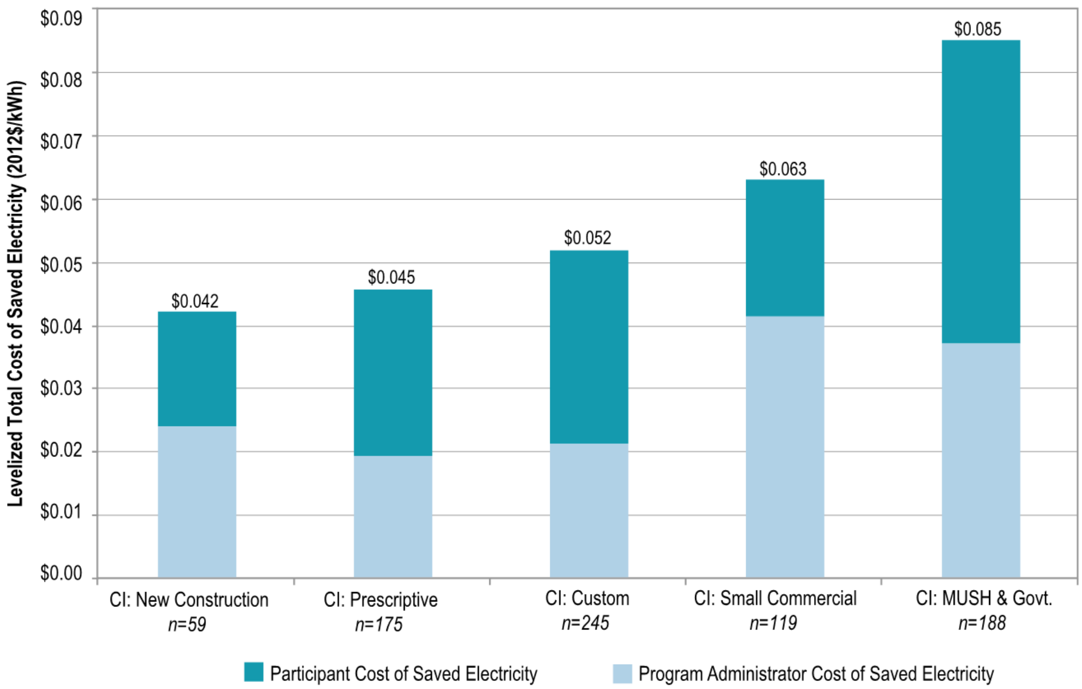

Figure 7. Total cost of saved electricity for various commercial, industrial and agricultural program types. The total cost consists of the program administrator and participant costs.

Figure 8 shows that the range in cost performance among programs in the LBNL dataset tended to be narrower for most types of C&I programs, compared to results in our sample of residential sector programs. For example, the interquartile range values vary by a factor of two for nearly all types of C&I programs (except for programs that target MUSH market customers), compared to a factor of three to five among various types of residential programs.

