# The Cost of Saving Electricity Through Energy Efficiency Programs Funded by Utility Customers: 2009–2015

## Technical Appendices

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## Technical Appendices

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

| | |
|---|---|
| C&I | Commercial and Industrial |
| C&S | Codes and Standards |
| CFL | Compact fluorescent light bulbs |
| CHP | Combined heat and power |
| CSE | Cost of Saved Electricity |
| CVR | Conservation voltage regulation/reduction |
| DSM | Demand-Side Management |
| EE | Energy efficiency |
| EM&V | Evaluation, Measurement and Verification |
| GWh | Gigawatt-hour |
| HVAC | Heating, ventilating, and air conditioning |
| kWh | Kilowatt-hour |
| LBNL | Lawrence Berkeley National Laboratory |
| LED | Light-emitting diodes |
| ME&O | Marketing, Education & Outreach |
| MT | Market Transformation |
| NYSERDA | New York State Energy Research and Development Authority |
| PA | Program Administrator |
| PAML | Program Average Measure Life |
| QAQC | Quality assurance and quality control |

# Appendix A. Research on the Cost of Saved Energy[1]

In this appendix, we review and summarize research on the cost of saved energy and our contributions.

**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.

Efforts to develop performance metrics for utility ratepayer-financed energy efficiency programs, particularly to quantify the cost of saved energy, began in the late 1970s (e.g., Sant 1979). Initially, researchers and analysts developed a "levelized" cost of lifetime energy savings metric, in which costs were amortized over the economic life of efficiency measures. Conceptually, this levelized cost of efficiency treats measure costs as though they were financed with a loan, with a repayment term equal to the economic life of the measure. The key motivation for this approach was to enable rough comparisons of a utility's efficiency investment costs with its levelized cost of building and operating a power plant. Meier (1982, 1984) and others refined these methods and applied them to construct conservation "supply" curves for individual measures.

These early calculations of levelized costs were based on the costs of purchasing and installing more efficient measures and so are best understood as a means of estimating likely technical and economic potential on a measure basis: What measures can deliver what quantity of savings at an incremental measure cost below the price of energy supply?

As utility ratepayer-funded programs proliferated in the 1980s, program administrators provided the first substantial data to regulators on the costs of implementing programs. These included the cost of designing and administering the programs, identifying energy saving measures for customers, promoting measures, and providing incentives and verifying the savings, among other expenses. In essence, these are the transaction costs of educating and motivating customers to invest in saving energy. The more common cost-performance metrics for program administrators were the costs of first-year and lifetime savings, from the perspective of the utility. Several cost-effectiveness screening tests (e.g., Total Resource Cost, Utility Cost Test) also were developed during this period in order to establish that programs or measures were cost-effective — i.e., that the monetized benefits of the efficiency actions

[1] The text in this appendix is adapted from Billingsley et al. 2014, with updates to reflect recent studies.

exceeded their costs, so that utilities and their customers could weigh competing investments (Krause and Eto 1988).

Several researchers noted the incompleteness, inconsistency and lack of standardization in report program data (e.g., Hirst and Goldman 1990), and others saw those issues as problematic for estimation of program costs and use of the results in utility planning. For example, Joskow and Marron (1992) reviewed costs and estimated savings for 12 U.S. utility efficiency "portfolios"—sets of 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." In a study conducted in response, Eto et al. (1996) adopted Joskow and Marron's analytical framework and applied it to 20 U.S. commercial lighting efficiency programs. Eto et al. (1994) found that the reported data for these programs were subject to a number of uncertainties—including omitted costs—but concluded that, when these uncertainties were addressed and the costs thoroughly accounted for, the programs' benefits exceeded their total costs.

In the early 1990s, some studies sought to address these problems and calculate the full costs of energy efficiency for comparison with the utility costs of energy supply (e.g., Eto et al. 1994; Goldman and Kito 1995). These studies required substantial effort to obtain data beyond that contained in standard program administrator reports, including oral interviews with utility demand-side management (DSM) staff. Researchers since have tended to rely upon the lifetime or levelized administrator cost of saved energy as the primary metrics of program cost performance. These efforts have been useful for indicating overall trends and costs of efficiency.

In recent years, a number of researchers have examined the cost of saved energy (Baatz, Gilleo and Barigye 2016; Molina 2014; Arimura et al. 2012; and Takahashi and Nichols 2008, 2009). Most of these efforts have focused on datasets involving up to 19 states and reported the cost of saved energy at the portfolio level or by market sector. Ackerman, Knight and Biewald (2016) compared the cost of saved electricity at the program administrator level and savings as a percent of retail sales, based upon national 2010–2015 utility survey data collected by the U.S. Energy Information Administration.

Our contributions to this literature are as follows. First, our analysis is based upon the most comprehensive dataset of efficiency program results filed with utility regulators and incorporates extensive protocols for maximizing data quality and consistency. Second, we analyze energy efficiency impacts and costs at a more disaggregated level than previous studies: from the national "portfolio" of U.S. programs, to state portfolios and market sector-specific initiatives and by type of program. Third, we collect and, where unreported, derive program average measure lifetimes that are required for calculating the cost of saved electricity at multiple scales (e.g., by program type, at the portfolio level). Fourth, we examine both program administrator and participant costs, jointly and in relative terms, in order to assess the full cost of efficiency. Fifth, we have begun decomposing program costs to examine the relative share of non-incentive vs. incentive costs. Lastly, we have constructed a comprehensive cost curve for energy efficiency programs to rank program-driven savings by the cost of savings acquisition and by the magnitude of the savings acquired.

# Appendix B. Energy Efficiency Program Administrators Included in the Study

In this Appendix, we provide information on program administrators that are included in the LBNL DSM Program Database between 2009 and 2015.

**Table B - 1. Program Administrators in this study: 2009-2015**

| State | Program Administrator |
|---|---|
| **Arkansas** | |
| | Entergy Arkansas |
| | Oklahoma Gas & Electric - Arkansas |
| | Southwestern Electric Power Company - Arkansas |
| **Arizona** | |
| | Arizona Public Service Company |
| | Tucson Electric Power |
| | UNS Electric |
| **California** | |
| | Pacific Gas and Electric Company |
| | San Diego Gas & Electric Company |
| | Southern California Edison |
| **Colorado** | |
| | Public Service Company of Colorado |
| **Connecticut** | |
| | Connecticut Light & Power Company |
| | United Illuminating Company |
| **Florida** | |
| | Florida Power & Light Company |
| | Florida Public Utilities Company |
| | Gulf Power Company |
| | Progress Energy Florida |
| | Tampa Electric Company |
| **Georgia** | |
| | Georgia Power Company |
| **Hawaii** | |
| | Hawaii Energy |
| | Hawaii Energy Efficiency Program |
| **Iowa** | |
| | Interstate Power and Light Company - Iowa |
| | MidAmerican Energy Company - Iowa |
| **Idaho** | |
| | Idaho Power - Idaho |
| | Rocky Mountain Power - Idaho |

| State | Program Administrator |
|---|---|
| **Illinois** | |
| | Ameren Illinois |
| | Commonwealth Edison Company |
| **Indiana** | |
| | Duke Energy - Indiana |
| | Indiana Michigan Power - Indiana |
| | Indianapolis Power & Light |
| | Northern Indiana Public Service Company |
| | Vectren Energy Delivery of Indiana |
| **Kentucky** | |
| | Kentucky Power |
| | Louisville Gas & Electric Company |
| **Louisiana** | |
| | Cleco Power |
| | Entergy Gulf States Louisiana |
| | Entergy Louisiana |
| | Entergy New Orleans |
| | Southwestern Electric Power Company - Louisiana |
| **Massachusetts** | |
| | Cape Light Compact |
| | Fitchburg Gas and Electric Light Company |
| | National Grid - Massachusetts |
| | NSTAR |
| | Western Massachusetts Electric Company |
| **Maryland** | |
| | Baltimore Gas and Electric Corporation |
| | Delmarva Power and Light - Maryland |
| | Potomac Edison Company - Maryland |
| | Potomac Electric Power Company - Maryland |
| **Maine** | |
| | Efficiency Maine Trust |
| **Michigan** | |
| | Consumers Energy Company |
| | Detroit Edison Company, The |
| **Minnesota** | |
| | Minnesota Power |
| | Northern States Power - Minnesota |
| **Missouri** | |
| | Ameren Missouri |
| **Mississippi** | |
| | Entergy Mississippi |
| | Mississippi Power Company |

