The Sustainability and Costs of Increasing Efficiency Impacts: Evidence from Experience to Date

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ABSTRACT

As interest in increasing the scale of electric energy efficiency programs grows, one question is whether such programs can achieve and sustain high levels of impact. Another question is how the unit cost of saved energy (CSE) for overall portfolios of programs may change as program scale increases. To see what light experience casts on these questions, data covering program performance for numerous jurisdictions and years were collected.

We define high savings as incremental reductions in annual energy sales of one percent or more due to one year's program activities. Data show that some utilities have achieved high levels of savings over several years, implying that high levels of savings can be sustained.

A more complex question concerns CSE. One view is that CSE should increase as more of the energy savings potential is tapped. Steady-state analysis can readily arrange technologies on a "conservation supply curve" of increasing costs per unit of saved energy. Alternatively, CSE may not increase in this way given innovation, economies of scale, and learning curves. To analyze how CSE changes in practice as the scale of programs increases, we analyzed CSE for several programs in different regions that have pursued energy efficiency on a comprehensive basis.

This analysis of actual program CSE finds that program CSE seems to decrease as program scale and impact grows. Of course, program CSE fluctuates due to many factors such as year, utility, and program type and size. Analysis of factors contributing to decreases or increases in CSE is underway.

Introduction and Background

Electric energy efficiency has been seen as one of the most promising and cost-effective strategies for addressing numerous problems associated with conventional power generation including climate change disruption. Many states and utilities are intensifying their consideration of the potential of energy efficiency measures and are interested in the cost of achieving higher level of energy savings and greenhouse gas emission reductions. Various stakeholders are investigating the possibility of increasing the scale and impact of buildings and industry sector energy efficiency programs operated by utilities or other administrators. At the same time, there are concerns that unprecedented efforts and resources would be required to achieve significantly increased energy savings.

This analysis of empirical data on efficiency programs is intended to provide some useful information and more confidence to program administrators and policy makers with regard to how much savings can be realistically achieved and at what cost.

Empirical Evidence on High Energy Savings Performance

It is useful to inquire whether a number of utilities or other administrators have achieved high energy savings over a number of years. The *National Action Plan for Energy Efficiency* (NAPEE) states that well-designed energy conservation programs are "delivering annual energy savings on the order of 1 percent of electricity and natural gas sales." (DOE and EPA 2006, ES-4) But such activities have not been documented comprehensively, in NAPEE or elsewhere. Consequently, we have investigated this issue in order to identify the utilities (or other program administrators) that have achieved high savings, addressing only electricity savings. For purposes of this paper, we define high savings as incremental reductions in annual energy sales of one percent or more due to one year's program activities. Table 1 presents a list of entities that achieved high energy savings and the sources for the energy impacts shown. Where high savings were achieved in several years, only the year of highest savings is shown.

Table 1. Examples of High Annual Electric Energy Savings Realized through DSM

Jurisdiction or Entity	Annual Savings (Percent)	Year(s)	Source
Interstate Power & Light (MN)	3.0	2001	Garvey, E. 2007. "Minnesota's Demand Efficiency Program."
San Diego Gas & Electric (SDG&E) (CA)	2.1	2005	SDG&E 2006. Energy Efficiency Programs Annual Summary
Minnesota Power	1.9	2005	Garvey, E. 2007
Sacramento Municipal Utility District (SMUD) (CA)	1.9	1994	Data provided by SMUD
Vermont	1.8	2007	Efficiency Vermont 2008. 2007 Preliminary Results and Savings Estimate Report
Southern California Edison (SCE)	1.7	2005	SCE 2006. Energy Efficiency Annual Report
Western Mass. Electric Co. (MA)	1.6	1991	MA Dept. of Telecommunications & Energy (DTE) 2003. Electric Utility Energy Efficiency Database
Pacific Gas & Electric (PG&E) (CA)	1.5	2005	PG&E 2006. Energy Efficiency Programs Annual Summary
Massachusetts Electric Co.	1.3	2005	MECo 2006. 2005 Energy Efficiency Annual Report Revisions
Connecticut IOUs	1.3	2006	CT Energy Conservation Management Board (ECMB). 2007
Commonwealth Electric (MA)	1.2	1990	MA DTE 2003.
Cambridge Electric (MA)	1.1	2000	MA DTE 2003.
Seattle City Light (WA)	1.0	2001	Seattle City Light 2006. Energy Conservation Accomplishments: 1977-2005
Eastern Edison (MA)	1.0	1994, 1998	MA DTE 2003.

