LONG-TERM ENERGY SAVINGS IN A COMMERCIAL EFFICIENCY PROGRAM

Brian Coates
Seattle City Light

Patrick Lilly
Regional Economic Research

Abstract

An evaluation was conducted on the long-term energy savings and status of the conservation measures installed through a commercial efficiency program. Site visits on measure status were conducted at 94 buildings four years following measure installation. Sixteen percent of the measures had been changed, with more of them being changed to equal or more efficient measures. At the time of the visits, 93% of the measures currently installed were energy efficient. A Statistically Adjusted Engineering model was used to assess the program's energy savings one, two, and three years following measure installation in 1992. Overall, energy savings per project were 74 annual megawatt-hours, 88% of the engineering savings estimates. There was considerable persistence in the savings, as savings over the three years were 77, 72, and 75 annual megawatt-hours. Four lessons learned from the evaluation are presented in the paper's conclusions section.

Introduction

Program Description

Seattle City Light has operated the Energy Smart Design Program (ESDP) since 1988, with the Bonneville Power Administration providing program financing from 1988 to 1996. In the initial program years, City Light offered technical and financial assistance to commercial building owners and developers for designing new and remodeled buildings. The conservation measures identified in these designs, although not available for utility financial assistance, could be installed by the building owners.

Beginning in 1991, the Energy Smart Design Program was expanded to include financial incentives for installing energy conservation measures in new, remodeled, and existing commercial buildings. Under the current program design, two types of incentives are offered to customers for installing conservation measures in their buildings. Standard incentives are available for lighting and motor measures and for the heating, ventilating, and air conditioning system. Customers can also participate in the Custom Incentive options for building envelope measures, energy management control systems, and other measures not funded in the Standard Incentives option.

Evaluation Purposes

The long-term success of energy efficiency programs for commercial customers is dependent in part on utilities/energy service providers and the customers having accurate information on the energy savings to be expected from the measures, the incentive being offered by the utility for participating in the program, and the lifetime of the efficiency equipment being installed in the buildings. Once accurate information has been assembled on savings, the program incentive, and the measure lifetime, the customer can decide whether it is cost-effective for them to participate in the program.

Earlier evaluations have typically focused on a one-time follow-up of the energy savings after the measures have been installed in the buildings. This one-time follow-up can miss important changes in subsequent years (i.e., remodeling, installation of additional efficiency measures) which can affect both measure lifetimes and programmatic energy savings (Keating, 1991; Vine, 1992). Given the importance of changes from first year savings to the savings obtained in later years for program cost-effectiveness, load forecasting, and the lifetime of conservation measures, one purpose of the current evaluation was to examine the persistence of energy savings over a three-year period for 1992 ESD program participants. Savings assessment was done through a billing analysis in which changes in participant's electrical consumption over time are compared to the changes in consumption for a group of nonparticipants.

Energy savings for ESDP participants are based on the installation and maintenance of energy conservation measures in commercial buildings. Given that conservation measures can be removed, replaced with more (or less) efficient measures, or disabled, it is important to verify that persistence of energy savings is based on installed energy efficient measures. Given this importance, a second purpose of the evaluation was to conduct site visits on the current status of the conservation measures in participants' buildings.

As described in greater detail in the Method section, site visits were conducted for all but a few of the buildings that were in the energy savings analysis. During these visits, observations were conducted to determine whether the conservation measures were still operating in the buildings. For those measures that had been modified, site personnel were asked a series of questions on what happen to the measures and the reasons for the changes. For those measures replaced with new equipment, observations were conducted to determine the type of new equipment installed.

Energy Conservation Measures

Method

The site visits[a] for the energy conservation measures were conducted at 94 buildings that participated in the Energy Smart Design Program during 1992. A stratified sample based on conservation measure type and building type was drawn from the 1992 participants. The main objective of the site visits was to determine the extent to which 286 measure groups (e.g., T-8 fluorescent fixtures, heat pumps) were still installed and operating correctly. A secondary purpose was to determine where changes had been made to the funded measures, and to understand the efficiency-related impacts and the reasons that such changes were made by the program participants.