| State | Program Administrator |
|---|---|
| **Montana** | |
| | NorthWestern Energy - Montana |
| **North Carolina** | |
| | Duke Energy - North Carolina |
| | Progress Energy Carolinas - North Carolina |
| **New Hampshire** | |
| | National Grid - New Hampshire |
| | Public Service Company of New Hampshire |
| | Unitil Energy Systems |
| **New Jersey** | |
| | New Jersey Clean Energy Program |
| **New Mexico** | |
| | El Paso Electric - New Mexico |
| | Public Service Company of New Mexico |
| | Southwestern Public Service Company - New Mexico |
| **Nevada** | |
| | Nevada Power Company |
| | Sierra Pacific Power Company |
| **New York** | |
| | Central Hudson Gas & Electric Corporation |
| | Consolidated Edison Company of New York |
| | Long Island Power Authority |
| | National Grid - New York Upstate |
| | New York State Electric & Gas Corporation |
| | NYSERDA |
| | Orange & Rockland Utilities |
| | Rochester Gas and Electric Corporation |
| **Ohio** | |
| | Cleveland Electric Illuminating Company |
| | Columbus Southern Power |
| | Dayton Power & Light Company |
| | Duke Energy - Ohio |
| | Ohio Edison Company |
| | Ohio Power Company |
| | Toledo Edison Company, The |
| **Oklahoma** | |
| | Oklahoma Gas & Electric - Oklahoma |
| | Public Service Company of Oklahoma |
| **Oregon** | |
| | Energy Trust of Oregon |

| State | Program Administrator |
|---|---|
| **Pennsylvania** | |
| | Duquesne Light Company |
| | Metropolitan Edison Company |
| | PECO Energy |
| | Pennsylvania Electric Company |
| | Pennsylvania Power Company |
| | PPL Electric Utilities Corporation |
| | West Penn Power |
| **Rhode Island** | |
| | National Grid - Rhode Island |
| **South Carolina** | |
| | Duke Energy - South Carolina |
| | Progress Energy Carolinas - South Carolina |
| | South Carolina Electric & Gas |
| **South Dakota** | |
| | Black Hills Power - South Dakota |
| | Northern States Power - South Dakota |
| | NorthWestern Energy - South Dakota |
| **Texas** | |
| | AEP Texas Central |
| | AEP Texas North |
| | CenterPoint Energy Houston Electric, LLC |
| | El Paso Electric - Texas |
| | Entergy Texas |
| | Oncor |
| | Southwestern Electric Power Company - Texas |
| | Southwestern Public Service Company - Texas |
| | Texas-New Mexico Power Company |
| **Utah** | |
| | Rocky Mountain Power - Utah |
| **Vermont** | |
| | Efficiency Vermont |
| **Washington** | |
| | Avista Utilities - Washington |
| | Puget Sound Energy |
| **Wisconsin** | |
| | Focus on Energy |
| **Wyoming** | |
| | Rocky Mountain Power - Wyoming |

# Appendix C. Energy Efficiency Program Typology and Data Reporting

In this appendix, we describe the LBNL DSM Program Database which includes a program typology that is used to characterize and classify energy efficiency programs, definitions for market sector and simplified and detailed program categories, and definitions for reporting various types of efficiency program data.

We describe and define simplified and detailed program categories for seven sectors: residential, commercial, industrial/agricultural, commercial/industrial, cross-cutting and other, low income and demand response programs (see Table C - 1 through Table C - 7). For each sector, the left column of the table lists the *detailed* program category names, the middle column provides detailed program definitions, and the right column indicates the corresponding *simplified* program category.

We also include a glossary of reported data, which provides definitions for reporting various types of energy efficiency program data: number of participants, program activity (e.g., number of measures installed, buildings retrofitted), budgets, committed spending, actual expenditures grouped into various categories of program costs, measure lifetimes and energy savings.

## Program Typology

We developed program categories in order to characterize and analyze similar types of efficiency programs as defined by market sector and technology, delivery approach, intervention strategy or other common themes. The programs that comprise a utility efficiency portfolio can span multiple market sectors and contain a range of technologies offered through various delivery mechanisms. For example, programs that target industrial customers can include dozens of potential technologies, but a residential pool pump program offers a narrower set of options. Site inspections and analyses may precede installation of efficiency measures in custom rebate programs, but consumer products programs only require a rebate and self-installation. Marketing and education programs may be "cross-cutting" if they span several market sectors and impact a broad range of customers. This diversity complicates comparative analysis across utilities, regions and time. We address this challenge in part by creating a standardized typology for categorizing efficiency programs.

The typology contains three tiers: (1) sector, (2) simplified program categories and (3) detailed program categories. We present a partial snapshot of this three-tiered efficiency program typology in Figure C - 1, which includes seven sectors, 27 simplified program categories and 62 detailed program categories (see Hoffman et al. 2013 for a detailed description of the typology). With the three tiers, we are able to compare programs in common markets (e.g., Commercial Custom and Commercial Prescriptive) and analyze the differences in programs that share a market but have subtle variations in program designs (e.g., Whole Home/Direct Install vs. Whole Home/Audits). Where program documentation is sparse or programs lack specificity in implementation, we use more general program categories to characterize programs.

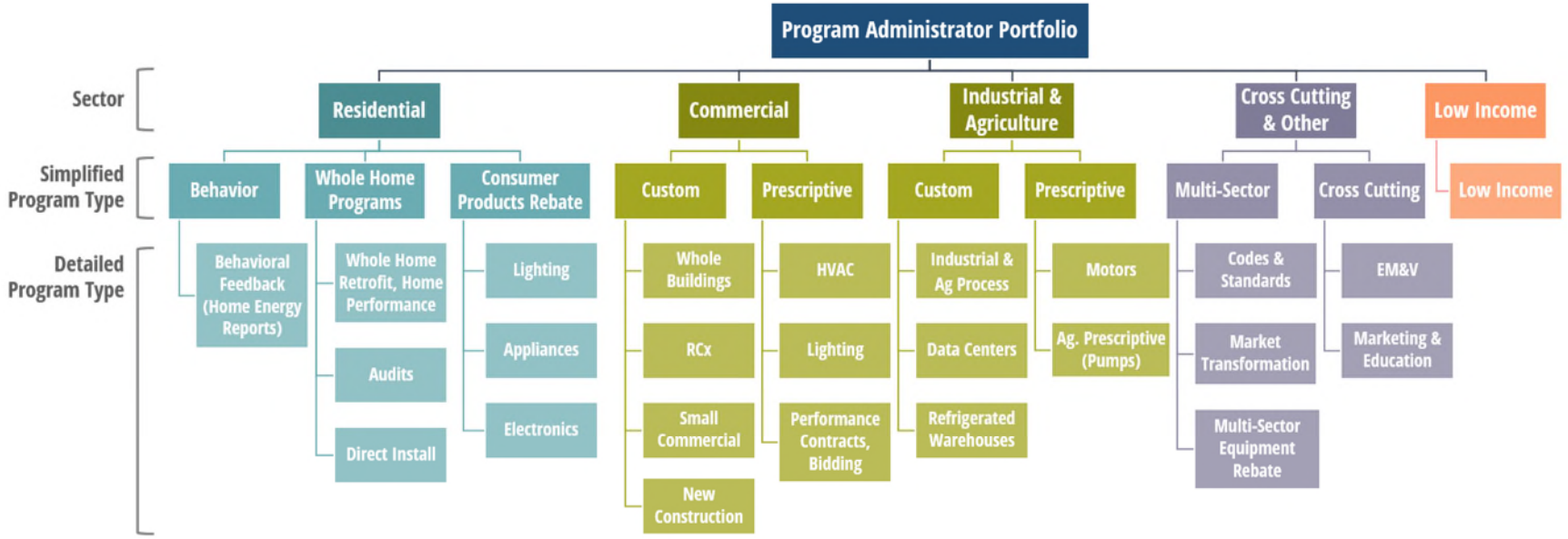


**Figure C - 1. Selected program types in the LBNL program typology**

Some program typology categories are likely to evolve over time. For example, utilities historically have designed specific programs that target low-income customers. However, program administrators and policymakers are interested in the extent to which low-income customers participate in the broader suite of residential programs. This requires program administrators or evaluators to collect additional demographic information on customers.

## Program Categories and Definitions

In this section, we include summary tables that list our detailed categories for programs that target residential customers (Table C - 1), commercial customers (Table C - 2) and industrial/agricultural customers (Table C - 3). Table C - 4 includes program categories and definitions for those commercial and industrial (C&I) programs that were highly aggregated to target all C&I markets and, based upon the limits of the reported data, could not be characterized as obtaining the large majority of their savings from either the commercial or industrial sector. Table C- 5 summarizes various types of cross-cutting programs. Table C - 6 describes programs that target low-income customers. For each detailed program category, we include a definition used by LBNL researchers to classify programs and map it to a simplified program category.

Table C – 7 includes program categories for demand response programs. These categories were included chiefly to enable the Consortium for Energy Efficiency, which adopted the program categories to collect demand response spending and savings data and to enable LBNL to potentially include demand response program data in the future.