We also investigated whether such high energy savings were sustained over multiple years. We identified seven cases where utilities have sustained 1% or more savings over multiple years. Those cases are presented in Table 2 and Table 3.

Table 2. Examples of High DSM Performance (Part 1)

	Mass. Electric	SMUD	W. Mass. Electric
1991	1.0%	0.7%	1.6%
1992	0.7%	1.3%	1.0%
1993	0.7%	1.1%	1.3%
1994	1.0%	1.9%	0.8%
1995	1.0%	1.6%	0.7%
1996	0.9%	0.9%	0.8%
1997	1.0%	0.4%	1.0%
1998	0.8%	0.4%	0.8%
1999	0.9%	0.3%	0.7%
2000	0.7%	0.3%	1.0%

Data source: SMUD 2007; MA DTE. 2003.

Table 3. Examples of High DSM Performance (Part 2)

	CT IOUs	Efficiency Vermont	Interstate Power & Light	SDG&E
2000	0.9%	0.4%		0.8%
2001	1.1%	0.7%	3.0%	1.2%
2002	0.9%	0.8%	2.5%	1.2%
2003	0.4%	1.0%	2.7%	0.7%
2004	1.0%	0.9%	2.6%	1.3%
2005	1.1%	1.0%	2.6%	2.1%
2006	1.3%	1.0%		0.8%
2007		1.8%		

Data source: CT ECMB 2001-2007; Efficiency Vermont 2007b; Garvey, E. 2007;
California Energy Commission (CEC) 2008

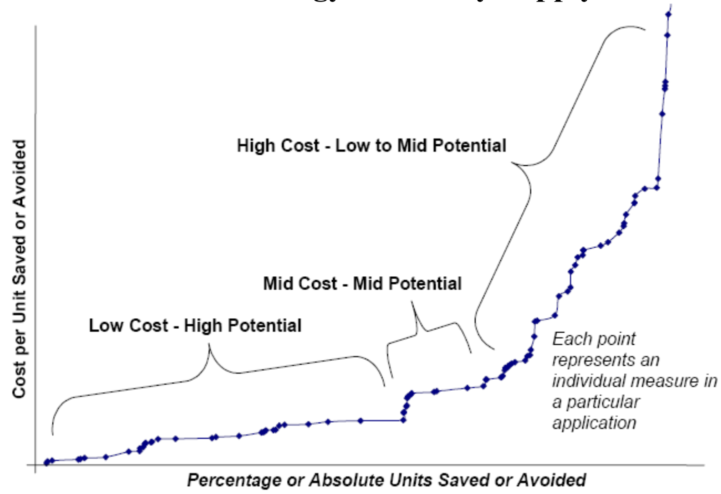
The data summarized above show that utilities or program administrators in varying regions of the country and during varying periods of time have indeed achieved annual incremental levels of energy efficiency savings equal to or in excess of one percent of annual electricity sales. Some have occasionally saved over two percent of annual energy sales per year. The data themselves provide a sort of "existence proof" that incremental annual energy savings of at least one percent of annual sales can be achieved and sustained. But at what cost? And does the cost increase as the penetration reaches or exceeds one percent of annual sales? These questions are especially relevant in light of the growing interest in several jurisdictions in achieving, sustaining, or even surpassing these high levels of savings.

Analysis of Trends in the Cost of Saved Energy

The Conservation Supply Curve

One view expects that the CSE should increase as more of the energy savings potential is tapped. Steady-state analysis can readily arrange efficiency technologies on a "conservation supply curve" (CSC) of increasing costs per unit of saved energy so that it would appear as if increasing acquired savings would require an increase in the cost per unit savings. (See Figure 1.)

Figure 1. Illustrative Energy-Efficiency Supply Curve



Source: XENERGY Inc. 2002. California's Secret Energy Surplus: the Potential for Energy Efficiency

Many studies develop CSE," also known as "energy-efficiency supply curves", for use in energy planning studies and policy analysis. (Bernow 2002; Coito & Rufo 2002; Donovan et al. 2003). These curves are always presented with "steps" that increase as one moves along the horizontal axis from left to right (increasing energy savings). This notion of an "increasing cost supply curve for saved energy" is theoretically appealing. It reflects a logical order of prioritization of opportunities. Why would someone implement a high cost measure but not a lower cost measure?