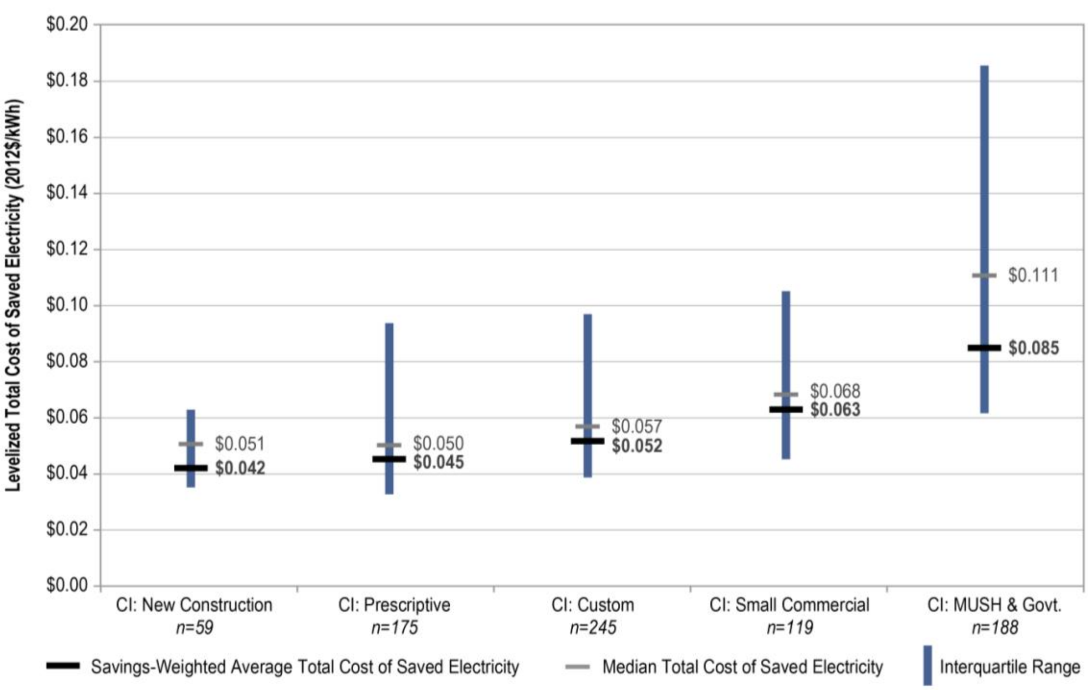

Figure 8. Savings-weighted average, median value and interquartile range for total cost of saved electricity for non-residential program types

Among the States: Total and Program Administrator Cost of Saved Electricity

Figure 9 summarizes the total cost of saved electricity for each state where one or more program administrators report sufficient program data. The total cost across all programs for which data could be collected in a given state, weighted by the energy saved, ranged from about $0.03 per kWh for programs in New Mexico and Maine to $0.079 per kWh in Massachusetts. The savings-weighted average was $0.046 per kWh (denoted by the red dotted line) for all programs in our sample. The ratio of program administrator spending to participant spending also varies widely by state (Figure 9).

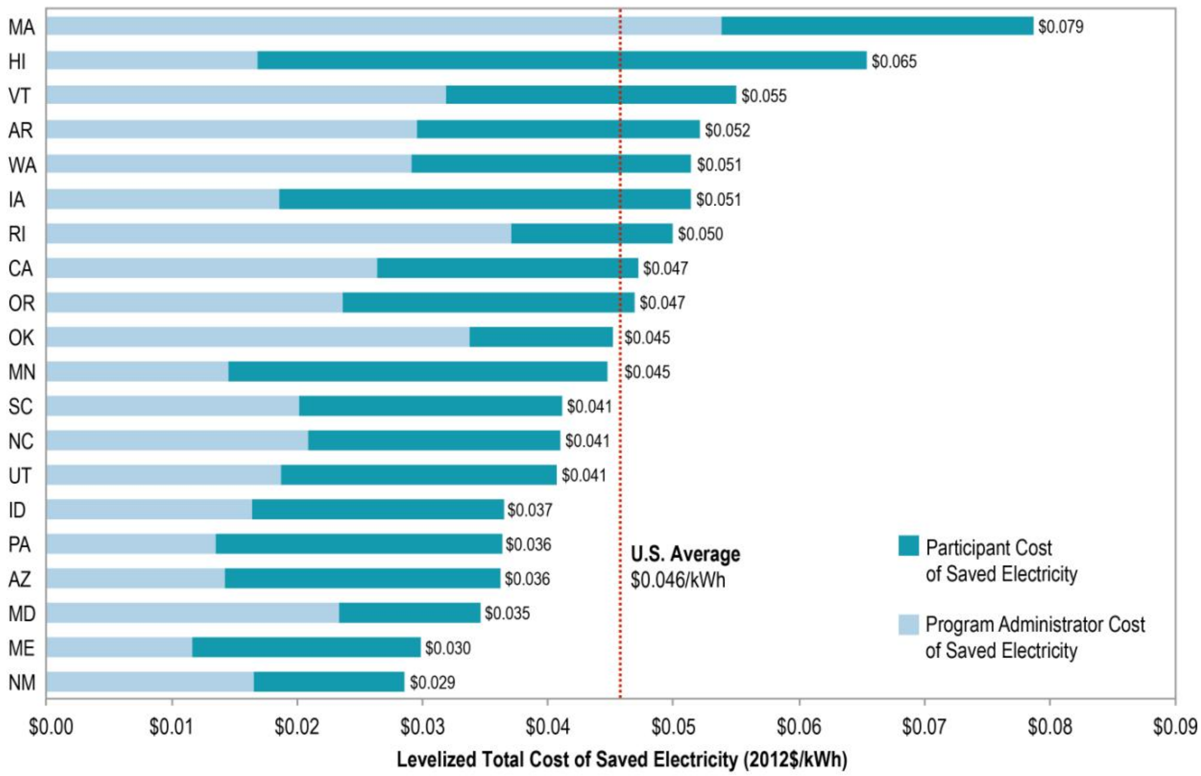

Figure 9. Savings-weighted average total cost of saved electricity, by state

Many factors are likely to influence the total cost of saved electricity in a state (Billingsley et al. 2014). These factors include but are not limited to the following:

- Policy objectives and context (e.g., acquiring all cost-effective efficiency; rising savings targets required by an Energy Efficiency Resource Standard)
- Program planning requirements (e.g., cost-effectiveness screening practices, avoided supply costs)
- Technical opportunities (e.g., characteristics of the existing building/housing stock and equipment)
- Program administrator performance and motivation
- Program scale
- Technical resources and approach used to evaluate, measure and verify savings[46]

[46] A number of states and regions (e.g., Pacific Northwest, New England, California) that have offered efficiency programs for several decades have devoted significant resources to evaluation, measurement and verification (EM&V) activities (e.g., developed comprehensive EM&V protocols, robust technical reference manuals). Their EM&V practices often include frequent updates to savings estimates, measure lifetimes and, to a lesser extent, measure costs. In many cases, these updates result in lower estimates of annual or

- Electricity prices (e.g., impact on economic payback times for efficiency investments) and
- Labor and materials costs.

For example, Hawaii and Massachusetts are at the upper tier for average cost of saved electricity values in this study. Retail electricity rates are above the national average in both states. Participating customers in Hawaii, with the highest retail electricity rates in the nation, are contributing a larger share of total costs than in most states. Program administrators in Massachusetts have implemented efficiency programs for more than 25 years, capturing much of the lowest-cost technical opportunities. Massachusetts also has a legislative mandate to pursue all cost-effective energy efficiency. The total cost of saved electricity across all programs and expenditures was less than $0.06 per kWh in all other states.

Figure 10 illustrates the electricity savings acquired by program administrators in a state and the total cost of acquiring those savings. Specifically, we show the program administrators' reported electricity savings as a share of the state's retail electricity sales by IOUs on the x-axis compared to the savings-weighted average total cost of saved electricity value for programs in a state on the y-axis. Squares signify that the data are from program administrators serving customers of utilities accounting for more than 75 percent of 2012 retail electricity sales of IOUs in that state, while diamonds represent data accounting for 50 percent to 75 percent of retail electricity sales.

Vermont, Massachusetts, and Maryland had the highest reported electricity savings of our sample, exceeding 2 percent of annual retail electricity sales. Program administrators in 13 states reported electricity savings in 2012 between 0.8 percent and 1.8 percent of annual retail sales. Program administrators in four states reported saving 0.5 percent or less of annual retail sales. In many cases, these program administrators recently ramped up their energy efficiency efforts and may have faced higher initial administrative costs, but newer administrators also have more opportunity to offer programs targeting lower-cost measures.

If program administrators (and states) pursue higher savings targets, they must achieve greater market penetration, deeper savings per project (e.g., install more measures, more comprehensive retrofits), or both. These higher savings targets therefore could cost more to achieve as program administrators follow a rising "conservation supply curve" of technical efficiency options that are more costly to access or, for example, as program administrators spend more money to encourage customers to participate in programs. But the actual relationship between the cost of saved electricity and the level of savings is more complicated, and some analyses have shown a negative slope (i.e., the cost of saved electricity has declined as savings have increased) (Takahashi and Nichols 2008). New high-efficiency technologies and greater operational efficiencies in program delivery may reduce the cost of savings. We plan to explore factors that influence the total cost of saved electricity in more depth in future work.

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lifetime savings (e.g., reducing the assumed operating hours or measure life of high-efficiency lighting), which will result in a higher total cost of saved electricity, all else being equal. Longer measure lifetimes will result in longer program-average measure lifetime, which likewise can lead to a lower cost of saved electricity. Using full versus incremental measure costs for specific measures in a program may also result in a higher cost of saved electricity.