**Table C - 1. Residential programs**

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Behavioral/ Online Audit/ Feedback** | Residential programs designed around directly influencing household habits and decision-making on energy consumption through quantitative or graphical feedback on consumption, sometimes accompanied by tips on savings energy. These programs include behavioral feedback programs (in which energy usage reports compare a consumer's household energy usage with those of similar consumers); online audits that are completed by the consumer; and in-home displays that help consumers assess their usage in near real time. This program category does not include on-site energy assessments or audits. | **Behavior/ Education** |
| **Consumer Product Rebate/ Appliances** | Programs that incentivize the sale, purchase and installation of appliances (e.g., refrigerators, dishwashers, clothes washers and dryers) that are more efficient than current standards. Appliance recycling and the sale/purchase/installation of HVAC equipment, water heaters and consumer electronics are accounted for separately. | **Consumer Product Rebate** |
| **Consumer Product Rebate/ Electronics** | Programs that encourage the availability and purchase/lease of more efficient personal and household electronic devices, including but not limited to televisions, set-top boxes, game consoles, advanced power strips, cordless telephones, PCs and peripherals specifically for home use, chargers for phones/smart phones/tablets. A comprehensive | |

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| | efficiency program to decrease the electricity use of consumer electronics products includes two focuses: product purchase and product use. Yet not every consumer electronics program will seek to be comprehensive. Some programs will embark on ambitious promotions of multiple electronics products, employing upstream, midstream, and downstream strategies with an aggressive marketing and education component. At the other end of the continuum, a program administrator may choose to focus exclusively on consumer education. | |
| **Consumer Product Rebate/Lighting** | Programs aimed specifically at encouraging the sale/purchase and installation of more efficient lighting in the home. These programs range widely from point-of-sale rebates to CFL mailings or giveaways. Measures tend to be CFLs, fluorescent fixtures, LED lamps, LED fixtures, LED holiday lights and lighting controls, including occupancy monitors/switches. | |
| **Appliance Recycling** | Programs designed to remove less efficient appliances (typically refrigerators and freezers) from households. | |
| **Multi-Family** | Multi-family programs are designed to encourage the installation of energy efficient measures in common areas, units or both for residential structures of more than four units. These programs may be aimed at building owners/managers, tenants or both. | **Multi-Family** |
| **New Construction** | Programs that provide incentives and possibly technical services to ensure new homes are built or manufactured to energy performance standards higher than applicable code (e.g., ENERGY STAR Homes). These programs include new multi-family and new/replacement mobile homes. | **New Construction** |
| **HVAC** | Programs designed to encourage the distribution, sale/purchase, proper sizing and installation of HVAC systems that are more efficient than current standards. Programs tend to support activities that focus on central air conditioners, air source heat pumps, ground source heat pumps, and ductless systems that are more efficient than current energy performance standards, as well as climate controls and the promotion of quality installation and quality maintenance. | **Prescriptive** |
| **Insulation** | Programs designed to encourage the sale/purchase and installation of insulation in residential structures, often through per-square-foot incentives for insulation of specific R-values versus an existing baseline. Programs may be point-of-sale rebates or rebates to insulation installation contractors. | |
| **Pool Pump** | Programs that incentivize the installation of higher efficiency or variable speed pumps and controls, such as timers, for swimming pools. | |
| **Prescriptive** | Residential programs that provide or incentivize a set of pre-approved measures not included in, or distinguishable from, the other residential program categories (e.g., direct install, HVAC, lighting). For example, if a residential program features rebates for a large set of mixed, pre-approved offerings (e.g., insulation, HVAC, appliances, lighting), yet the relative contribution of each measure to program savings is unclear or no single measure accounts for a large majority of the savings, then the program should be classified as a residential prescriptive program. | |

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Water Heater** | Programs designed to encourage the distribution, sale/purchase and installation of electric and/or gas water-heating systems that are more efficient than current standards, including high efficiency water storage tank and tankless systems. | |
| **Windows** | Programs designed to encourage the sale/purchase and installation of efficient windows in residential structures. | |
| **Whole Home/ Direct Install** | Direct-install programs provide a set of pre-approved measures that may be installed at the time of a visit to the customer premises or provided as a kit to the consumer, usually at modest or no cost to the consumer and sometimes accompanied by a rebate. Typical measures include CFLs, low-flow showerheads, faucet aerators, water-heater wrap and weather stripping. Such programs may also include a basic, walk-through energy assessment or audit, but the savings are principally derived from the installation of the provided measures. Education programs that supply kits by sending them home with school children are not included in this program category; they are classified as education programs. | **Whole Home Upgrade (Incl. audits, retrofits, etc.)** |
| **Whole Home/ Audits** | Residential audit programs provide a comprehensive, standalone assessment of a home's energy consumption and identification of opportunities to save energy. The scope of the audit includes the whole home although the thoroughness and completeness of the audit may vary widely from a modest examination and simple engineering-based modeling of the physical structure to a highly detailed inspection of all spaces, testing for air leakage/exchange rates, testing for HVAC duct leakage and highly resolved modeling of the physical structure with benchmarking to customer utility bills. | |
| **Whole Home/ Retrofit** | Whole-home energy upgrade or retrofit programs combine a comprehensive energy assessment or audit that identifies energy savings opportunities with house-wide improvements in air sealing, insulation and, often, HVAC systems and other end uses. The HVAC improvements may range from duct sealing to a tune up to full replacement of the HVAC systems. Whole-home programs are designed to address a wide variety of individual measures and building systems, including but not limited to: HVAC equipment, thermostats, furnaces, boilers, heat pumps, water heaters, fans, air sealing, insulation (attic, wall, and basement), windows, doors, skylights, lighting, and appliances. As a result, whole-home programs generally involve one or more rebates for multiple measures. Whole-home programs generally come in two types: comprehensive programs that are broad in scope and less comprehensive, prescriptive programs sometimes referred to as "bundled efficiency" programs. This category addresses all of the former and most of the latter, but it excludes direct-install programs that are accounted for separately. | |
| **Financing** | Programs designed to provide or facilitate loans, credit enhancements or interest rate reductions/buy downs. As with other programs, included costs are utility costs, including the costs of any inducements for lenders, e.g., loan loss reserves, interest rate buy-downs, etc. Where participant costs are available for collection, these ideally will include the total customer share, i.e., both principal (the participant payment to purchase and install measures) and interest on that debt. Most of these programs will be directed toward enhancing credit or financing for residential structures. | **All Other Residential** |

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Other** | Programs designed to encourage investment in energy efficiency activities in residences but are so highly aggregated (e.g., Existing Homes programs that include retrofits, appliances, equipment, etc.) and undifferentiated that they cannot be sorted into the residential program categories that are detailed in this document. | |

**Table C - 2. Commercial programs**

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Audit** | Programs in which an energy assessment is performed on one or more participant commercial facilities to identify sources of potential energy waste and measures to reduce that waste. | **Custom** |
| **Custom** | Programs designed around the delivery of site-specific projects typically characterized by an extensive onsite energy assessment and identification and installation of multiple measures unique to that facility. These measures may vary significantly from site to site. This category is intended to capture "whole-building" approaches to commercial sector efficiency opportunities for a wide range of building types and markets (e.g., office, retail) and wide range of measures. | |
| **Commissioning/ Retro-Commissioning** | Programs aimed at diagnosing energy consumption in a commercial facility and optimizing its operations to minimize energy waste. Such programs may include installation of certain measures (e.g., occupancy monitors and switches), but program activities tend to be characterized more by tuning or retuning, coordinating and testing the operation of existing end uses, systems and equipment for energy efficient operation. The construction of new commercial/industrial facilities that includes energy performance commissioning should be categorized as "Com: New Construction". The de novo installation of energy management systems with accompanying sensors, monitors and switches is regarded as a major capital investment and should be categorized under "Com: Custom". | |
| **Govt./Nonprofit/ MUSH** | MUSH (Municipal, University, School & Hospital) and government and nonprofit programs cover a broad swath of program types generally aimed at public and institutional facilities and which include a wide range of measures. Programs that focus on specific technologies (e.g., HVAC and lighting) have their own commercial program categories. Examples include incentives and/or technical assistance to promote energy efficiency upgrades for elementary schools, recreation halls and homeless shelters. Note that street lighting is accounted for as a separate program category. | **MUSH & Government** |
| **Street Lighting** | Street lighting programs include incentives and/or technical support for the installation of higher efficiency street lighting and traffic lights than the current baseline. | |
| **New Construction** | Programs that incentivize owners or builders of new commercial facilities to design and build beyond current code or to a certain certification level (e.g., ENERGY STAR or LEED). | **New Construction** |