There is no question that CSC analysis is a useful tool for comparing the relative costs of energy efficiency measures and for understanding the aggregate potential for cost-effective energy efficiency that is available up to any given CSE level. However, CSCs are generally constructed in a manner that is limited to demonstrated and currently well-understood measures and programs. They may imply increased market share for advanced technologies, but only rarely do they reflect true technological or institutional improvement over time. In contrast, analysts of fossil fuel supply do not limit their analyses to "proven" resources, but routinely include hydrocarbon reserves that are described as "undiscovered," "possible," or "prospective." (Bruce Biewald 2004). This appears to be a bias against demand-side resources in long-term energy modeling.

Further, CSC analysis can lead to an assumption that energy efficiency programs must mimic the CSC curve, such that the greater their amount of savings, the greater their program cost. However, program CSE might be expected to differ from the technology CSE that underlies CSC analysis, for several reasons. Beyond the obvious fact that energy efficiency program costs[1] typically cover a substantial fraction, but not all, of efficiency's incremental costs, the program CSE fluctuates due to many factors such as year, utility, sector, type of program, and size of program.

[1] The costs of the utility or other program administrator including the costs for marketing, administration, program rebates, and measurement and verification of energy savings.

In fact, the data for actual energy efficiency programs do tell a different story from that which might be inferred from CSCs. Utility and non-utility DSM programs generally include a range of measures, ranging from zero (or even negative net cost) per kWh saved up to (and in rare occasions) exceeding avoided costs. The overall cost per kWh saved for a utility program in a particular year turns out to be lower for the more ambitious programs. This could be because there are fixed costs that can be spread out over more measures or participants. On the electricity supply side it is generally accepted that there are "economies of scale" in power plant construction costs (i.e., larger equipment costs less on a per MW basis).

Utility efficiency programs are often composed of various programs that target each sector, including the low-income, residential, and commercial and industrial sectors. Therefore, the overall cost of saved energy for the program is always the weighted average cost of saved energy through a portfolio of various measures. This reality is different from a wholesale power market which sets market clearing prices of the market according to the costs of most expensive power plants to meet incremental energy consumption.

As noted above, CSC analysis often does not address economies of scale. Theoretically, a company can enjoy economies of scale by expanding its operation of energy efficiency programs. For example, a large program allows for bulk purchase of certain efficiency measures at a lower price or allows for bulk discounts for contracts with energy service companies to deliver energy savings. In another instance, large-scale programs can allocate the cost of marketing and administration of those programs over greater amount of energy savings, which would tend to reduce program cost per kWh saved as program scale increases.

Also, marketing and customer education will increase customers' adoption of new technologies, which in turn will accelerate the mass production of such technologies and thus reduce price per unit in the long term. Furthermore, greater scope of programs could reduce marketing expense or provide synergistic savings.[2]

Historical Trends in Program CSE

We analyzed several comprehensive energy efficiency programs in varying regions in order to explore the empirical relationship between program CSE and program scale. In this investigation, we collected and analyzed numerous amounts of data (over 160 cases) with regard to expenditures, costs, and savings associated with energy efficiency programs delivered by numerous utilities and over many years. This analysis focused on utilities or other entities with comprehensive electric energy efficiency programs, and was not restricted to the 13 programs that have achieved or surpassed savings equal to one percent of sales. We obtained the data either from utility efficiency annual reports, directly from program administrators or staff at state energy offices or regulatory commissions. Note that data on achieved energy savings originate in reports by program administrators and/or regulators. Data on savings are inherently less certain than data on costs. Regular impact evaluation activities to verify savings estimates have been conducted by virtually all entities that have pursued comprehensive energy efficiency programs on a sustained basis;[3] nevertheless, uncertainty regarding exact savings necessarily remains.

[2] For example, combining a lighting retrofit with a large commercial AC retrofit can reduce the size of the AC unit needed, making the retrofit both cheaper and more cost-effective.

[3] For detailed information how M&V has been conducted in Northeast states see Northeast Energy Efficiency Partnerships, Inc. 2006. *The Need for and Approaches to Developing Common Protocols to Measure, Verify and*

Moreover, the quality of savings estimation and verification could vary from jurisdiction to jurisdiction; this is not an issue we explored for this analysis. We think it unlikely that variability in the quality of savings estimates accounts for the trends found in the analysis described below, particularly since our analytical focus is on the relation of costs to the level of savings achieved within different entities' programs (as opposed to across them).

