NOVA SCOTIA UTILITY AND REVIEW BOARD

IN THE MATTER OF: **THE PUBLIC UTILITIES ACT**

-and-

IN THE MATTER OF: **AN APPLICATION by Efficiency Nova Scotia Corporation ("ENSC") for approval of 2012 Electricity Demand Side Management ("DSM") Plan for 2012**

NON-CONFIDENTIAL INFORMATION REQUESTS

To: Efficiency Nova Scotia Corporation
c/o Sean Foreman
Regulatory Counsel
Wickwire Holm
2100 – 1801 Hollis Street
Halifax, NS B3J 2X6

From: Board Counsel Consultant
Nova Scotia Utility & Review Board

Responses Due: **March 29, 2011**

Copies: 8 and an electronic copy (pdf searchable)

Contact Person: **Tim Woolf**
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Issued at Halifax, Nova Scotia, this 17th day of March, 2011.

Nancy McNeil

Nancy McNeil, Regulatory Affairs Officer/Clerk

Request IR-1:

With respect to page 14, Figure 5.1,

a) Please provide the results for the TRC test in terms of costs, benefits and net benefits in cumulative present value dollars, for each program and the total.

b) Please provide the results for the PAC test in terms of costs, benefits and net benefits in cumulative present value dollars, for each program and the total.

c) Please provide the worksheets and calculations used to determine the TRC and PAC results.

Request IR-2

With respect to page 14, Figure 5.1,

a) Please provide the cent/kWh charge that will be applied to ratepayers to collect the 2012 total DSM budget of $43.7 million. If appropriate, please provide the charges separately for each customer class.

b) Please provide cent/kWh charge that is currently applied to ratepayers to collect the 2011 total DSM budget. If appropriate, please provide the charges separately for each customer class.

c) Please provide cent/kWh charge that was applied to ratepayers to collect the 2010 total DSM budget. If appropriate, please provide the charges separately for each customer class.

Request IR-3

Please provide any analyses that ENSC or NSPI have performed to indicate the short-medium- or long-term rate impacts of the 2012 DSM programs. Please provide any and all documentation of such analyses.

Request IR-4

Please provide any analyses that ENSC or NSPI have performed to indicate the short-medium- or long-term bill impacts of the 2012 DSM programs. Please provide any and all documentation of such analyses.

Request IR-5

With respect to page 23, paragraph 2, please provide any assessment you have of the extent to which the energy efficiency savings in the 2012 DSM Plan will help contribute to the objective outlined in Nova Scotia's Environmental Goals and Sustainable Prosperity Act. In particular, please provide any quantitative estimates you have of the greenhouse gas emissions avoided by the efficiency savings in the 2012 DSM Plan, as well as the extent to which they will help NSPI comply with the 2015 and 2020 greenhouse gas emission targets.

Request IR-6

With respect to Appendix A, the 2012 DSM Plan, please provide customer participation rates for each of the residential and commercial & industrial programs. Please present in terms of (a) number of customers participating in the program, and (b) percent of total eligible customers participating in the program.

Request IR-7

Please provide customer participation rates for each of the residential and commercial & industrial DSM programs, separately for each of the years 2008, 2009, 2010 and 2011. Please present in terms of (a) number of customers participating in the program, and (b) percent of total eligible customers participating in the program.

Request IR-8

With respect to Appendix C, page 18, bullet #2, please explain the statement that "IRP targets in the *short term* (2011-2012) may be too ambitious." Please explain the extent to which the targets are too ambitious with respect to the following factors (a) achieving deeper savings per customer than in the past, (b) administering programs that have higher savings goals, (c) marketing programs to customers, (d) obtaining the relevant contractors, vendors, manufacturers and equipment associated with the higher savings, or (e) other factors.

Request IR-9

With respect to Appendix C, page 20, Figure 2, please provide all of the numbers underlying the chart, including eligible demand (GWh), program savings (GWh), and non-program savings (GWh), for each year.

Request IR-10

With respect to Appendix C, page 20, Figure 2, please provide a similar chart presenting the DSM expenditures as a percent of total NSPI revenues. Please provide all of the numbers underlying the chart, including total NSPI revenues and DSM expenditures.

Request IR-11

With respect to Appendix C, page 22, Figure 4, please provide ENSC's views on the alternative ramp-up schedule shown. In particular:

a) Does ENSC believe that the alternative ramp-up schedule is appropriate? If not, why not?
b) Does ENSC believe that the alternative ramp-up schedule is achievable? If not, why not?
c) Does ENSC intend to follow the alternative ramp-up schedule in future years?

Request IR-12

With respect to Appendix C, page 27, paragraph 2, please present a three-year projection of IRP DSM savings targets as an illustration of likely future targets for ENSC, in the same way that this was done for past DSM plans.

Request IR-13

With respect to Appendix C, page 23, Issue C, please provide ENSC's views on the 2008 ACEEE and 2009 EEDAL papers by David Nichols and Kenji Takahashi which indicate that DSM costs per MWh in other jurisdictions have decreased as energy efficiency program budgets increased. For reference, those papers are attached.

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

Kenji Takahashi and David Nichols, Synapse Energy Economics, Inc.