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **HVAC** | C&I HVAC programs encourage the sale/purchase and installation of heating, cooling and/or ventilation systems at higher efficiency than current energy performance standards, across a broad range of unit sizes and configurations. Most of these programs will be directed toward commercial structures. | **Prescriptive** |
| **Lighting** | C&I lighting programs incentivize the installation of efficient lighting and lighting controls. Typical measures might include T-8/T-5 fluorescent lamps and fixtures; CFLs and fixtures; LEDs for lighting, displays, signs and refrigerated lighting; metal halide and ceramic lamps and fixtures; occupancy controls; daylight dimming; and timers. | |
| **Performance Contracting/ DSM Bidding** | Programs that incentivize or otherwise encourage energy services companies (ESCOs) and participants to perform energy efficiency projects, usually under an energy performance contract (EPC), a standard offer or other arrangement that involves ESCOs or customers offering a quantity of energy savings in response to a competitive solicitation/bidding process with compensation linked to achieved savings. | **Prescriptive** |
| **Prescriptive/IT & Office Equipment** | Programs aimed at improving the efficiency of office equipment, chiefly commercially available PCs, printers, monitors, networking devices and mainframes not rising to the scale of a server farm or floor. | |
| **Prescriptive/ Grocery** | Grocery programs are prescriptive programs aimed at supermarkets and are usually designed around indoor and outdoor lighting and refrigerated display cases. | |
| **Other** | Prescriptive programs that encourage the purchase and installation of some or all of a specified set of pre-approved measures besides those covered in other measure-specific prescriptive programs (e.g., HVAC and Lighting). | |
| **Custom (Small Comm.)** | Custom programs applied to small commercial facilities. (See definition of custom programs for additional detail.) | **Small Commercial** |
| **Prescriptive (Small Comm.)** | Prescriptive programs applied to small commercial facilities. (See definition of prescriptive programs for additional detail.) Such programs may range from a walk-through audit and direct installation of a few pre-approved measures to a fuller audit and a fuller package of measures. Audit only programs have their own category. | |
| **Financing** | Programs designed to provide or facilitate loans, credit enhancements or interest rate reductions/buy downs. As with other programs, included costs are utility costs, including the costs of any inducements for lenders, e.g., loan loss reserves, interest rate buy-downs, etc. Where participant costs are available for collection, these ideally will include the total customer share, i.e., both principal (the participant payment to purchase and install measures) and interest on that debt. Most of these programs will be directed toward enhancing credit or financing for commercial structures. | **All Other Commercial** |
| **Other** | Programs not captured by any of the specific commercial program categories but are sufficiently distinct to the commercial sector to not be treated as a "Commercial/Industrial Other" program. Example: An EE program aimed specifically at the commercial subsector but is not clearly prescriptive or custom in nature. | |

**Table C - 3. Industrial/agricultural programs**

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Audit** | Programs in which an energy assessment is performed on one or more participant industrial or agricultural facilities to identify sources of potential energy waste and measures to reduce that waste. | **Custom** |
| **Custom** | Programs designed around the delivery of site-specific projects typically characterized by an extensive onsite energy assessment and identification and installation of multiple measures unique to that facility. These measures may vary significantly from site to site. This category is intended to capture "whole-facility" approaches to industrial or agricultural sector efficiency opportunities for a wide range of building types and markets | |
| **Custom/ Data Centers** | Data center programs are custom-designed around large-scale server floors or data centers that often serve high-tech, banking or academia. Projects tend to be site-specific and involve some combination of lighting, servers, networking devices, cooling/chillers, and energy management systems/software. Several of these may be of experimental or proprietary design. | |
| **Custom/Ind. & Ag. Process** | Industrial programs deliver custom-designed projects that are characterized by an onsite energy and process efficiency assessment and a site-specific measure set focused on process related improvements that may include, for example, substantial changes in a manufacturing line. This category includes all EE program work at industrial or agricultural sites that is process focused and not generic (and thus would be in the custom category) and not otherwise covered by the single-measure prescriptive programs below (e.g., lighting, HVAC, water heaters). | |
| **Custom/ Refrigerated Warehouses** | Warehouse programs are typically aimed at large-scale refrigerated storage facilities and often target end uses such as lighting, climate controls and refrigeration systems. | |
| **New Construction** | Programs that incentivize owners or builders of new industrial or agricultural facilities to design and build beyond current code or to a certain certification level, e.g., ENERGY STAR or LEED. | **New Construction** |
| **Prescriptive Industrial** | Prescriptive programs that encourage the purchase and installation of some or all of a specified set of pre-approved industrial measures besides those covered in other measure-specific prescriptive programs on this list, e.g., industrial compressor programs. | **Prescriptive** |
| **Prescriptive/ Agriculture** | Farm- and orchard-based agricultural programs that primarily involve irrigation pumping and do not include agricultural refrigeration or processing at scale. | |
| **Prescriptive/ Motors** | Motors programs usually offer a prescribed set of approved higher efficiency motors, with industrial motors programs typically getting the largest savings from larger, high powered motors (>200 hp). | |
| **Financing** | Programs designed to provide or facilitate loans, credit enhancements or interest rate reductions/buy downs. As with other programs, included costs are utility costs, including the costs of any inducements for lenders, e.g., loan loss reserves, interest rate buy-downs, etc. Where participant costs are available for collection, these ideally will include the total customer share, i.e., both principal (the participant payment to purchase and install measures) and interest on that debt. Most of these programs will be directed toward enhancing credit or financing for industrial and/or agricultural facilities. | **All Other I/A** |

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Self Direct** | Industrial programs that are designed and delivered by the participant, using funds that otherwise would have been paid as ratepayer support for all DSM programs. These programs may be referred to as "opt out" programs, among other names. | |
| **Other** | Programs not captured by any of the specific industrial/agricultural categories but are sufficiently distinct to the industrial and/or agricultural sectors to not be treated as a "Commercial/Industrial Other" program. Example: An efficiency program aimed specifically at the industrial and agricultural sectors but is not clearly prescriptive or custom in nature might be classified as Other. | |

**Table C - 4. Commercial/industrial programs**

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Custom (C&I)** | Programs designed around the delivery of site-specific industrial and commercial projects typically characterized by an extensive onsite energy assessment and identification and installation of multiple measures unique to that facility. This category is for programs that address both the commercial and industrial sectors and cannot be relegated to one sector or another for lack of information on participation or savings. | **Custom** |
| **New Construction (C&I)** | Programs that incentivize owners or builders of new commercial and industrial facilities to design and build beyond current code or to a certain certification level, e.g., ENERGY STAR or LEED. This category should be used sparingly for those programs that cannot be identified with either the commercial or industrial sector on the basis of information available about participation or the source(s) of savings. | **New Construction** |
| **Prescriptive (C&I)** | Prescriptive programs that encourage the purchase and installation of some or all of a specified set of pre-approved industrial and/or commercial measures but which cannot be differentiated by sector based upon the description of the participants or nature or source of the savings. | **Prescriptive** |
| **Self Direct (C&I)** | Generally large commercial and industrial programs that are designed and delivered by the participant, using funds that otherwise would have been paid as ratepayer support for all DSM programs. This category is to be used for self-direct or opt-out programs that address both large commercial and industrial entities but which cannot be differentiated between these sectors because the nature and source of the savings is not available or is too highly aggregated. | **All Other C&I** |
| **Mixed Offerings** | Programs that cannot be classified under any of the specific commercial or industrial program categories and span a large variety of offerings aimed at both the commercial and industrial sectors. | |
| **Other** | Programs not captured by any of the specific commercial/industrial categories but are sufficiently distinct to the industrial and/or agricultural sectors to not be treated as a "Commercial/Industrial Other" program. | |