We analyzed these data to compare lifetime CSE per MWh (defined as the levelized cost of energy savings) for a given delivery entity and given year of program delivery with annual energy savings as percentage of sales for that entity and year. We also compared lifetime CSE with the quantity of projected lifetime energy savings.

Some utilities reported both first year and lifetime savings. Other utilities reported only first year savings. Where lifetime savings were not available, we assumed extrapolated lifetime savings based on the average lifetime of efficiency measures for a specific program or sector within a specific utility from other years for which lifetime savings for that utility were available. Where no lifetime savings data were available for a specific utility or program, we used a 12-year average lifetime that has been recognized as an industry rule of thumb estimate (DOE & EPA 2006; Martin, York, & Witte 2005; Bender et al. 2005).[4] For cases in which available information indicated that savings were measured at the customer level, we adjusted savings from customer to generation level to account for transmission and distribution line loss. We then estimated levelized CSE with a 4 percent discount rate used by CEC (2005) and the following formula:

Levelized CSE = Program Costs x Capital Recovery Factor / First year kWh saved

Capital Recovery Factor = $i(1+i)^n / \{(1+i)^n - 1\}$
i = real discount rate
n = weighted average of useful measure life (years)

We considered the use of program cost per lifetime MWh energy savings versus the use of program cost per first year savings. First-year savings is a somewhat more certain number because first year savings are often measured and verified savings while lifetime savings are projected. Although lifetime savings projections are usually based on empirical data concerning measure life, there are some uncertainties concerning actual measure lifetimes as well as energy savings performance over time. However, we chose a levelized cost of energy efficiency as a normalized value over the potential, useful energy savings, and one that is comparable to the cost of power generation. Additionally, the cost of first year energy savings ignores the fact that measure lives vary considerably among different types of technologies.

Program CSE versus annual incremental savings as percentage of annual retail sales is a measure of the relative aggressiveness of each utility program and addresses economies of scale

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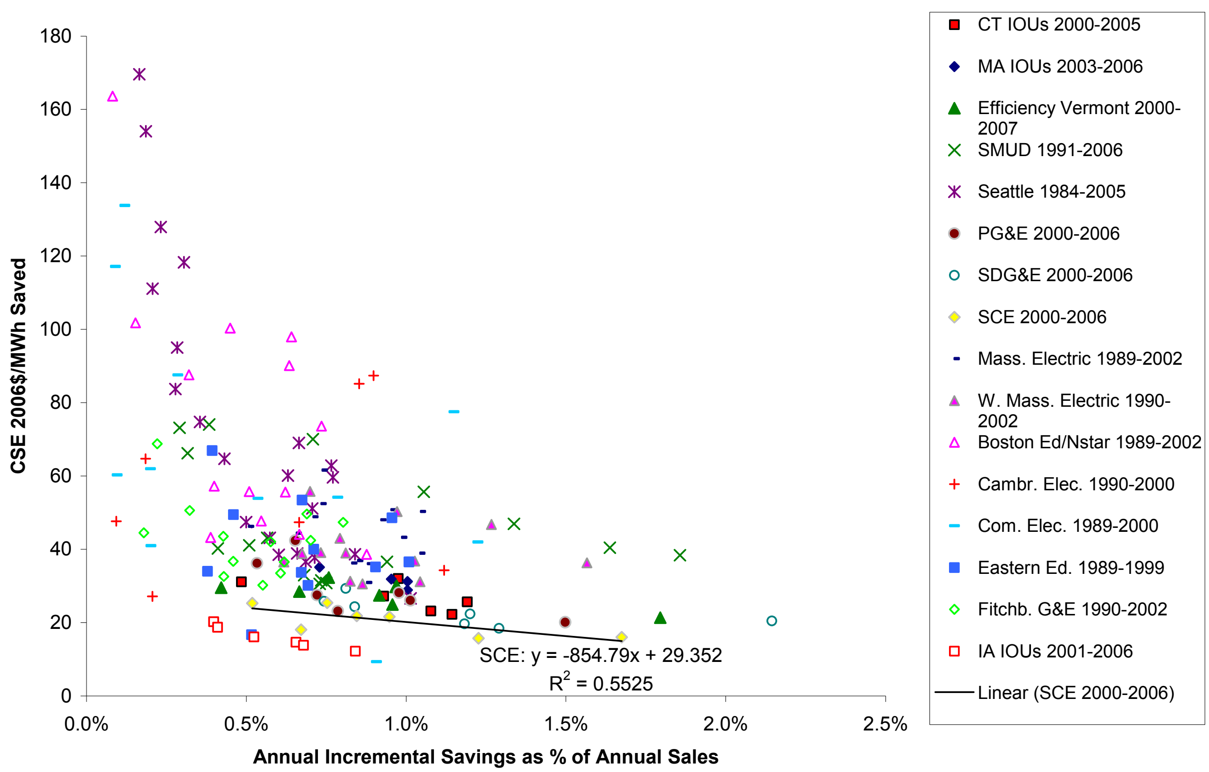
Report Energy Efficiency Savings in the Northeast, January 2006. Also for California's historical practice on M&V, see page 26 of Edward Vine and Jayant Sathaye 1999. *Guidelines for the Monitoring, Evaluation, Reporting, Verification, and Certification of Energy-Efficiency Projects for Climate Change Mitigation*, March 1999L Lawrence Berkeley National Laboratory.