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

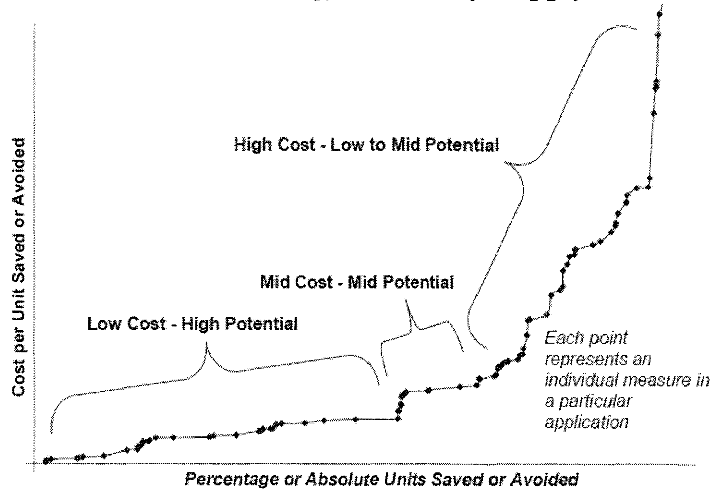
The data summarized above show that utilities or program administrators in varying regions of the country and during varying periods of time have indeed achieved annual incremental levels of energy efficiency savings equal to or in excess of one percent of annual electricity sales. Some have occasionally 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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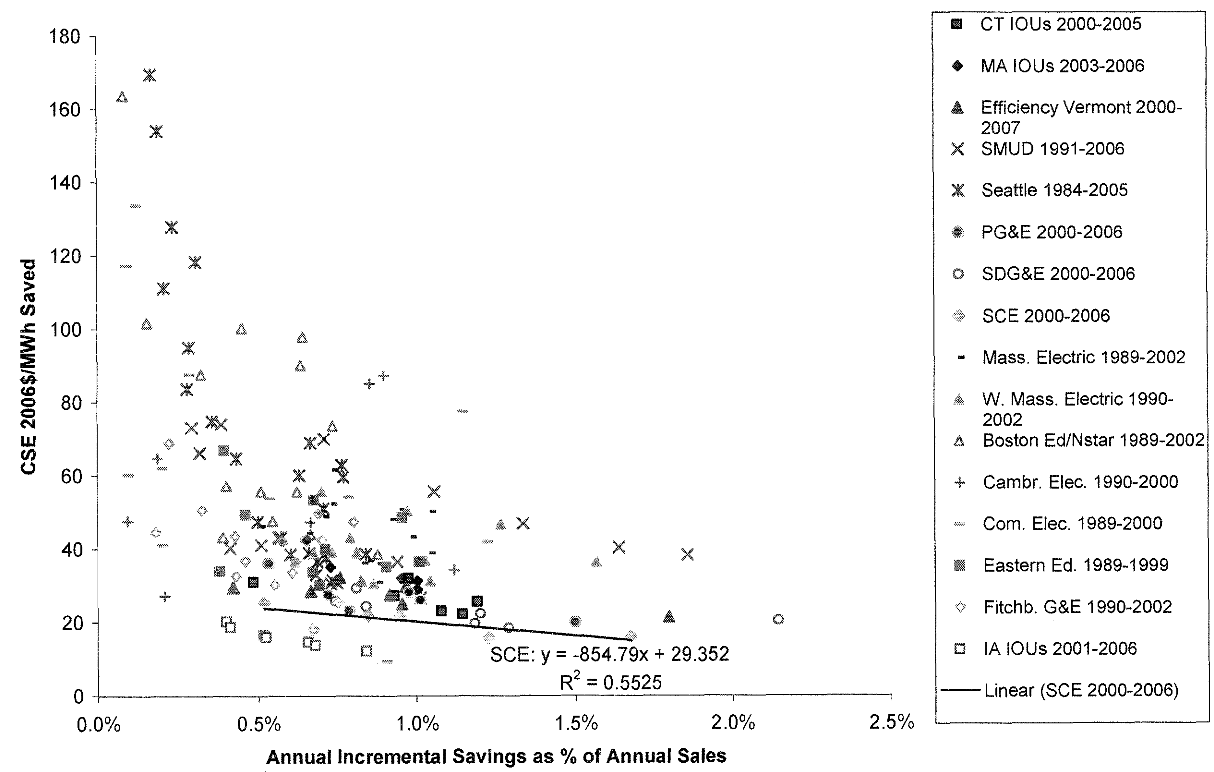
Report Energy Efficiency Savings in the Northeast, January 2006. Also for California's historical practice on M&V, see page 26 of Edward Vine and Jayant Sathaye 1999. *Guidelines for the Monitoring, Evaluation, Reporting, Verification, and Certification of Energy-Efficiency Projects for Climate Change 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.

References

Bender, S., M. Messenger, and C. Rogers. 2005. *Funding and Savings for Energy Efficiency Programs for Program Years 2000 through 2004.* Sacramento, CA: California Energy Commission.

Bernow, S., M. Lazarus, and D. von Hippel. 2002. "Clean Electricity Options for the Pacific Northwest: An Assessment of Efficiency and Renewable Potentials through the Year 2020." Presentation to the NW Energy Coalition, October.

Biewald, B. 2004. "The Shape of Things to Come: Incorporating Unproven Reserves of Efficiency Savings into Energy Models." Presentation to the East Coast Energy Group, Washington, DC. November 10.

[CEC] California Energy Commission. 2008. "Data File for Energy Savings and Program Expenditures for Three Investor Owned Utilities for 2000 to 2005". (Unpublished raw data obtained from Cynthia Rogers in February 2008).

Coito, F., and M. Rufo. 2002. *California's Secret Energy Surplus: the Potential for Energy Efficiency.* Prepared by Xenergy Inc. for the Energy Foundation and Hewlett Foundations. Burlington, Mass.: Xenergy Inc.