**Table C - 5. Cross-cutting & other programs**

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Codes & Standards (C&S)** | In C&S programs, the Program Administrator (PA) may engage in a variety of activities designed to advance the adoption, application or compliance level of building codes and end-use energy performance standards. Examples might include advocacy at the state or federal level for higher standards for HVAC equipment; training of architects, engineers and builder/developers on code compliance; and training of building inspectors in ensuring the codes are met. | **Codes & Standards** |
| **Market Transformation (MT)** | Programs that encourage a reduction in market barriers resulting from a market intervention, as evidenced by a set of market effects that is likely to last after the intervention has been withdrawn, reduced, or changed. MT programs are gauged by their market effects (e.g., increased awareness of energy efficient technologies among customers and suppliers); reduced prices for more efficient models; increased availability of more efficient models; and ultimately, increased market share for energy efficient goods, services and design practices. Example programs might include upstream incentives to manufacturers to make more efficient goods more commercially available; and point-of-sale or installation incentives for emerging technologies that are not yet cost effective. Workforce training and development programs are covered by a separate category. Upstream incentives for commercially available goods are sorted into the program categories for those goods (e.g., consumer electronics or HVAC). Many utilities conduct market transformation activities as a cross-cutting, multi-sector activity, while some utilities treat market transformation as an element or feature of individual programs. | **Market Transformation** |
| **Workforce Development** | Workforce training and development programs are a distinct category of market transformation program designed to provide the underlying skills and labor base for deployment of energy-efficiency measures. | |
| **Marketing, Education, Outreach (ME&O)** | ME&O programs include most standalone marketing, education and outreach programs (e.g., statewide marketing, outreach and brand development). In-school energy and water efficiency programs are also included in this category, including those that supply school children with kits of prescriptive measures such as CFLs and low-flow showerheads for installation at home. | **Marketing, Education, Outreach** |
| **Other** | This category is intended to capture all programs that cannot be allocated to a specific sector (or are multi-sectoral) and cannot be allocated to a specific program type. | **Multi-Sector and Other** |
| **Planning/ Evaluation/ Other Programmatic Support** | Non-ME&O support programs include the range of activities not otherwise accounted for in program-specific costs but needed for planning & designing a portfolio of programs and otherwise complying with regulatory requirements for DSM activities outside of program implementation. These activities generally are focused on the front and back end of program cycles, in assessing prospective programs; designing programs and portfolios; assessing the cost effectiveness of measures, programs and portfolios; and arranging for, directing or delivering reports and evaluations of the process and impacts of those programs—where those costs are not captured in program costs. Evaluation, Measurement and Verification (EM&V) is a cost associated with implementing and performing QA/QC activities for programs; however, some utilities have an EM&V group and report their costs separately. | |

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Voltage Reduction/ Transformers** | Programs that support investments in distribution system efficiency or enhance distribution system operations by reducing losses. The most common form of these programs involve the installation and use of conservation voltage regulation/reduction (CVR) or optimization systems and practices that control distribution feeder voltage so that utilization devices operate at their peak efficiency, which is usually at a level near the lower bounds of their utilization or nameplate voltages. Other measures may include installation of higher efficiency transformers. These programs generally are not targeted to specific end users but typically involve changes made by the electricity distribution utility. | **Multi-Sector and Other** |
| **Shading/ Cool Roofs** | Shading/reflective programs include programs designed to lessen heating and cooling loads through changes to the exterior of a structure (e.g., tree plantings to shade walls and windows, window screens and cool/reflective roofs). These programs are not necessarily specific to a sector. | |
| **Multi-Sector Rebates** | Multi-sector rebate programs include providing incentives for commercially available end-use goods for multiple sectors (e.g., PCs, HVAC). | |
| **Research** | These programs are aimed generally at helping the PA identify new opportunities for energy savings (e.g., research on emerging technologies or conservation strategies). Research conducted on new program types or the inclusion of new, commercially available measures in an existing program are accounted for separately under cross-cutting program support. | **Research** |

**Table C - 6. Low-income programs**

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Low Income** | Low-income programs are efficiency programs aimed at lower income households, based upon some type of income/means testing or eligibility. These programs most often take the form of single-family weatherization, but a variety of other program types also are included in this program category (e.g., multi-family/affordable housing weatherization, low-income direct-install programs). | **Low Income** |

**Table C - 7. Demand response programs**

| Detailed Category | Detailed Program Definition | Simplified Category |
|---|---|---|
| **Time-of-Use Pricing** | Demand-side management that uses a retail rate or Tariff in which customers are charged different prices for using electricity at different times during the day. Examples are time-of-use rates, real time pricing, hourly pricing, and critical peak pricing. Time-based rates do not include seasonal rates, inverted block, or declining block rates. | **Pricing** |
| **Critical Peak Pricing** | Demand-side management that combines direct load control with a pre-specified high price for use during designated critical peak periods, triggered by system contingencies or high wholesale market prices. | |
| **Critical Peak Pricing with Load Control** | Demand-side management that combines direct load control with a pre-specified high price for use during designated critical peak periods, triggered by system contingencies or high wholesale market prices. | |
| **Real-Time Pricing** | Demand-side management that uses rate and price structure in which the retail price for electricity typically fluctuates hourly or more often, to reflect changes in the wholesale price of electricity on either a day-ahead or hour-ahead basis. | |
| **Peak Time Rebate** | Peak time rebates allow customers to earn a rebate by reducing energy use from a baseline during a specified number of hours on critical peak days. Like Critical Peak Pricing, the number of critical peak days is usually capped for a calendar year and is linked to conditions such as system reliability concerns or very high supply prices. | **Rebate** |
| **Other** | Load management programs that are not captured by the specific DR categories named on this list. | **Other** |

## Program Data Glossary

In this section, we include definitions for various data fields in the LBNL DSM Program Database and describe our efforts to treat the data in a consistent, transparent fashion.

***# of Participants:*** Total number of consumers participating in the program. For new construction programs, we classify "number of homes or buildings" as the number of participants. In some programs, the number of participants is the number of structures or multi-family units that received efficiency measures through a program.

***# of Units:*** Total number of measures installed or credited with savings in the program (e.g., number of compact fluorescent lamps (CFLs) for which savings are claimed in a lighting program). If the number of units reported for a new construction or retrofit program is defined as structures built or retrofitted to a higher level of energy performance, then these are not counted as units but as participants.

***Administration Costs ($):*** Actual spending by the program administrator (PA) on costs associated with planning, designing and implementing an energy efficiency program in a defined geographic area, unless some of those costs are specifically accounted for elsewhere. In general, 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 contract implementer. If costs for evaluation, compliance and marketing and outreach & education are not reported separately, they typically are included under program administration costs. When a program is being terminated, shut-down costs also are included in administration costs.

***Annual Incremental Savings:*** The savings acquired or planned to be acquired as a result of energy efficiency activities in that program year. These are annualized, "full-year" savings, regardless of when measures were installed during the program year. The cost of first-year savings is derived for a full, 12-month first year.

***Average Measure Lifetime (Years):*** The weighted average economic lifetime of all measures installed in a program year.

***Detailed Program Categorization:*** One of about 70 unique and specific program categories described in detail in the Detailed Program Category Definitions (see Table C - 1 through Table C - 7).

***Evaluation Costs ($):*** PA spending on any form of evaluation, measurement and verification (EM&V) activity, whether internal, external or pass-through funding for EM&V overseen by PUCs. EM&V includes impact and process evaluations and may include an allocation of portfolio-level EM&V down to each program.

***Gross Savings:*** 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.

***Lifetime Electric Gross Savings (GWh):*** The expected gross electricity savings over the lifetime of the measures installed as part of the program. For the purposes of this collection effort, we use values reported by the program administrator.

***Lifetime Electric Net Savings (GWh):*** The expected net electricity savings over the lifetime of the measures installed as part of the program. These savings may be calculated by multiplying the annual energy use reduction associated with those measures by the lifetime of the measures. For the purposes of this collection effort, these values are reported by the program administrator.

***Marketing/Education/Outreach Costs (ME&O) ($):*** Actual PA spending on efforts to gain access to potential participants (e.g., through recruitment of community leaders), the promotion of a program or the education of participants in conservation/efficiency behaviors as a part of a program. In some cases, program administrators treat ME&O as its own program or have a separate statewide ME&O effort that is not program-specific and addresses branding for the PA or the portfolio of efficiency programs.

***Market Sector:*** The segment of the economy that is the source for most of the acquired savings of the program.

***Net Savings:*** The change in energy consumption that is attributable to a particular energy efficiency program. This change in energy use and/or demand typically includes some consideration of free riders

but also may include, implicitly or explicitly, consideration of participant and non-participant spillover and induced market effects. These factors may be considered in how a baseline is defined (e.g., common practice), in adjustments to gross savings values or both.

***Other Costs ($):*** Other costs include those categories of spending that may not fit well into the other categories (i.e., are not administration, incentives, ME&O or evaluation costs).

***Participant Costs ($):*** Spending by program participants who receive incentives, technical assistance, product installations, training, energy efficiency information or other services, or items from a program in a given program year. These costs are the participant share of the costs of an installed measure or project; they may also take the form of fees. In the case of financed projects, they should include principal and interest payments.

***Participant Incentive Costs ($):*** Actual spending by the program administrator on financial strategies intended to encourage a change in behavior related to energy use. Incentives can take various forms (e.g., rebates, subsidies, financing, prizes). Customer incentives are commonly used in energy efficiency programs as rebates for individual measures or as buy-downs in more custom-oriented projects. Financial incentives can also include monetary inducements to manufacturers, distributors, contractors, or retailers to increase the availability and affordability of energy-efficient goods and services in the market.