To fulfill these objectives, a four-step procedure was used in the on-site verification of the conservation measures. The four steps were: (1) meeting with the site contact to review/update building characteristics and contact information, (2) perform a walk-through of the facility and verify the existence and operability of ESDP funded efficiency equipment, (3) ask follow-up questions where appropriate on the status of replaced/inoperable measures funded by ESDP and the reasons for the replacement, and (4) document all site-verified data.

[a] Unicade Inc., Bellevue, Washington, performed the site visits.

Table 1

Status of Conservation Measures by Measure Type

Measure Type/ (Number)	**% Measures Changed**	**% Currently Efficient**	**% Currently Inefficient**
HVAC (24)	0%	100%	0%
Fluorescent Lamps (35)	29	91	9
Compact Fluorescents (89)	23	88	12
Fluorescent Fixtures (77)	10	94	6
High Intensity Discharge (56)	14	96	4
Other Lighting (5)	0	100	0
Total (286)	16%	93%	7%

Results

The results of the 94 site visits clearly indicate that changes have been made to the original equipment installed under the program in 1991-92. As summarized in Table 1, four of the six efficiency measure categories experienced measure changes in excess of the 10 percent level. Note that fluorescent lamp retrofits and compact fluorescent lamp conversions both exceeded the 20 percent change-out level. HVAC and other lighting measure categories reported no change-out in measures over the four-year period.

It is also evident from the data, however, that more of the changes made by the participants were at least as/or more efficient than the ESDP measures that were replaced. Over all measure categories an average of 93 percent of the changed measures were considered currently efficient, while only 7 percent were considered inefficient relative to the originally installed measures.

Not surprisingly, the greatest changeover occurred in the fluorescent lamp and compact fluorescent lamp/fixture categories, where lamp failure provided the participant an opportunity to replace the lamps and/or fixtures with other lamps. In at least one case, lower lighting intensity levels were the driving motivation for the change out of the measure. It is worth noting that compact fluorescent and fluorescent lamps experienced the highest rates of currently inefficient equipment, at 12% and 9% respectively. The primary reason for reported measure changes of high intensity discharge fixtures was lamp burnout over the four to five year period. In all cases except one, the lamps were replaced with equal (or greater) efficiency lamp products. There were no changes found to either the HVAC or lighting controls equipment installed under the 1992 program.

During the on-site measure verification process, participants were queried on the reasons for any equipment changes. These participant change-out responses were categorized into two groups: (1) efficiency measure related reasons, and (2) customer related reasons. Table 2 summarizes these responses by these two general categories and by those instances in which the measure was removed, replaced with a less efficient measure, or replaced with an equal or more efficient measure.

Clearly the majority of the equipment changes (80%) are for customer-related issues, including in the order of response: the need for additional lighting, facility remodeling, relamping, lack of interest, no reason provided, and measure cost. Measure-related reasons included measure failure, lamp burnout, and the lamp no longer being produced. In the cases where additional light was required, there was a slight preference for less efficient equipment which is likely tied to ease of replacement (e.g., incandescent for compact fluorescent screw-ins). In the few cases where the measure failed, there was a clear preference for equal or more efficient measure replacement.

The field verification of the 286 measure groups at 94 facilities clearly demonstrates that the vast majority of the ESDP funded measures are still present and reported as operating efficiently.   Where equipment changes have occurred, it has primarily been due to customer related reasons and not the efficiency equipment life (i.e., ballast/fixture life for lighting measures) or poor performance. The data suggests that a small amount of reversion back to pre-program efficiencies has occurred in the sample of 1992 participants. In the relatively few instances where changes have occurred, the program participants have installed a greater percentage of equal or greater efficiency equipment when replacing failed lighting equipment.

Energy Savings

Method

Annual electrical consumption was collected for participants and a group of nonparticipants during 1991, the year prior to the installation of the conservation measures, and for three years, 1993 through 1995, following measure installation. Energy savings were initially estimated in each of the post-program years by comparing the pre- to post-program change for participants with the consumption change for nonparticipants. Energy savings for each of the post-program years were also obtained through multiple regression models which not only compared the pre- to post-program consumption change for participants and nonparticipants, but also incorporated several adjustments for weather changes and for building changes in 22 outlier buildings. The energy savings analyses are described further below.