[CT ECMB] Connecticut Energy Conservation Management Board. 2007. *Energy Efficiency Investing in Connecticut's Future: Report of the Energy Conservation Management Board Year 2006 Programs and Operations.*
CT ECMB. 2006. *Energy Efficiency Investing in Connecticut's Future: Report of the Energy Conservation Management Board Year 2005 Programs and Operations.*
CT ECMB. 2005. *Energy Efficiency Investing in Connecticut's Future: Report of the Energy Conservation Management Board Year 2004 Programs and Operations.*
CT ECMB. 2004. *Energy Efficiency Investing in Connecticut's Future: Report of the Energy Conservation Management Board Year 2003 Programs and Operations.*
CT ECMB. 2003. *Energy Efficiency Investing in Connecticut's Future: Report of the Energy Conservation Management Board Year 2002 Programs and Operations.*
CT ECMB. 2002. *Report of the Energy Conservation Management Board Year 2000-2001 Programs and Operations.*
CT ECMB. 2001. *Report of the Energy Conservation Management Board Year 2001 Programs and Operations.*

[DOE and EPA] U.S. Department of Energy and U.S. Environmental Protection Agency. 2006. *National Action Plan For Energy Efficiency*. Washington, DC: U.S. Department of Energy and U.S. Environmental Protection Agency.

[DOE] U.S. Department of Energy. Not dated. Energy Information Administration Form EIA-861. Final Data Files, available at http://www.eia.doe.gov/cneaf/electricity/page/eia861.html

Donovan, C., R. N. Elliott, D. Hill, P. Mosenthal, S. Nadel, C. Neme, and J. Plunkett. 2003. *Energy Efficiency and Renewable Energy Resource Development Potential In New York State*. Prepared for the New York State Energy Research and Development Authority. Bristol, Vt.: Optimal Energy, Inc.

Efficiency Vermont. 2004. *2003 Annual Report*. Burlington, Vt.: Efficiency Vermont.

Efficiency Vermont. 2006. *Year 2005 Annual Report and Annual Energy Savings Claim*. Burlington, Vt.: Efficiency Vermont.

Efficiency Vermont. 2007a. *Year 2006 Annual Report and Annual Energy Savings Claim*. Burlington, Vt.: Efficiency Vermont.

Efficiency Vermont. 2007b. *2006 Executive Summary*. Burlington, Vt.: Efficiency Vermont.

Efficiency Vermont. 2008. *Year 2007 Preliminary Results and Savings Estimate Report*. Burlington, Vt.: March 31Efficiency Vermont, 2008.

Garvey, E. 2007. "Minnesota's Demand Efficiency Program." Presentation to the National Action Plan for Energy Efficiency – Midwest Implementation Meeting, Minneapolis, Minn. June 21.

Kushler, M., D. York, and P. Witte. 2005. *Examining the Potential for Energy Efficiency to Help Address the Natural Gas Crisis in the Midwest*: Washington, DC: American Council for an Energy Efficient Economy, 2005.

Massachusetts Department of Telecommunications and Energy. 2003. "Massachusetts Electric Utility Energy Efficiency Database." Unpublished raw data obtained from Gene Fry, June 2007.

Massachusetts Division of Energy Resources. 2008. "Data File for Energy Savings and Program Expenditures for Massachusetts Utilities for 2003 to 2006 (PARIS database)". (Unpublished raw data obtained from Lawrence Masland in February 2008).

[MECo] Massachusetts Electric Company. 2006. *2005 Energy Efficiency Annual Report Revisions.*

[PG&E] Pacific Gas & Electric. 2007. *Energy Efficiency Program Portfolio Annual Report For 2006*

PG&E. 2006. *2006 Annual Earnings Assessment Proceeding Volume III: Energy Efficiency Programs Annual Report for 2005 and Energy Efficiency Programs Annual Report for 2005 Technical Appendix.*

PG&E 2005. *2005 Annual Earnings Assessment Proceeding Volume III: Energy Efficiency Programs Annual Report for 2004 and Energy Efficiency Programs Annual Report for 2004 Technical Appendix.*

Rogers, C. (California Energy Commission). 2008. Personal Communication. February.

[SCE] Southern California Edison. 2007. *2007 Energy Efficiency Annual Report*

SCE. 2006. *2006 Energy Efficiency Annual Report.*

SCE. 2005. *2005 Energy Efficiency Annual Report.*

SCE. 2004. *2004 Energy Efficiency Annual Report.*

SCE. 2003. *2003 Energy Efficiency Annual Report.*

SCE. 2002. *2002 Energy Efficiency Annual Report.*

SCE. 2001. *2001 Energy Efficiency Annual Report.*

[SDG&E] San Diego Gas & Electric. 2007. Energy Efficiency Annual Report 2006 Results.

SDG&E. 2006. *Energy Efficiency Programs Annual Summary and Technical Appendix: 2005 Results.*

SDG&E. 2005. *Energy Efficiency Programs Annual Summary and Technical Appendix: 2004 Results.*

Seattle City Light. Pearson, D. and D. Tachibana, ed. 2006. *Energy Conservation Accomplishments: 1977-2005.* Seattle, Wash.: Seattle City Light.

Sherman, M. and L. Masland. (Massachusetts Division of Energy Resources). 2008. Personal Communication. February.

[SMUD] Sacramento Municipal Utility District. 2007. Data files for energy savings and program expenditures for SMUD. Unpublished raw data obtained from Jim Parks.

The Costs of Increasing Electricity Savings through Utility Efficiency Programs: Evidence from US Experience

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Abstract

Interest in increasing the scale of electric energy efficiency programs is growing in the US. Funded through utility surcharges or tariffs, these programs use information and financial incentives to induce adoption of energy efficiency measures in the buildings and industrial sectors.

One question regarding such energy programs is whether or not they can sustain high levels of savings. We define high savings as incremental reductions in annual electricity sales of one percent or more due to one year's program activities. Data show that some utilities achieved high savings over several years, implying that high levels of savings can be sustained.

Another question is how the unit cost of saved energy (CSE) for programs may change as program scale increases. To address this basic question, we collected data covering program performance from numerous jurisdictions over many years.