[4] For example, we used the 12 year average lifetime number to estimate lifetime savings for SMUD, Seattle City Light, and Iowa IOUs. For California IOUs' data, slightly less than half of the data have projected lifetime savings and for the other half of the data, we used the average life of a certain program (e.g., residential, non-residential, new construction, others) to estimate the values for the same program in different years.

to some extent. Substantial absolute energy savings do not necessarily mean a utility is aggressively pursuing energy efficiency if such savings are small relative to the size of annual sales. On the other hand, small absolute savings could mean a utility is aggressively saving energy and working efficiently. This aggressiveness and efficiency of program administration could lower the cost of per-unit energy savings. For example, if a utility allocates relatively fixed marketing, planning, and administration costs over more sizable savings, the cost per unit of energy savings could decrease. Additionally, the materials and services that utilities obtain from vendors and contractors may have a lower relative cost as the scale of their programs grows. Figure 2 presents a comparison between utility levelized CSE in real 2006$ per MWh saved and projected lifetime savings. We generated linear trend lines to all datasets and identified slopes (coefficient) and R-square values for those lines. Figure 2 includes the trend line for SCE as an example. Table 4 presents the coefficient and R-square values for all data sets in Figure 2.

Program CSE versus lifetime savings measures the absolute size of each utility program and also addresses economies of scale to some extent. Bulk discounts for efficient products or for contracts with energy service companies might be more pronounced in this measurement than the savings as % of sales. We also drew linear trend lines for all datasets in this analysis, the results for which are presented in Table 5.[5]

Figure 2. Utility Cost of Saved Energy (2006$/MWh) vs. Incremental Annual Savings as % of Sales



[5] Due to the page limit of this paper, the figure for this analysis corresponding to Table 5 is not presented here.

Table 4. Slope Coefficient and R-Squared Values for Linear Trend Lines for Figure 2.

Data	Coefficient	R-square
CT IOUs 2000-2005	-1073	0.462
MA IOUs 2003-2006	-1798	0.834
Efficiency Vermont 2000-2007	-659	0.591
SMUD 1991 - 2006	-1257	0.136
Seattle 1984 - 2006	-13935	0.715
PG&E 2000-2006	-1936	0.526
SDG&E 2000-2006	-561	0.400
SCE 2000-2006	-855	0.553
Mass. Electric 1989-2002	-1185	0.050
W. Mass. Electric 1990-2002	-220	0.006
Boston Ed/Nstar 1989-2002	-9855	0.403
Cambr. Elec. 1990-2000	-48857	0.271
Com. Elec. 1989-2000	-8189	0.213
Eastern Ed. 1989-1999	-858	0.020
Fitchb. G&E 1990-2002	-1903	0.125
Iowa IOUs 2001-2006	-1712	0.943

Table 5. Slope Coefficient and R-Squared Values for Linear Trend Lines for CSE vs. Projected Lifetime Savings

Data	Coefficient	R-square
CT IOUs 2000-2005	-2.695E-06	0.457
MA IOUs 2003-2006	-4.950E-06	0.676
Efficiency Vermont 2000-2007	-1.135E-05	0.658
SMUD 1991 - 2006	-1.590E-05	0.207
Seattle 1984 - 2006	-1.271E-04	0.731
PG&E 2000-2006	-1.841E-06	0.552
SDG&E 2000-2006	-2.249E-06	0.420
SCE 2000-2006	-6.484E-07	0.591
Mass. Electric 1989-2002	-9.022E-06	0.168
W. Mass. Electric 1990-2002	-8.284E-06	0.026
Boston Ed/Nstar 1989-2002	-4.542E-05	0.454
Cambr. Elec. 1990-2000	-1.747E-03	0.183
Com. Elec. 1989-2000	-1.390E-04	0.186
Eastern Ed. 1989-1999	-2.854E-05	0.034
Fitchb. G&E 1990-2002	-1.760E-04	0.078
Iowa IOUs 2001-2006	-3.927E-06	0.948