There were 102 ESDP participants and 174 nonparticipants in the study. The participants had been chosen from 1992 ESDP participants who were not included in the Northwest Commercial Evaluation Project study on 1991 and 1992 ESDP participants (Xenergy et al., 1996a) and had usable energy consumption data during four years, 1991 and 1993-1995. Although the buildings had not been in the Xenergy et al. study, they were similar to the buildings used in that study. This similarity was due to the Xenergy et al. study using a stratified random sample to obtain participant buildings. Stratification factors were commercial sector building type and the type of conservation measures installed in the buildings.

Table 2

Reasons for Changing Conservation Measures

Reason for Change	Removed and Never Replaced?	Replaced with Less Efficient Measure?	Replaced with Equal or More Efficient Measure?
Measure Related :			
Bulb no longer produced			1
Burned out			3
Measure failed		1	4
Customer Related :			
Cost		3	
Didn't like light		1	
Inefficient bulbs in storage		2	
Lack of interest		4	
Less light needed		1	
More light needed		5	3
No reason given		1	3
Preferred more efficiency		1	1
Relamping			4
Remodeling	2		4
Seattle City Light change	1		1
Total	3	19	24

The nonparticipants were also originally chosen to be part of the Northwest Commercial Evaluation Project study on energy savings for 1991 and 1992 ESDP participants (Xenergy et al., 1996a). To increase the comparability between the participant and nonparticipant groups on factors related to energy consumption, nonparticipants had to meet several criteria before they could be included in the study. These criteria included being in the same commercial sector as the participants (e.g., offices) and, for that sector only, having pre-program electrical consumption that was within the range of consumption for program participants. When these criteria were applied to 221 buildings in the nonparticipant group, 47 nonparticipants were removed from the study, leaving 174 buildings in the nonparticipant sample.

Following the selection of the participant and nonparticipant groups, 22 buildings with unusually high increases (or decreases) in annual energy consumption were identified in the sample. The buildings were identified with an annual energy consumption divergence index, which related the difference between the ESDP's engineering savings estimates and unadjusted energy savings to the pre-program energy consumption. The unexplained changes in year-to-year consumption required that additional information be collected for the 22 buildings to better understand and statistically model the program impacts across the three post-program years. This information included building characteristics and end-use equipment that could help explain the energy consumption changes. Once the information was collected, it was used to estimate the load impacts from the consumption changes. The impacts were then incorporated into the models for estimating the programmatic energy savings.

Three analytic methods were used in estimating the energy savings for 1992 program participants from the 1991 and 1993-1995 electrical consumption data. In the first method, Comparison of Means, net energy savings for program participants were calculated for each of the three post-program years by subtracting the mean change score (pre-program consumption minus post-program consumption) for nonparticipants from the corresponding change score for program participants. In this analysis, the nonparticipants are a proxy for the savings that participants would have achieved on their own if they had not participated in an energy conservation program.

In the second method, the Program Participation model, a regression analysis was done on the energy consumption for program participants and nonparticipants. Energy savings for each of the post-program years were estimated by interacting a program participation binary variable in each year with the pre-program energy consumption in 1991. Additional control of nonprogram factors was obtained by including in the analysis weather changes and load impacts for the outlier buildings.

In the third method, the Statistically Adjusted Engineering (SAE) model, regression analyses were done on the annual electricity consumption for program participants and nonparticipants. In the first of two SAE model variations, the annual electricity consumption for program participants and nonparticipants was not weather adjusted. Variables in the analysis included pre-program electrical consumption in 1991, the load impacts for the 22 outlier buildings, and variables for identifying the participants' energy savings in each of the post-program years. The savings variables consisted of the interaction of the engineering energy savings for program participants and nonparticipants with a binary (0,1) participation variable in each post-program year. With this approach, savings in the post-program years were calculated by simply multiplying the coefficient for the savings variable in a given year by the engineering energy savings for participants.