Steady-state analysis arranges technologies on a "conservation supply curve" of increasing costs per unit of saved energy. However, CSE for programs may not increase in this way given innovation, economies of scale, and learning curves. To analyze how CSE changed in practice as program scale increased, we investigated program CSE for several programs in different regions. Our statistical analysis finds that program CSE decreased as program scale and impact grew.

This paper updates preliminary results reported at Summer Study of the American Council for an Energy-Efficiency Economy in 2008. In particular, it adds an initial analysis focused on residential programs alone. It also discusses factors which may contribute to decreases in CSE.

Introduction and Background

In the U.S., there are a variety of governmental policies and programs intended to accelerate the acceptance of energy-efficient technologies and practices. Some policies are mandates, while others rely on education and financial incentives to induce voluntary actions. Policies may emanate from the central (Federal) government, state-level government, or jointly. This paper focuses on experience with one particular type of governmental initiative, namely, energy efficiency (EE) programs, also sometimes called energy conservation programs. These EE programs are funded by the ratepayers of electric and gas distribution utilities and are based on state laws and / or regulations. They are often carried out by energy utilities operating under governmental supervision.

EE programs funded by utility ratepayers are intended to increase the productivity with which utility customers use energy. These programs aim to improve the energy efficiency of the stock of buildings and equipment and to improve energy management practices. The programs rely in large part on inducing utility customers to adopt energy efficient equipment, buildings, and practices through financial incentives, as well as research, education, and training. Incentives are directed primarily to customers, but can also be offered to businesses which make, distribute, or install energy-using measures. Financial incentives constitute a major part of the budget of ratepayer-funded EE programs.

Electric EE is often a cost-effective strategy for addressing electricity costs, fossil fuel use, and emissions. Many U.S. states and utilities have given increasing consideration to efficiency measures and have stated an interest in achieving higher levels of energy savings and emission reductions (both greenhouse and criteria pollutants). State governors and legislatures have announced plans to achieve substantial savings, such as 15 or 20 percent savings in projected levels of energy use over several years. Prominent among the means that are being set forth to realize these plans is increased ratepayer-funded energy efficiency. [1]

Despite the accelerating pace of EE program adoption, there are concerns that unprecedented managerial efforts and financial resources are required to achieve significantly increased energy savings through such programs. The analysis of empirical data on EE programs described in this paper is intended to provide useful information to program administrators and policy makers interested in how much energy savings can be realistically achieved through efficiency measures, and at what cost. Utilities and other EE program administrators typically know the costs of their own programs. However, research considering information across sectors, regions, and utilities is sparse. This research seeks to examine the relationship between the costs of and the scale of EE programs for a large number of utilities or third party program administrators over multiple years.

A number of utilities or other administrators have achieved high energy savings over a number of years. The *National Action Plan for Energy Efficiency* states that well-designed energy programs are now "delivering annual energy savings on the order of 1 percent of electricity and natural gas sales." [2] Data summarized by K. Takahashi et al. (2008) show that programs in varying U.S. regions during varying time periods have indeed achieved annual incremental energy savings equal to or in excess of one percent of annual electricity sales.[3] Some programs have saved over two percent of annual energy sales per year.[3] These data themselves provide evidence that incremental annual energy savings of at least one percent of annual sales can be achieved and sustained. But at what cost? In particular, does the relative cost or programs increase as their 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

It is useful to step back and consider the theoretical perspective that the unit cost of saved energy (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.)

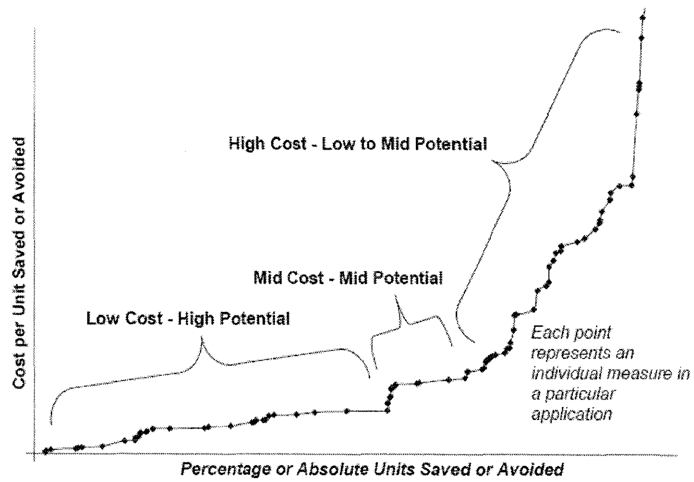

Figure 1. Illustrative Energy-Efficiency Supply Curve

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 planning studies and policy analysis.[4] 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 intuitive and reflects a logical order of prioritization of opportunities (Figure 1).

CSC analysis is certainly useful for comparing the relative costs of EE measures and for understanding the aggregate potential for EE that is available up to any given CSE level. However, CSCs are based on 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."[5] This appears to be a bias against demand-side resources in long-term energy modeling.

A recent study of CSCs that had been prepared for the same region of the U.S. at intervals between 1983 and 2005 found that the assumptions regarding the incremental cost and the potential market penetration of specific residential efficiency technologies changed significantly over time from one CSC analysis to the next. Certain technologies were becoming more available, economical, and applicable over time, even though each successive CSC analysis had no framework for projecting dynamic change in the technologies used to construct it.[6] While this study did not find this "trend" true for all technology inputs it selected for examination, the study does constitutes a recognition that, even within the conceptual framework of the CSC, the static nature of assumptions about technologies is a limitation.

Additionally, CSC analysis can lead to an assumption that EE *programs* must mimic the CSC curve, such that the greater their amount of savings, the greater their program cost.[1] 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[2] 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.

