LONGITUDINAL EVALUATION OF ENERGY SAVINGS FROM SEATTLE CITY LIGHT'S HOME ENERGY LOAN PROGRAM

David Sumi and Brian Coates
Seattle City Light

ABSTRACT

Evaluations of conservation programs tend to be single snap-shots of program effects, typically including a single year of post-program consumption data. Depending upon the uses of such evaluation results, this could result in over-estimation of long-term impacts, or it may overlook delayed or persisting effects of the program. In either case it is unlikely that program-induced savings are constant over time.

The evaluation reported here seeks to improve upon the snap-shot approach by identifying several evaluation cohorts and obtaining energy consumption data for additional years before and after program participation. Thus, the primary purpose of the analysis is to estimate Home Energy Loan Program (HELP) participants' savings over time by examining the impact of the program on cohorts' electricity consumption across the period 1980 through 1987. Consumption data are analyzed for 1,030 single family dwelling HELP program participants from this time period who received insulation and window measures. A quasi-experimental research design was implemented with two comparison group approaches: a randomly selected non-participant group; and, "waiting list" comparison groups comprised of future years' participants.

The evaluation found that the net (program-induced) electricity savings averaged about 2,300 annual kilowatt-hours across participant cohorts for the first year after weatherization. As a percentage of pre-program electricity use, these savings were about 9.5%. Net savings for subsequent follow-up years ranged from approximately 2,100 kilowatt-hours (third year) to 2,650 kilowatt-hours (fifth year), with sixth-year savings (the last follow-up year in the study) estimated at about 2,350 annual kilowatt-hours. These estimates were derived from a time-series, cross-section regression model which combined PRISM weather-adjusted consumption information from all participant cohorts and the non-participant group.

A Longitudinal Analysis of Energy Savings From Seattle City Light's Home Energy Loan Program

David Sumi and Brian Coates
Seattle City Light

INTRODUCTION

Evaluations of energy savings for conservation programs tend to be single "snap-shots" of program effects, typically including a single year of post-program consumption data. Depending upon the uses of such evaluation results, this could result in overestimation of long-term impacts, or it may overlook delayed or persisting effects of the program. In either case it is unlikely that program-induced savings are constant over time.

The evaluation reported here seeks to improve upon the snap-shot approach by identifying several evaluation cohorts and obtaining energy consumption data for additional years before and after their program participation. We therefore analyzed the impact of the program on electricity consumption during the period 1980 through 1987 for six groups (cohorts) of program participants. These cohorts participated in Seattle City Light's Home Energy Loan Program (HELP) during one of six years: 1981, 1982, 1983, 1984, 1985, or 1986.

The HELP program is part of a larger City-wide conservation effort designed to reduce electricity usage in residential structures through retrofitting of weatherization measures. The HELP program was created to provide loans for weatherization to residential customers who reside in single-family to fourplex units and heat their homes with electricity.

Financing is provided for: ceiling, wall, floor, and heating duct insulation; pipe wrap; storm windows; caulking and weatherstripping; and, automatic clock thermostats. In order to participate in the program, installation of some of the measures is mandatory. Although there has been some variation in optional measures across the years of this evaluation, the mandatory measures have consistently included: ceiling insulation to R-38; crawl space insulation to R-19; and, hot water tank wraps. Windows have tended to be one of the most preferred optional measures.

In order to ensure proper evaluation of the impacts of the conservation program on the City Light load it was necessary to separate reductions in electricity use due to the program (program-induced savings) from customer responses to increases in electricity rates and information regarding conservation actions. Thus, a quasi-experimental research design was required where a comparison group (or groups) was used to estimate programmatic or net savings. Two comparison group methods were used: (a) a randomly selected non-participant group (NP); and, (b) "waiting list" comparison groups comprised of future years' participants.

With this design we estimated Home Energy Loan Program participants' savings over time (persistence, or durability, of first year savings). It is expected that this information will modify load forecast assumptions for electricity savings attributable to the HELP program now and in the forecast period. Also of interest are questions relating to: variability in savings across participant cohorts; and, the energy use trend exhibited by the randomly selected, but program-eligible, non-participant group.