The second SAE model differed from the first in that a series of weather adjustment variables were included in the model. Weather changes over the 1991 through 1995 period were controlled by interacting both heating and cooling degree day change scores with several variables: pre-program energy consumption for program participants and nonparticipants, outlier load impacts, and the projected energy savings for 10 buildings which had HVAC measures installed through the ESDP. For

Table 3

Mean Annual Megawatt-hour Consumption by Group and Year

Group	1991	1993	1994	1995
Participants (N=102)	1,936	1,823	1,862	1,817
Nonparticipants (N=174)	1,396	1,385	1,416	1,379

program participants only, the interactions of pre-program consumption and heating and cooling degree-days took into account whether the customer had electric heat and/or cooling.

Results

Table 3 presents the mean annual megawatt-hour consumption for program participants and nonparticipants during the pre-program year, 1991, and three post-program years, 1993 through 1995. This electrical consumption has been not been adjusted for weather changes over the four year time period. As shown in the table, buildings with conservation measures installed through the ESDP showed a substantial decline in energy consumption from the pre-program year to the first post-program year, 1993. This decline in electrical consumption was maintained during the subsequent two post-program years. In contrast to the decline for program participants, electrical consumption for nonparticipants remained steady from the pre-program year to each of the post-program year. Consumption for nonparticipants in each of the post-program years was within 1.5% of the pre-program consumption.

In the Comparison of Means analysis, participant energy savings in each of the post-program years were calculated by subtracting their pre- to post-program change score from the corresponding change score for nonparticipants. For example, 1993 savings were calculated as: (1,936 mWh - 1,823 mWh) - (1,396 mWh - 1,385 mWh). As shown in Table 4, the mean savings for participants during 1993 were 102 annual megawatt-hours. The savings were maintained during the subsequent two post-program years, with the annual savings being 95 megawatt-hours in 1994 and 102 megawatt-hours in 1995. Thus, at least on the Comparison of Means approach, there was considerable persistence in the energy savings for 1992 participants in the EMSD program.

Table 4 also shows that the participants' energy savings ranged from 4.9% to 5.2% of their pre-program energy consumption, and were somewhat above the projected energy savings of 85 annual megawatt-hours. Table 5 presents the savings realization rate for each of the post-program years. As shown in the table, the participants' savings were 112% to 120% of the projected energy savings. The average realization rate across the post-program years was 117%.

The purpose of the second analysis was to estimate a weather adjusted, Program Participation model in each of the three post-program years. The overall model fit was excellent, adjusted R square = .975, but the energy savings coefficients varied considerably across the post-program years. These savings coefficients, which are interpreted as the percent saved per pre-program megawatt-hour, were 2.4% in 1993, rose to 4.1% in 1994, and increased sharply to 8.0% in 1995. As shown in Table 4, the savings estimates ranged from 47 annual megawatt-hours in 1993 to 155 megawatt-hours in 1995. The

Table 4

Mean Annual Megawatt-hour Energy Savings for
Program Participants by Savings Method and Year

Savings Method	**1993**	**1994**	**1995**	**All Years**
Comparison of Means	102	95	102	100
% of pre-program	5.1%	5.2%	4.9%	5.1%
Program Participation (weather adjusted)	47	79	155	94
% of pre-program	2.4%	4.1%	8.0%	4.9%
Statistically Adjusted Engineering	77	60	73	71
% of pre-program	4.0%	3.3%	3.8%	3.8%
Statistically Adjusted Engineering (weather adjusted)	77	72	75	74
% of pre-program	4.0%	3.7%	3.9%	3.7%

realization rates for the savings also varied widely, ranging from 55% in 1993 to 155% in 1995 (Table 5).

Two variations of Statistically Adjusted Engineering multiple regression analyses were performed on the 1991 and 1993-1995 electrical consumption for program participants and nonparticipants**.** The purpose of the first variation was to estimate the non-weather adjusted energy savings for program participants in each of the three post-program years. The overall model fit was excellent, adjusted R square = .975, and there were large and statistically significant energy savings for program participants. The non-weather adjusted savings for participants ranged from 60 to 77 megawatt-hours, with the average savings across the three years being 71 megawatt-hours (Table 4).