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[1] This assumption can be found in studies of the achievable potential for energy efficiency in various regions as conducted by research firms. As one example, the "New Jersey Energy Efficiency and Distributed Generation Market Assessment" prepared by KEMA, Inc., for this U.S. state in 2004 projected that for its higher "Advanced Efficiency" scenario, incentives to EE program participants would have to rise from 40- 50% of incremental measure costs to 80% (page 2-6)."

[2] 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, we found that the data for actual energy efficiency programs do tell a different story from that which might be inferred from CSCs. These programs generally include a range of measures, ranging from zero (or even negative net cost) per kWh saved up to (and occasionally exceeding) avoided costs. The overall cost per kWh saved for a utility program in a given year turns out to be lower in the more ambitious years. This could be because fixed program costs can be spread 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 market sector, including the low-income, residential, and commercial and industrial sectors. The overall CSE for a program is always the weighted average cost of saved energy through a portfolio of various measures.

As noted above, CSC analysis seldom addresses economies of scale. Theoretically, a program administrator can enjoy economies of scale by expanding its operation of EE programs. For example, a large program may allow for bulk purchase of certain efficiency measures at a lower price or for bulk discounts for contracts with energy service companies to deliver energy savings. Further, larger programs may be able to allocate the cost of marketing and administration over a greater amount of energy savings, tending to reduce program cost per kWh saved as program scale increases. Similarly, marketing and customer education will increase customers' adoption of new technologies, which in turn can accelerate the mass production of such technologies and thus reduce unit price over time. Furthermore, greater scope of programs could reduce marketing expense or provide synergistic savings.[3]

Analysis of Historical Trends in Program CSE

Data and Methods:

We analyzed several comprehensive EE programs in varying regions in order to explore the empirical relationship between program CSE and program scale for all sectors (residential, commercial, and industrial, or "RCI") combined as well as for the residential sector alone. Data from over 160 cases (years and regions or utilities) were collected on expenditures, costs, and savings associated with efficiency programs.[4] This analysis focused on utilities or other entities with comprehensive electric energy efficiency programs. Data were obtained either from utility efficiency annual reports or directly from program administrators or staff at state energy offices or regulatory commissions.

There are important caveats and uncertainties associated with the collected data. In particular, data on achieved energy savings are derived from reports by program administrators and/or regulators, and are inherently less certain than data on costs. Regular impact evaluation activities to verify savings estimates have been conducted by virtually all entities pursuing comprehensive energy efficiency programs on a sustained basis;[5] nevertheless, there is still uncertainty when quantifying exact savings. Quality of savings estimation and verification may, in fact, vary between jurisdictions, but this variability is unlikely to impact this analysis. Indeed, our analysis focuses on trends and behavior within utilities and jurisdictions, which are likely to have internally consistent measures and metrics. Trends observed across utilities are of interest, but not explored in this analysis.

Utility reports on savings did not consistently report a consistent metric of savings. Reports sometimes contained both first year and lifetime savings, and others reported only first year savings. Where lifetime savings were not available, we estimated lifetime savings based on the average lifetime of efficiency

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[3] 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.

[4] All of the references used for this analysis are presented at the end of this paper.

[5] 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 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 1999. Lawrence Berkeley National Laboratory.

measures. Where specific programs were described, EE lifespan data for analogous programs were utilized. Where no lifetime savings data were available for a specific program, we used a 12-year average EE lifetime that has been recognized as an industry rule of thumb estimate.[6] [7] When available information indicated that savings had been measured at the customer level, we adjusted savings to the generation level by accounting for transmission and distribution line loss.

Generally, first-year savings are estimated with greater certainty because first year savings are often measured and verified, while lifetime savings are projected. Although lifetime savings projections are usually based on empirical data concerning measure life, there are uncertainties concerning actual measure lifetimes as well as energy savings performance over time.

A levelized CSE was estimated using 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)

In this analysis, we used a discount rate of four percent, following Bender et al. (2005) [8]

We considered the use of program cost per lifetime energy (MWh) savings versus the use of program cost per first year savings. However, the cost of first year energy savings ignores the fact that measure lives vary considerably among different types of technologies. Therefore, we chose a levelized cost of energy efficiency as a normalized value over the lifetime energy savings, a measure that is comparable to the cost of power generation.

Program CSE measured against annual incremental savings (as a percentage of annual retail sales) is a measure of the relative aggressiveness of each program, and may indicate economies of scale at work (i.e., reductions in unit cost as the scale of programs increases).. Substantial absolute energy savings do not necessarily mean a utility is aggressively pursuing efficiency if such savings are small relative to 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, administration and measurement and verification costs over larger 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 programs grows.

This analysis seeks to determine if the cost of saved energy changes with the size of the EE program in terms of savings relative to annual sales and of projected lifetime savings. We analyzed these data to compare lifetime CSE per MWh (defined as the levelized cost of energy savings) for a given delivery entity and year of program delivery with annual energy savings as a percentage of sales for that entity and year. We also compared lifetime CSE with the absolute quantity of projected lifetime energy savings. For these comparisons, we created linear trend lines to all datasets and identified slopes (coefficients) and r-squared values for those lines.

Results:
Figure 2 presents a comparison between utility levelized CSE in real 2006$ per MWh saved and annual incremental savings as a percentage of annual sales. Figure 2 includes the trend line for SCE as an example. Table 1 presents the slope coefficient and R^2 values for all data sets in Figure 2 (CSE vs. first-year savings). Trend lines were created to examine the behavior of the data and do not represent a best

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

fit or idealized parameterization of the data. Trend lines comparing CSE to lifetime savings are presented in Table 2.