A key result is that, among all of the datasets that we have collected, all of the slope coefficients of the linear trend lines are negative. This strongly suggests that per-unit cost of energy efficiency (EE) decreases as the amount of EE savings increases. It is important to emphasize that this finding contradicts the generally accepted theory that costs of EE increase when EE savings amounts increase.[6] The fact that the coefficient is negative in every case is

[6] For example, the data for SCE, PG&E, MA IOUs, and Seattle City Light show that a more than 50% of the variation in CSE can be explained by the amount of energy savings; for others, like Mass. Electric, Cambridge

particularly striking. While there exists a possibility that unit costs might begin to increase at much higher levels of EE program savings, this evidence suggests that current program savings levels have not yet approached any such point.

It is also important to note that variation of per unit cost of energy efficiency for a given utility generally decreases as the amount of efficiency savings increases. In other words, the data show that the cost of efficiency becomes smaller and less variable for higher savings amounts. For example, there are several cases where costs of efficiency reach over $100 per MWh saved below 0.5% savings penetration.

Possible reasons for this finding include (1) economies of scale are at work (e.g., allocating marketing and administration costs over more EE savings, achieving lower unit costs for program inputs); (2) economies of scope are at work (e.g., exploiting synergies among different measures); (3) administrators become smarter and more organized in designing and developing EE programs; or (4) administrators have more credibility or more resources available for quality program design and development, etc.

We recognize that the data and analysis presented here are preliminary. They by no means pin point the underlying sources of variation in program CSE across utilities and across years. However, the macro-level trends identified do at least call into question what is a common explicit or implicit assumption concerning the achievability and program costs of large-scale EE.

Conclusion

There is growing interest in increasing the scale and impacts of electric energy efficiency programs in the United States. The experience of the utilities or other administrators that have achieved the greatest levels of savings in the past suggests that high levels of program impact can be achieved and sustained. At least 13 programs have reported overall incremental annual electricity savings equal to or exceeding one percent of annual sales in one or more years. Recently some have even achieved savings levels of two or more percent annually.

We explored the relationship of program cost for saved energy to the level of electricity savings achieved by numerous utilities over many years. This analysis focused on utilities or other entities with comprehensive electric energy efficiency programs, and was not restricted to the 13 programs that have achieved or surpassed savings equal to one percent of sales.

One aspect of this analysis compared each utility's program CSE for a given year to the total quantity of lifetime electricity savings projected from that year's energy efficiency program. For every program analyzed, we found a trend of decreasing utility CSE as the absolute quantity of EE savings increased. Another aspect of this analysis compared each utility's program CSE to annual incremental savings as percent of sales. For every program analyzed, we found a trend of decreasing utility CSE as the relative quantity of EE savings increased.

Our overall finding thus is that the per-unit program cost of achieving energy efficiency seems to decline as program scale and aggressiveness increase, at least based on the experience to date of many utilities with comprehensive programs. This may surprise those who would expect the opposite trend based on theoretical conservation supply analysis.

This is a preliminary analysis that we expect to extend in several directions. Possibilities for further research include:

Electric, and Eastern Edison, show the amount of energy savings explains a smaller fraction of the variations in CSE.

- Adding data for additional utilities and regions to the analysis.
- Investigation of CSE by type of programs or sector (e.g. residential versus non-residential).
- Review of the data sets to ensure that load management type programs have been fully excluded. (As this was done where evident, this would be in the nature of double-checking.)
- Explicit analysis of the share of administrative and marketing costs to total program costs as a function of program impact, to test one of the hypotheses about economies of scale.
- Investigation of the impact of bulk discounts for products and service contracts on program costs.
- Investigation of the impact of synergistic program effects on program costs.
- Review of the savings evaluation and verification history associated with each data set.
- Comparison of total CSE (i.e., utility plus participant costs) with electricity savings achieved.
- Analysis of CSE/savings trends among gas energy efficiency programs.

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