The purpose of the second variation for the Statistically Adjusted Engineering regression analysis was also to estimate the energy savings for program participants in each of the three post-program years. In this instance, however, several variables were incorporated into the analysis to weather adjust both the participants' and nonparticipants' electrical consumption and the projected savings for 10 buildings in which weather-sensitive HVAC measures were installed. The results of this analysis, revealed an excellent model fit, adjusted R square = .977, and statistically significant savings in each of the post-program years. The SAE coefficient was .91 in the initial post-program year, 1993, declined slightly to .85 in the second year, 1994, and then increased slightly to .88 in 1995. These coefficients are again

Table 5

Energy Savings Realization Rate by
Evaluation Method and Year

Evaluation Method	1993	1994	1995	All Years
Comparison of Means	120%	112%	120%	117%
Program Participation (weather adjusted)	55	93	155	111
Statistically Adjusted Engineering	91	71	86	83
Statistically Adjusted Engineering (weather adjusted)	91	85	88	87

interpreted as the percentage of the projected energy savings that were realized in the program participants' buildings (Table 5). Given that the projected savings were 85 annual megawatt-hours, then the realized savings for the three years, as shown in Table 4, were: 77 megawatt-hours (1993), 72 megawatt-hours (1994), and 75 megawatt-hours (1995). This pattern of savings indicates that there was considerable persistence in the program energy savings across the three years following the installation of the conservation measures.

Several other variables in the second SAE model had a statistically significant impact on energy consumption. These variables included pre-program energy consumption, outlier load impacts, and the interaction, for participants only, of pre-program energy consumption by heating and cooling degree-days.

Conclusions

The first part of the Conclusions section covers the major findings in the energy savings evaluation for Seattle City Light's Energy Smart Design Program. Following this summary, four lessons learned from this project are presented for others who may conduct evaluations of energy savings in commercial buildings.

Findings

- Eighty-four percent of the conservation measure groups examined were still installed and operating efficiently at the time of the site visit. Of the measures that had been changed, nine percent were changed to an equal or more efficient conservation measure. With this changeout pattern, 93% of the measures were energy efficient at the time of the site visit.

- For measures that had been changed at the time of the site visits, the reasons given for these changes were typically due to the customer rather than to the measure. Examples of these customer related reasons included lack of interest in efficient lighting, needed more (or less) lighting, remodeling the facility, and the customer's decision to relamp.

- Substantial energy savings were found in the evaluation, with the average savings across the three post-program years being 74 annual megawatt-hours per project.

- The realization rate for the savings was 88%, as the savings were somewhat below the projected savings for Energy Smart Design Program participants (85 megawatt-hours per project).

- There was considerable persistence in the energy savings, as savings varied very little across the three post-program years. Savings with the SAE approach were 77 annual megawatt-hours in 1993, dropped slightly to 72 megawatt-hours in 1994, and then rose slightly to 75 megawatt-hours in 1995.

Lessons Learned

The evaluation of energy savings in the Energy Smart Design Program was time consuming and moderately expensive. The following list of lessons learned is provided for others who may do evaluations of the persistence of conservation measures and energy savings in commercial buildings.

- Use a sampling procedure for determining which buildings should receive a site visit to check on the status of the conservation measures. Buildings can be sampled which have those measures most frequently installed through the conservation program and/or have high-energy savings. With this sampling approach, a representative picture can be obtained of the status of the conservation measures installed through the program, and the costs for the site visits can be reduced.

- As in other evaluations of energy savings in commercial buildings (e.g., Xenergy et al. 1996a), weather adjust the energy consumption data for both program participants and nonparticipants. The importance of weather adjusting the energy consumption was reinforced in the current evaluation, as in the final SAE model there were a number of statistically significant relationships between weather factors, such as heating and cooling degree-days, and energy consumption.

- Conduct site visits for buildings in which there are unusually high increases (or decreases) in the annual energy consumption. In the site visits, information should be collected on the building characteristics and end-use equipment that can help explain the year-to-year changes in energy consumption. This information can then be incorporated into the analysis of energy savings, and thereby improve the energy savings estimates for conservation measures.

- Use a Statistically Adjusted Engineering model to establish the energy savings for conservation measures installed through the utility program. For the four energy savings methods used in the evaluation, the greatest statistical precision was obtained with a weather adjusted, Statistically Adjusted Engineering model. This model improves upon the other savings models by incorporating the staff developed engineering savings estimates for each project.

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