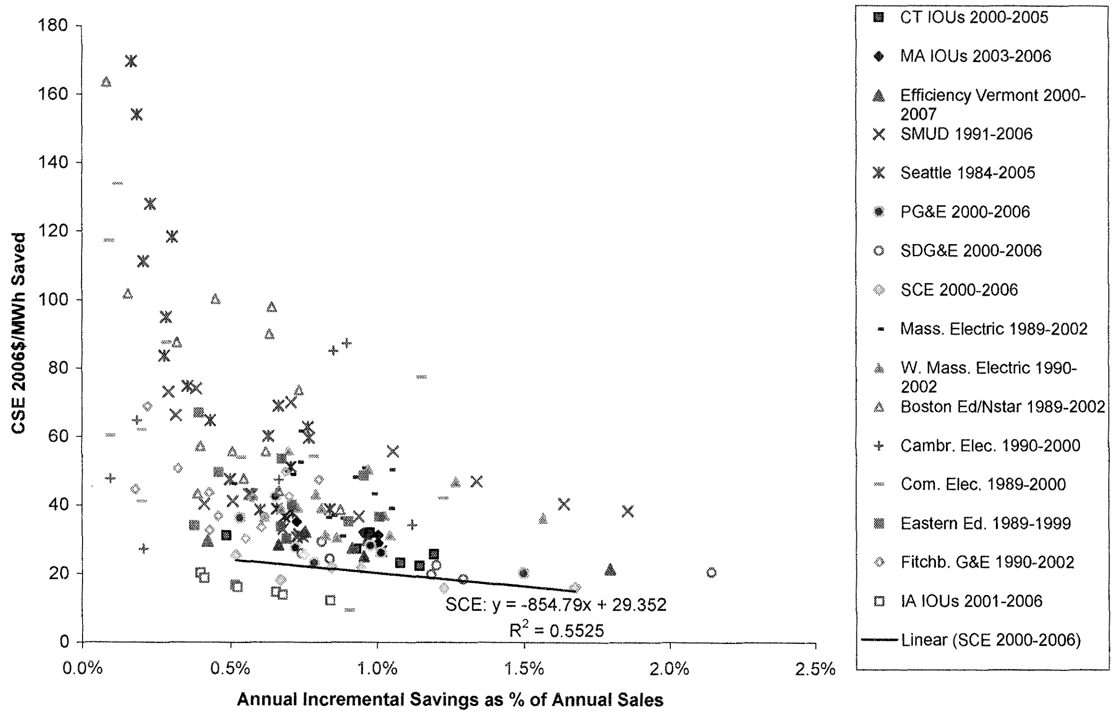

Figure 2. Utility Cost of Saved Energy (2006$/MWh) vs. Incremental Annual Savings as Percentage of Sales

Table 1. Slope of Regression of Utility Cost of Saved Energy vs. Incremental Annual Savings as Percentage of Sales.

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 2. Slope of Regression of Utility Cost of Saved Energy 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

Most recently, we conducted similar analysis on residential EE programs alone. Due to limited availability of sector-specific data, at this writing we had collected data on 9 utilities and one pair of utilities.[7,8] We disaggregated the data for MA IOUs presented in Figure 2 into five program administrators.[9] Figure 3 compares utility levelized CSE in real 2006$ per MWh saved with first year savings as a percentage of sales. We generated linear trend lines to all datasets and identified slopes and R^2 values for those lines. Figure 3 includes the trend line for SCE as an example. Table 3 presents the coefficients and R^2 values for all data sets in Figure 3. We also drew linear trend lines for to compare CSE with lifetime energy savings. Table 4 presents the coefficient and R^2 values for all data sets for this analysis.

[7] Note that residential programs for California utilities (i.e., SCE, PG&E, and SDG&E) do not include new construction programs.
[8] All of the references used for this analysis are presented at the end of this paper.
[9] Due to confidentiality requirements of the MA PARIS database we obtained, Massachusetts programs are not named.

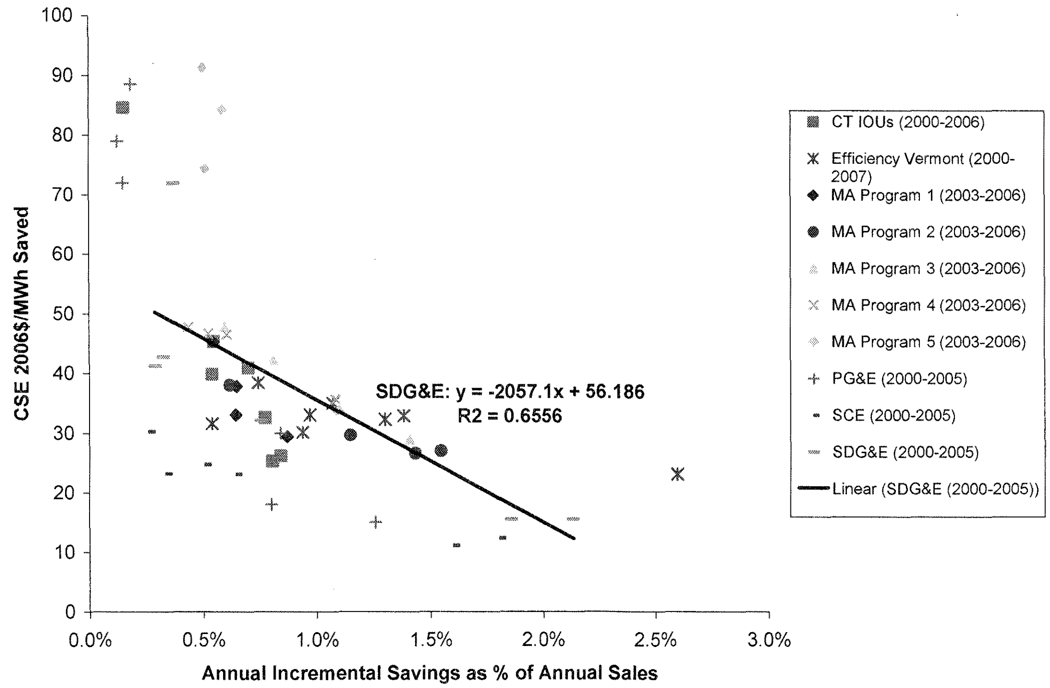

Figure 3 Utility CSE vs. Incremental Annual Savings – Residential Programs

Table 3. Slope Coefficient and R-Squared Values for Linear Trend Lines for Figure 3.