***Program Administrator (PA) Name:*** Name of the entity that administers the energy efficiency programs for which the data are provided. Program administrators include utilities, energy efficiency and clean energy utilities (e.g., the District of Columbia's Sustainable Energy Utility), hybrid governmental/quasi-governmental/third-party administrator agencies (e.g., NYSERDA), and nonprofit and for-profit third-party administrators (e.g., Hawaii Energy, Energy Trust of Oregon).

***Program Name:*** Name of the program as used in the report or evaluation.

***Resource Program:*** A program intended and designed for directly acquiring energy savings.

***Simplified Program Category:*** One of 27 general program categories that represents a higher level of aggregation among types of programs. In general, simplified program categories are characterized by a more detailed breakdown of sector (e.g., residential vs. C&I), an indication of whether the program targets individual measures or comprehensive set of measures, and prescriptive versus custom program design.

***Total Claimed Gross Annual Electric Savings (kWh):*** Gross annual incremental electricity savings as reported by an implementer or program administrator (using their own staff or an evaluation consulting firm) after the energy efficiency activities have been completed in the defined geographic area (e.g., a utility territory within a state).

***Total Claimed Net Annual Electric Savings (kWh):*** Net annual incremental electricity savings as reported by an implementer or program administrator after the energy efficiency activities have been completed in the defined geographic area (e.g., a utility territory within a state).

***Total Electric Budget ($):*** Total dollar amount that a program administrator budgeted or was projected to spend on an electricity efficiency program over the defined program year in the geographic area where the program is to be implemented. The total program budget includes all program administrative costs, incentive costs, marketing and outreach costs and evaluation costs. Performance incentives that can be earned by the program administrator are not considered part of the program budget and are excluded.

***Total Electric Committed Spending ($):*** Program spending associated with measures and projects that are approved, contracted and often implemented during the program year. The actual outlay (e.g., payment of a rebate after installation) occurs after the program year has ended.

***Total Electric Expenditures ($):*** Total dollar amount that a program administrator actually spent on an electricity efficiency program over the defined program year in the geographic area where the program is implemented. Total program expenditures include all program administrative costs, incentive costs, marketing and outreach costs and evaluation costs. Performance incentives are not considered part of the program costs and are excluded.

***Total Projected Gross Annual Electricity Savings (kWh):*** Gross annual incremental electricity savings as estimated by a program administrator before the energy efficiency activities have been implemented. Projected savings are typically estimates prepared for program/portfolio design and planning purposes, based upon estimates made before the program year begins of such factors as per-unit savings values, operating hours, installation rates and savings persistence rates.

***Total Projected Net Annual Electricity Savings (kWh):*** Net annual incremental electricity savings as estimated by a program administrator before the energy efficiency activities have been implemented. Projected savings are typically estimates prepared for program/portfolio design and planning purposes, based upon estimates made before the program year begins of such factors as per-unit savings values, operating hours, installation rates and savings persistence rates.

***Total Verified Gross Annual Electricity Savings (kWh):*** Annual incremental gross electricity savings estimates that are generated by an independent, third-party evaluator after the energy efficiency activities have been implemented and an impact evaluation has been completed in the defined geographic area (e.g., a utility territory within a state).

***Total Verified Net Annual Electricity Savings (kWh):*** Annual incremental net electricity savings estimates that are generated by an independent, third-party evaluator after the energy efficiency activities have been implemented and an impact evaluation has been completed.

# Appendix D. Issues in Data Quality and Standardization

In this appendix, we identify and summarize key issues related to quality, consistency and availability of efficiency program data. We review the limitations that these shortcomings pose for standardization and analysis and discuss procedures and processes that we have adopted to improve quality control. In previous reports, we have described the LBNL DSM Program Database, the information sources from which the data are collected, and our methods for standardizing and analyzing the data (Billingsley et al. 2014; Hoffman et al. 2015; Hoffman et al. 2017).

## Program data quality, consistency and availability: Issues, challenges and resolutions

In general, we took all data reported to regulators by program administrators as given. The results of LBNL's calculations are therefore highly dependent on values as reported by program administrators. We documented three broad sets of issues that created challenges in working with program data for this and previous reports: (1) incomplete or inconsistent data reporting; (2) issues in reporting of measure lifetimes and annual savings; and (3) definition and reporting of participant costs.

### Incomplete and Inconsistent Data Reporting

We were not able to include program-level data from programs funded by customers of investor-owned utilities in a few states because they chose to redact such information (e.g., Virginia) or simply did not report basic information on program costs and savings (e.g., Alabama). We were unable to identify clear rationales for redacting or withholding basic spending and savings data, given the availability of that data in 41 other states.

In states where program-level data are available, we find a wide range of practices in the estimation and reporting of spending and savings values.

#### *Expenditures not allocated by fuel*

Some program administrators offer efficiency programs and measures (e.g., insulation, windows, infiltration reduction) that target end uses served by multiple fuels (e.g., electricity, natural gas, fuel oil). Program administrators often report electric and gas savings values separately but do not report costs separated by fuel type. Separate costs are necessary to calculate the levelized cost of saved electricity (or cost of saved gas). Thus, we developed a methodology to estimate the cost share for each fuel.

Program administrators use a variety of methods for distinguishing program costs by fuel. Some administrators use each fuel's share of incentive payments, while some use each fuel's share of aggregate savings in British thermal units. Other administrators use each fuel's share of total benefits. Each of these approaches has pros and cons, but we find the latter method most defensible. When data on program benefits are available, we calculated the share of each fuel's benefits relative to total fuel-related benefits for each program and assumed cost allocations in the same proportions.

### *End-Use Versus Generator or Busbar Energy Savings*

Most program administrators reported end-use savings—at the customer's meter. For those administrators that only reported savings at the generator or busbar, we used utility-specific line losses to calculate the equivalent savings at the meter.

### *Energy Savings Reporting Practices: "Gross" and "Net" Savings*

Program administrators do not all follow the same accounting system for estimating and reporting savings. Some administrators report "gross" savings while others report "net savings"; some administrators report both.

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).[2]

An important example of the difference between the two is participant self-selection, or "free-riding." This refers to the propensity of those who enlist in programs to take efficiency-increasing actions even in the absence of the program. In some cases, program administrators also include estimates for spillover effects in their estimates of net savings. These spillover savings are those attributed to program participants and non-participants that exceed savings that the program was designed to promote and yet are driven in some fashion by program activities. We find significant variability in program administrator definitions of free-ridership and spillover and in the methods used to estimate those factors. We rely upon gross energy savings primarily because net savings are not universally reported and because inconsistencies in the definition and estimation of net-to-gross ratios add considerably to the uncertainties in estimating program impacts.

When program administrators report savings only in "net" terms, we convert them to gross. We do so using net-to-gross ratios, which program administrators occasionally report. When net –to-gross ratios are not available in program administrator reports or in evaluations, we request them from program administrators and regulators directly.[3]

### *Issues with Estimation and Reporting of Program Average Measure Lifetimes*

Program average measure life (PAML) is a critical input into the levelized CSE calculation. Table D - 1 shows the frequency with which program administrators provided information on PAML or lifetime savings expressed in terms of program years of data or number of administrators. For 32% of program years, the LBNL DSM Program Database has reported lifetime savings. In this situation, we divide lifetime savings by annual savings to estimate PAMLs. For 9% of program years, the administrator has

[2] 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.
[3] We thus far have managed to avoid imputing any national average net-to-gross ratios to any portfolios or programs.

provided information on PAML. For the 58% of program years that lack both PAML and lifetime savings, we impute PAMLs from similar programs.

**Table D - 1. Presence of Program Average Measure Lifetime (PAML) and Lifetime Savings in LBNL DSM Program Database**

| Values Reported | | | Program Years | | Program Administrators | |
|---|---|---|---|---|---|---|
| Annual Savings | Reported Measure Lifetime | Reported Program Lifetime Savings | Count | As Percent of Program Years with Annual Savings | Count | As Percent of Program Administrators with Annual Savings |
| Yes | Yes/No | Yes/No | 7348 | 100% | 116 | 100% |
| Yes | Yes | No | 691 | 9% | 13 | 11% |
| Yes | No | Yes | 2359 | 32% | 19 | 16% |
| Yes | No | No | 4298 | 58% | 84 | 72% |

Where we do have reported and calculated program average measure lifetimes, we find significant variation within program categories (see Figure D - 1). Interquartile ranges (shown as a box) are frequently five years or more for similar program types. Min-max differences (shown by the line graph for each program) can range between 10 and 25 years.