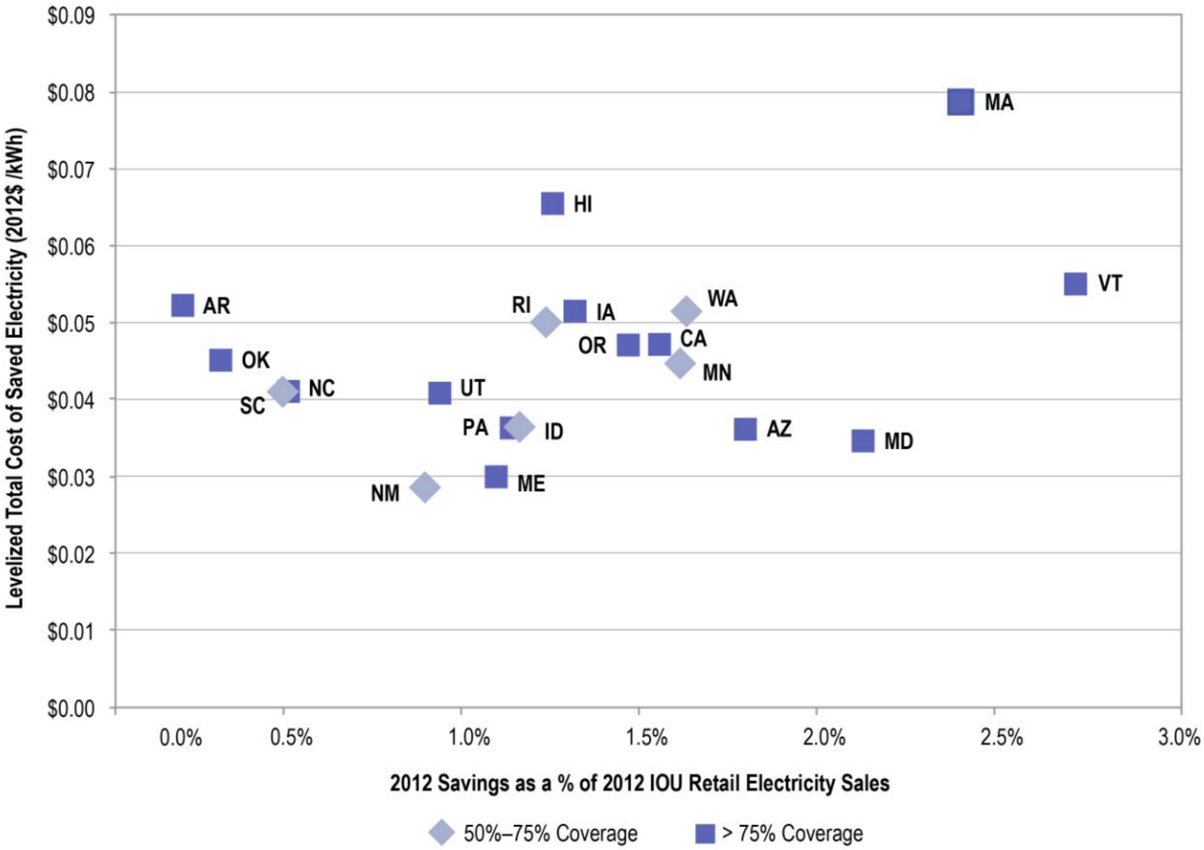

Figure 10. Total cost of saved electricity compared to electricity savings as a percentage of retail electricity sales by investor-owned utilities
Sources: LBNL DSM Program Database; U.S. Energy Information Administration, Form 861; Massachusetts Energy Efficiency Advisory Council; Hawaii Energy Annual Report

Conclusion

The average total cost of saved electricity, weighted by energy savings, was $0.046 per kWh of claimed savings for program administrators in 20 states that provided sufficient cost information for the 2009 to 2013 period. This estimate is based on the most expansive collection of total costs to date.

For the subset of residential programs for which savings were claimed, the savings-weighted average total cost of saved electricity was $0.030 per kWh. Residential consumer product rebate programs—especially lighting programs with an average total cost of $0.018 per kWh—were a primary driver of these results. If residential lighting-only programs were excluded to test the effect on the rest of the portfolio, the savings-weighted average total cost would have been $0.055 per kWh in the residential sector (72 percent higher) and $0.054 per kWh for all sectors (18 percent higher) for the programs in our dataset. These results illustrate the prominent role that lighting programs have played in utility efficiency endeavors to date.

Non-residential sector programs for which savings were claimed had a savings-weighted average total cost of $0.053 per kWh. Prescriptive C&I rebate programs ($0.045/kWh) and custom C&I rebate programs ($0.052/kWh) account for more than 60 percent of the savings in the non-residential sector. Cost performance among program types varied more in the residential sector than in the non-residential sectors, differing by a factor of three to five among various types of residential programs and by a factor of two for most types of non-residential programs.

Program administrators in fewer than half of states with efficiency programs funded by electric utility customers report total costs and savings. Where full costs are reported, differing definitions and interpretations of the components of total costs can make it challenging to aggregate and compare data. Continued efforts to establish more consistent reporting would better establish the cost effectiveness and potential of efficiency as an energy resource, as well as provide more accurate insights into programs, policies and system needs. This brief highlights varying approaches and practices used by program administrators to determine participant costs, including methodological issues (e.g., perceived challenges in estimating incremental measure costs).

For future research, we anticipate looking more closely at potential allocation schemes for spreading portfolio-level costs among programs not already carrying those costs. We also plan on three key areas of inquiry: (1) program reporting issues and establishing linkages between more rigorous, comprehensive reporting and the needs of program administrators, regulators and other stakeholders; (2) analyses of trends in the cost of saved electricity over time; and (3) analyses of factors that may influence the total cost of saved electricity.

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