Data	**Coefficient**	**R-square**
CT IOUs (2000-2006)	-8147.58	0.939
Efficiency Vermont (2000-2007)	-538.88	0.602
MA Program 1 (2003-2006)	-4324.49	0.760
MA Program 2 (2003-2006)	-1247.21	0.959
MA Program 3 (2003-2006)	-2361.93	0.987
MA Program 4 (2003-2006)	-1936.09	0.976
MA Program 5 (2003-2006)	-8704.63	0.911
PG&E (2000-2005)	-6573.83	0.892
SCE (2000-2005)	-1069.56	0.910
SDG&E (2000-2005)	-2057.12	0.656

Table 4. Slope Coefficient and R-Squared Values for Linear Trend Lines for Residential Program CSE vs. Projected Lifetime Savings

Data	Coefficient	R-square
CT IOUs (2000-2006)	-6.18E-05	0.684
Efficiency Vermont (2000-2007)	-4.14E-05	0.577
MA Program 1 (2003-2006)	-1.23E-04	0.499
MA Program 2 (2003-2006)	-2.73E-05	0.860
MA Program 3 (2003-2006)	-6.55E-05	0.939
MA Program 4 (2003-2006)	-1.86E-04	0.821
MA Program 5 (2003-2006)	-3.88E-03	0.904
PG&E (2000-2005)	-2.39E-05	0.884
SCE (2000-2005)	-3.76E-06	0.894
SDG&E (2000-2005)	-3.17E-05	0.646

A key result of the analysis for both comprehensive RCI programs and residential programs is that, while R^2 values are low in some cases, among all datasets that we collected, all slope coefficients of the linear trend lines are negative. The data strongly suggest that per-unit cost of EE decreases as the amount of EE savings increases.

We also found the following:

- 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.
- Declining trend curves were observed regardless of the size of the utilities or program administrators. Annual retail electricity sales range from about 500 GWh to close to 90,000 GWh. About half of the entities analyzed have less than 10,000 GWh of annual retail sales. Even small utilities experienced decreasing CSE when they expanded their programs.
- Finally, looking at the results of the analysis for the same utilities for the entire sector and the residential sector alone, residential programs generally show higher correlation. This implies that the programs for the other sectors (C&I) are likely to show lower correlation between CSE and savings. In other words, economies of scale may be more effective for residential programs.

We recognize that the data and analysis presented here are preliminary. They do not yet include quantitative analysis of 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

This study find that the relationship between the CSE and energy efficiency savings for ratepayer funded EE programs is broadly negative (i.e. costs decrease as program sizes increase). It is important to emphasize that this finding contradicts the generally accepted theory that costs of EE increase when EE savings amounts increase.[10] The fact that the coefficient is negative in every case is particularly striking. While it is possible 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.

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

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 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 for all sectors (RCI) as well as the residential sector alone. Our overall finding 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.

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. This trend was generally even stronger in the analysis of residential programs alone.

Another aspect of this analysis compared each utility's program CSE to annual incremental savings as percent of sales. For every program analyzed regardless of the size of utilities or program administrators, we found a trend of decreasing utility CSE as the relative quantity of EE savings increased. Again, this trend was generally even stronger in the analysis of residential programs alone.

We further found that variation of CSE for a given utility generally decreases as the amount of efficiency savings increases. We also observed that every case.

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

- Adding data for additional utilities and regions to the analysis.
- Further investigation of CSE by type of measure, program or sector (e.g. residential versus non-residential and the impact of compact fluorescent light).
- 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.

Works Cited

[1] [ACEEE] American Council for Energy Efficient Economy 2008. The 2008 State Energy Efficiency Scorecard, Washington, DC.: ACEEE

[2] [DOE and EPA] U.S. Department of Energy and U.S. Environmental Protection Agency. 2006. *National Action Plan For Energy Efficiency*. Washington, DC: U.S. Department of Energy and U.S. Environmental Protection Agency. DOE and EPA 2006, ES-4

[3] K. Takahashi and D. Nichols 2008. *The Sustainability and Costs of Increasing Efficiency Impacts: Evidence from Experience to Date*, proceedings of the 2008 ACEEE Summer Study on Energy Efficiency in Buildings, ACEEE, pp. 8-363 - 8-375.

[4] Bernow, S., M. Lazarus, and D. von Hippel. 2002. *Clean Electricity Options for the Pacific Northwest: An Assessment of Efficiency and Renewable Potentials through the Year 2020*. Presentation to the NW Energy Coalition, October. Bernow 2002; Coito & Rufo 2002; Donovan et al. 2003

[5] Biewald, B. 2004. *The Shape of Things to Come: Incorporating Unproven Reserves of Efficiency Savings into Energy Models.* Presentation to the East Coast Energy Group, Washington, DC. November 10.

[6] Gordon, F., Garth, L., Eckman, T., and Grist, C. 2008. *Beyond Supply Curves*, the 2008 Summer Study on Energy Efficiency in Buildings, ACEEE, pp. 8-98 - 8-109.])