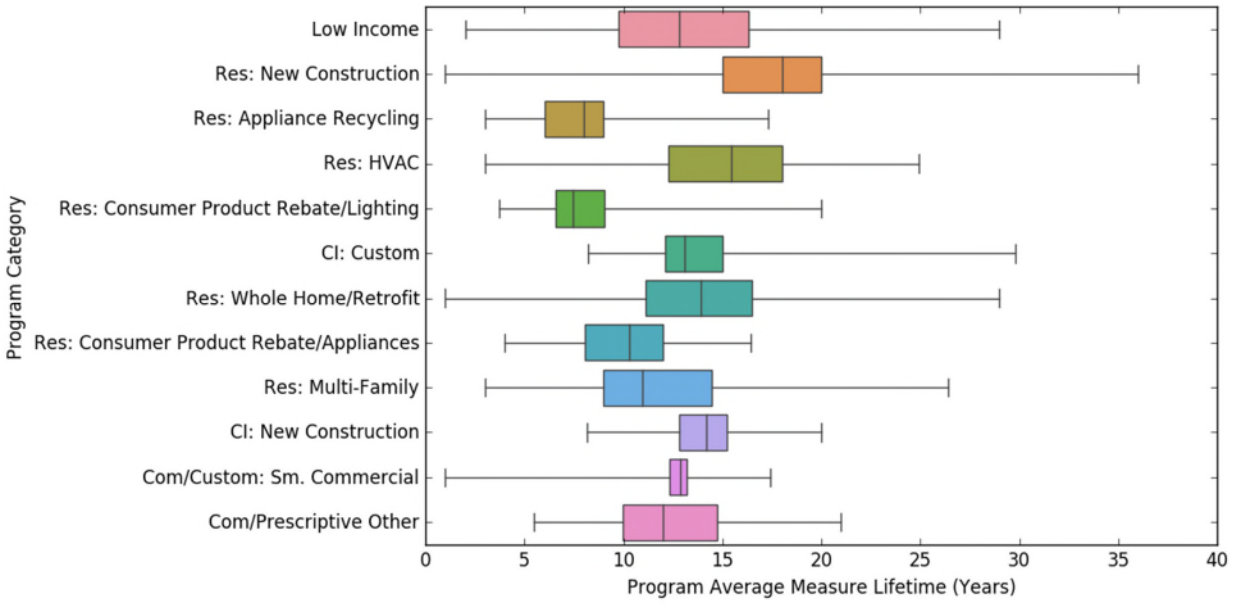


**Figure D - 1. Range of reported program average measure lifetime values for select detailed program categories**

Variability in estimates for measure lifetimes, and often annual savings as well, can arise from multiple sources (Hoffman et al. 2015):

- Limits or pre-specified, mandated caps on the maximum measure lifetimes (e.g., Texas and Pennsylvania cap measure lifetimes at 10–15 years);
- Differences among program administrators' EM&V approach and level of effort, as well as underlying assumptions and frequency of updating measure lifetimes and savings estimates;
- Differences in the types of efficiency project applications within a program (e.g., retrofit installation vs. replace on burnout vs. new construction, which may have different baselines for lifetimes);
- Differences in geography, building stock and environmental conditions—e.g., water heaters in regions with highly alkaline water have shortened lifetimes (Messenger 2014); icy and snowy conditions can shorten lifetimes for exterior lighting;
- Use of dual or dynamic baselines for energy consumption; and
- Extent to which estimates of savings for high-efficiency measures are disaggregated by market segment, such as savings from lighting measures for commercial sector vs. savings estimates that are based on operating regimes or operating hours for specific market segments (e.g., a lighting retrofit measure installed in a school, retail store or hospital).

Since measure life is critical to our cost of saved electricity (CSE) analysis, we developed a methodology to impute values when program administrators did not report this value. The implementation of the following procedure resulted in a PAML for each program in our database for which savings were claimed:

1. If available, we use the PAML reported by the program administrator.
2. If the program administrator does not report the PAML but reports lifetime gross savings and annual gross savings, we divide the lifetime savings by the annual savings to derive a PAML value for that program.
3. If neither program average measure life nor lifetime savings is available, we use the average of similar programs' PAMLs.

Table D -2 shows the average lifetime for programs in the LBNL DSM Program Database based on values reported by program administrators. These values were used to calculate CSE for programs where this information was not provided by the program administrator.

**Table D - 2. Program average measure lifetime for electricity efficiency programs**

| Sector | Detailed Program Category | Electricity Efficiency Program Measure Lifetime |
|---|---|---|
| C&I | CI: Behavioral | 2 |
| C&I | CI: Custom | 13 |
| C&I | CI: Financing | N/A |
| C&I | CI: General C&I | 11 |
| C&I | CI: New Construction | 14 |
| C&I | CI: Other | 14 |
| C&I | CI: Prescriptive | 12 |
| C&I | CI: Self Direct | 11 |
| Combined Heat & Power (CHP) | CHP | 21 |
| Commercial | Com/Custom | 12 |
| Commercial | Com/Custom: Commissioning/Retro-Commissioning | 7 |
| Commercial | Com/Custom: Sm. Commercial | 12 |
| Commercial | Com/Pres: Grocery | 13 |
| Commercial | Com/Pres: HVAC | 11 |
| Commercial | Com/Pres: IT & Office Equipment | 5 |
| Commercial | Com/Pres: Lighting | 11 |
| Commercial | Com/Pres: Performance Contract/DSM Bidding | 14 |
| Commercial | Com/Pres: Small Commercial | 11 |
| Commercial | Com/Prescriptive Other | 12 |
| Commercial | Com: New Construction | 14 |
| Commercial | Com: Audit | 8 |
| Commercial | Com: Financing | N/A |
| Commercial | Com: Govt./Nonprofit/MUSH | 11 |
| Commercial | Com: Other | 13 |
| Commercial | Com: Street Lighting | 11 |
| Cross Sectoral/Other | CS: Codes & Standards | 9 |
| Cross Sectoral/Other | CS: Education and Outreach - School and Community-Based Education | 10 |
| Cross Sectoral/Other | CS: Market Transformation | 7 |
| Cross Sectoral/Other | CS: Marketing, Education, Outreach - General Portfolio Branding and EE Awareness | N/A |
| Cross Sectoral/Other | CS: Multi-Sector Rebates | 10 |
| Cross Sectoral/Other | CS: Other | 7 |
| Cross Sectoral/Other | CS: Planning, Evaluation/Other Program Support | N/A |
| Cross Sectoral/Other | CS: Research | 16 |
| Cross Sectoral/Other | CS: Shading/Cool Roofs | 24 |
| Cross Sectoral/Other | CS: Voltage Reduction/Transformers | 17 |
| Cross Sectoral/Other | CS: Workforce Development | 11 |

| Sector | Detailed Program Category | Electricity Efficiency Program Measure Lifetime |
|---|---|---|
| Demand Response | Demand Response | N/A |
| Industrial/Ag | IA/Custom: Data Centers | 12 |
| Industrial/Ag | IA/Custom: Ind. & Ag. Process | 12 |
| Industrial/Ag | IA/Custom: Refrigerated Warehouses | 14 |
| Industrial/Ag | IA/Pres: Agriculture | 10 |
| Industrial/Ag | IA/Pres: Motors | 15 |
| Industrial/Ag | IA: Self Direct | 15 |
| Industrial/Ag | IA: Audit | 5 |
| Industrial/Ag | IA: Custom | 12 |
| Industrial/Ag | IA: New Construction | 19 |
| Industrial/Ag | IA: Other | 12 |
| Industrial/Ag | IA: Prescriptive | 12 |
| Low Income | Low Income | 13 |
| Renewables | Renewables | 18 |
| Residential | Res: Appliance Recycling | 8 |
| Residential | Res: Behavioral/Feedback - In-Home Displays | 7 |
| Residential | Res: Behavioral/Feedback - Normative Energy Reports | 1 |
| Residential | Res: Behavioral/Feedback - Online Audit | 5 |
| Residential | Res: Behavioral/Other | 1 |
| Residential | Res: Consumer Product Rebate/Appliances | 10 |
| Residential | Res: Consumer Product Rebate/Electronics | 7 |
| Residential | Res: Consumer Product Rebate/Lighting | 8 |
| Residential | Res: Financing | N/A |
| Residential | Res: General | 10 |
| Residential | Res: HVAC | 14 |
| Residential | Res: Insulation | 21 |
| Residential | Res: Multi-Family | 11 |
| Residential | Res: New Construction | 18 |
| Residential | Res: Other | 11 |
| Residential | Res: Pool Pump | 10 |
| Residential | Res: Prescriptive | 13 |
| Residential | Res: Water Heater | 12 |
| Residential | Res: Whole Home/Audits | 9 |
| Residential | Res: Whole Home/Direct Install | 11 |
| Residential | Res: Whole Home/Retrofit | 14 |
| Residential | Res: Windows | 20 |

We also examined reported measure lifetimes for similar programs over the time period of our study in order to assess whether there were significant technological changes that would impact measure lifetimes over the study period and thus influence CSE values. We paid close attention to any significant changes in assumptions that program administrators adopted in their savings claims. One change in particular warranted a modification to our methodology for estimating savings in the current study. Lighting programs underwent a major technological shift in the 2009-2015 period. With the advent of new federal lighting standards, early generation spiral compact fluorescent light bulbs (CFLs) that had been a mainstay of residential lighting programs for more than a decade became the market baseline for energy performance. By the time the new standard became effective in 2012, many program administrators had begun turning to new technologies with higher energy performance. Light-emitting diodes (LEDs) and other technologies offer savings as well as significantly longer measure lifetimes. Average measure lifetimes for residential lighting programs nationally rose about 60%, from 6.5 years in 2012 to 10.6 years in 2015. The same trend applied to a lesser degree for commercial lighting programs. Similarly, average measure lifetimes for behavioral programs increased 43% from 2011 to 2015 as several program administrators adopted lifetimes of two or three years. Where information on program average measure lifetime was not provided by the program administrator for these three program types (residential lighting, commercial lighting, behavioral programs), we imputed average lifetimes that increased dynamically over the study period, using the year-by-year national average of lifetimes that were reported for those types of programs.