[7] [DOE and EPA] U.S. Department of Energy and U.S. Environmental Protection Agency. 2006. National Action Plan For Energy Efficiency. Washington, DC: U.S. Department of Energy and U.S. Environmental Protection Agency; Kushler, M., D. York, and P. Witte. 2005. *Examining the Potential for Energy Efficiency to Help Address the Natural Gas Crisis in the Midwest*: Washington, DC: American Council for an Energy Efficient Economy, 2005..

[8] Bender, S., M. Messenger, and C. Rogers. 2005. *Funding and Savings for Energy Efficiency Programs for Program Years 2000 through 2004*. Sacramento, CA: California Energy Commission.

References used for Figure 2 and 3 and Table 1 - 4.

[9] [CEC] California Energy Commission. 2008. *Data File for Energy Savings and Program Expenditures for Three Investor Owned Utilities for 2000 to 2005.* (Unpublished raw data obtained from Cynthia Rogers in February 2008).

[10] [CT ECMB] Connecticut Energy Conservation Management Board. 2007. *Report of the Energy Conservation Management Board Year 2006 Programs and Operations.*
CT ECMB. 2006. *Report of the Energy Conservation Management Board Year 2005 Programs and Operations.*
CT ECMB. 2005. *Report of the Energy Conservation Management Board Year 2004 Programs and Operations.*
CT ECMB. 2004. *Report of the Energy Conservation Management Board Year 2003 Programs and Operations.*
CT ECMB. 2003. *Report of the Energy Conservation Management Board Year 2002 Programs and Operations.*
CT ECMB. 2002. *Report of the Energy Conservation Management Board Year 2000-2001 Programs and Operations.*
CT ECMB. 2001. *Report of the Energy Conservation Management Board Year 2001 Programs and Operations.*

[11] [DOE] U.S. Department of Energy. Not dated. *Energy Information Administration Form EIA-861.*
Final Data Files, available at http://www.eia.doe.gov/cneaf/electricity/page/eia861.html

[12] [MECo] Massachusetts Electric Company. 2006. *2005 Energy Efficiency Annual Report Revisions.*

[13] [PG&E] Pacific Gas & Electric. 2007. *Energy Efficiency Program Portfolio Annual Report For 2006*
PG&E. 2006. *Energy Efficiency Programs Annual Report for 2005*
PG&E 2005. *Energy Efficiency Programs Annual Report for 2004.*

[14] [SCE] Southern California Edison. 2007. *2007 Energy Efficiency Annual Report*
SCE. 2006. *2006 Energy Efficiency Annual Report.*
SCE. 2005. *2005 Energy Efficiency Annual Report.*
SCE. 2004. *2004 Energy Efficiency Annual Report.*
SCE. 2003. *2003 Energy Efficiency Annual Report.*
SCE. 2002. *2002 Energy Efficiency Annual Report.*
SCE. 2001. *2001 Energy Efficiency Annual Report.*

[15] [SDG&E] San Diego Gas & Electric. 2007. *Energy Efficiency Annual Report 2006 Results.*
SDG&E. 2006. *Energy Efficiency Programs Annual Summary and Technical Appendix*
SDG&E. 2005. *Energy Efficiency Programs Annual Summary and Technical Appendix*

[16] [SMUD] Sacramento Municipal Utility District. 2007. *Data files for energy savings and program expenditures for SMUD.* Unpublished raw data obtained from Jim Parks.

[17] Coito, F., and M. Rufo. 2002. *California's Secret Energy Surplus: the Potential for Energy Efficiency.* Prepared by Xenergy Inc. for the Energy Foundation and Hewlett Foundations. Burlington, Mass.: Xenergy Inc.

[18] Donovan, C., R. N. Elliott, D. Hill, P. Mosenthal, S. Nadel, C. Neme, and J. Plunkett. 2003. *Energy Efficiency and Renewable Energy Resource Development Potential In New York State.* Prepared for the New York State Energy Research and Development Authority. Bristol, Vt.: Optimal Energy, Inc.

[19] Efficiency Vermont. 2004. *Year 2003 Annual Report and Annual Energy Savings Claim.*
Efficiency Vermont. 2005. *Year 2004 Annual Report and Annual Energy Savings Claim.*
Efficiency Vermont. 2006. *Year 2005 Annual Report and Annual Energy Savings Claim.*
Efficiency Vermont. 2007. *Year 2006 Annual Report and Annual Energy Savings Claim.*
Efficiency Vermont 2008. *Year 2007 Annual Report.*
Efficiency Vermont. 2009. *Data files for energy savings and program expenditures for Efficiency Vermont.* (Unpublished raw data obtained from Huessy, F.)

[20] Garvey, E. 2007. *Minnesota's Demand Efficiency Program.* Presentation to the National Action Plan for Energy Efficiency – Midwest Implementation Meeting, Minneapolis, Minn. June 21.

[21] Massachusetts Department of Telecommunications and Energy. 2003. *Massachusetts Electric Utility Energy Efficiency Database.* Unpublished raw data obtained from Gene Fry, June 2007.

[22] Massachusetts Division of Energy Resources. 2008. *Data File for Energy Savings and Program Expenditures for Massachusetts Utilities for 2003 to 2006 (PARIS database).* (Unpublished raw data obtained from Lawrence Masland in February 2008).

[23] Rogers, C. (California Energy Commission). 2008. *Personal Communication.* February.

[24] Seattle City Light. Pearson, D. and D. Tachibana, ed. 2006. *Energy Conservation Accomplishments: 1977-2005.* Seattle, Wash.: Seattle City Light.

[25] Sherman, M. and L. Masland. (Massachusetts Division of Energy Resources). 2008. *Personal Communication.* February.