## Issues in Estimation, Reporting and Collection of Total Costs

Total cost data present unique challenges for data collection and input. Most states with large-scale efficiency programs funded by utility customers require administrators to perform benefit/cost tests that require knowledge of total costs. Yet fewer than half of program administrators actually report those total costs or data from which they might be derived.

### *Defining and Reporting Participant Costs*[4]

Participant costs are those incurred directly by program participants, excluding incentives provided by the program, and can be determined directly or indirectly. In the direct approach, participant costs can be identified by analyzing receipts, invoices or other transaction records of participants, retailers or contractors, often as a precursor to setting and awarding an incentive to the participant. This practice is often used in C&I custom rebate programs and whole-home retrofit programs. Often, the invoiced costs to the participant are costs of the project prior to taking incentives into account.

In the indirect approach, program administrators (and their consultants) often rely upon point-of-sale data from retailers. The indirect approach is more common and is often done on a state basis as part of a technical reference manual. It involves estimating the cost of the efficiency measure (and the standard product) and then subtracting any incentives, leaving the participant cost contribution. Figure D - 2 illustrates these two primary methods for arriving at participant costs.

[4] Hoffman et al. (2015) provides a fuller explanation of issues with the definition and reporting of participant costs.

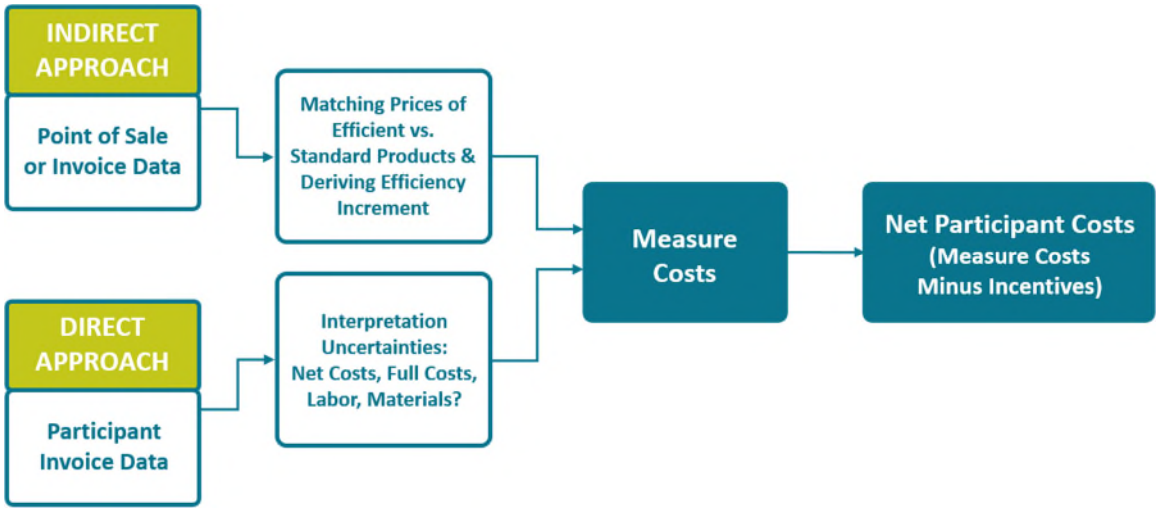


**Figure D - 2. Methods used in the estimation of measure and participant costs**

However, reliable cost data often are not available, and distilling the costs of many different equipment or appliance models into a single measure cost (e.g., a generic ENERGY STAR®-qualified refrigerator) can be challenging.

Definitions of the cost of a measure also can differ. 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.[5] Other program administrators define measure costs by program type or application. 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). Measure costs therefore may vary based on the sales channel, the nature of the sales transaction, and the scale of the purchase. They also vary across time and geography. Increased transparency of practices used by program administrators in accounting for participant costs and estimating measure costs would be helpful in facilitating comparisons and could lead to more accurate and consistent estimates of total costs.

The analyses presented here are limited to the offerings of program administrators for which data for computing program-level total costs were available or could be obtained with direct queries.[6] For each annual report, LBNL staff ascertained how the program administrator defined total resource costs and participant costs and took steps to standardize the cost data.

[5] The incremental cost of an efficient energy-using device, conditioning system or building shell component 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). 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. However, this method requires large sample sizes given the number and diversity of products and features in the market.

[6] Data were obtained directly from one or more program administrators in a few states, e.g., Oregon and New Jersey.

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.

## Quality Assurance and Quality Control Protocols

To augment the collection and standardization methodologies described above, we follow an internal quality assurance and quality control (QAQC) protocol that includes internal flags for aberrant values and verification of most collected values before addition to the LBNL database. Once a researcher finishes collecting and standardizing data for a state, a second researcher performs extensive spot-checking on one or more program administrators for as many years of data as were collected in each cycle. The data input and QAQC process helped identify some issues that we raised with program administrators as needed and corrected.

# Appendix E. Methodology for Panel Regressions and Results

In this study and earlier work (Hoffman et al. 2017), we examined ways in which the cost of saved electricity changes over time. Time can be a proxy for a composite of multiple influences on the cost of saved electricity (CSE)—for example, changes in the availability of cost-effective electricity savings such as fewer low-cost savings opportunities, other changes in the efficiency market such as deeper and broader relationships between the program administrator and trade allies, and changes in the experience level of the program administrator and its implementers. The simplest test for time-related changes is to regress the CSE values versus time.

The regression allows us to test the hypothesis that the CSE and time are associated in some way, without specifying the nature or component factors of the association. The null hypothesis would be that no relationship exists—that the CSE is not related to time. We performed linear regressions of the program administrator and total cost of saved electricity at the portfolio level on time to assess how cost performance changes for the 51 program administrators for which we had continuous data between 2010 and 2015.[7]

We applied a panel regression with fixed effects at the level of the program administrator because we recognize that multi-year observations from the same program administrator over time are not independent from each other. By controlling for program administrator fixed effects, we are controlling for everything about a given program administrator that does not change over time. The time variable here is coded as a unique digit for each year of the dataset (e.g., 1 for 2010; 2 for 2011 and so on). The coefficient on the time variable represents the predicted magnitude and direction of the association. The p-value indirectly indicates the significance of that relationship by measuring the likelihood that data support the null hypothesis—that no association exists. A small p-value (usually ≤ 0.05) indicates strong evidence against the null hypothesis. Thus, one would reject the null hypothesis and consider the relationship likely to be statistically significant.

Table E - 1 summarizes the results of statistical analyses of time trends for the CSE. The first column provides the number of observations used in each of the three regressions. The second column provides the coefficients for the time variable. These coefficients represent the change in the cost of saved electricity, in 2016 constant dollars, for each additional year of the series. The first row reflects the time coefficients and other metrics for a linear regression using the program administrator CSE as the dependent variable. The second and third rows provide the same metrics for linear regressions using the total CSE and the program administrator CSE. These latter two regressions were performed on the subset of data for which we had continuous paired values for the total and program administrator cost of saved electricity over the 2010–2015 study period, hence the smaller sample.

[7] We did not include program data from 2009 in the regression analysis because it would have significantly reduced the sample size of program administrators.

**Table E - 1. Results of linear regressions of the cost of saved electricity on time (2010–2015)**

| Dependent variable | Program administrator sample for 2010 to 2015 program years (balanced panel) | Coefficient on the time variable | P-value on the time variable (with clustering of standard errors) | R-squared overall |
|---|---|---|---|---|
| Program administrator cost of saved electricity | 52 | 0.0006 | 0.035 | 0.007 |
| Total cost of saved electricity | 21 | 0.0015 | 0.026 | 0.014 |
| Program administrator cost of saved electricity (total costs only) | 21 | 0.0013 | 0.011 | 0.015 |

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