EVALUATION DATA AND METHODS

Sample And Data Collection

Participant Group. The analysis is restricted to households in single-family, electrically heated homes who have lived in the same residence since January 1980 (one year prior to the first participant cohort in 1981). Six analysis groups were sampled from participants for the program years 1981 through 1986. For this analysis each of these homes has kept the same account during the entire eight year period (1980-1987). The 467 homes selected for the program cohorts representing years 1981 through 1984 were part of a random sample of 712 homes selected from the program files (245 homes were removed because of ownership/account changes). In addition, 285 homes for 1985 and 278 homes for 1986 were analyzed from program participants for these two years who, again, had no ownership/account changes or bill history problems during the study period. The smaller number of households for the program participant years 1981 through 1984 reflects the sampling for these years, rather than differences in levels of program participation between the 1981-84 and the 1985-86 periods.

Non-Participant Comparison Group. The sample of non-participants was prepared from King County Assessor Office information with the population of single-family homes corresponding to the Seattle City Light service territory. Stratified random sampling procedures were employed in defining this group so as to match it to a profile of HELP participants on the basis of house age, size, and electric heat system type. This sampling procedure reduced the liklihood that there would be systematic differences between the participant and non-participant groups on these variables.

Data Collection. To implement the evaluation design several types of data were collected:

1. For program participants and the non-participant sample, bill history consumption data from Seattle City Light's Customer Information System (CIS) for late 1979 through early 1988;

2. Actual daily temperature data (1975-1987) and Seattle City Light Normal Temperature ("Expected Weather") obtained for weather normalization; also, a heating degree-day performance factor on the sensitivity of electric heat homes to weather was used for weather normalization, as well as heating degree day data for the study period; and,

3. Structural characteristics information for as many houses as was available (age, size, type of electric heat system).

Energy Savings Analysis Methods

Stage 1: Weather Normalization. After bill histories were gathered for consumption data (from archived CIS master tape extracts), these data were compiled to yield annual sums of electricity usage for each house by year. These annual electrical consumption figures were then weather normalized with two separate normalization procedures. These two methods were the heating degree day approach and the Princeton Scorekeeping Method (PRISM) (Fels, 1984). The results reported here reflect use of the PRISM weather-adjusted consumption data. Information for results derived from heating degree day weather-adjusted data can be found in Sumi and Coates (1988).

PRISM yields estimates for each household/year of total weather-adjusted annual electricity use (NAC or Normalized Annual Consumption). In addition, PRISM yields estimates of reference temperature, and of the baseload and heating (more accurately, nonweather- and weather-sensitive) components of total electricity use. PRISM has also been validated against submetered data for total household consumption in the Northwest (Bronfman, et al., 1987).

Stage 2: Energy Savings. Various analytic methods were used to estimate total and net electricity savings once the weather-adjusted consumption data were produced. First, simple comparisons of mean values yielded preliminary first year estimates of savings due to the HELP program for the PRISM weather-adjusted data.

These first year net electricity savings for each program cohort were calculated by subtracting the change score (pre-program consumption minus post-program consumption) for the non-participant comparison group from the corresponding change score for the program participant group. These net savings are the difference between the total savings and the savings that these weatherized homes would have achieved on their own had there been no HELP program. Consumption data from the non-participants was used to infer the "no-program" energy savings for participants.

The same comparison of means method was also applied to program cohorts employing change scores for subsequent program participants ("wait list" groups) in place of the non-participant comparison group in order to generate "net" first year savings estimates. This method yielded first year savings for the 1981 through 1984 cohorts only, as the evaluation design "runs out" of subsequent program participant change scores corresponding to the appropriate pre- and post-program data years.

Results of the stage 1 weather adjustments were then used as the dependent variable to estimate time-series, cross-sectional regression models (SAS, 1986). Separate regressions were performed for: (1) each participant cohort with the non-participant group; (2) all participant cohorts with the non-participant group; and, (3) all participant cohorts without the non-participant group.

RESULTS

Profiles Of Cohort Characteristics

Data on the type of electric heat for the home, the year built, and square footage were gathered for approximately one-half of the HELP participants from the City Light Home Energy Check Audit Master File. Unfortunately, these data were not available for the remainder of the sample due to data base problems. For non-participants these data were obtained from the King County Assessors Office.

The participant and non-participant groups were similar in their utilization of an electric furnace for space heating. They differed, however, in that non-participants had a greater utilization of electric baseboard heat in their homes whereas there was more frequent use of heat pumps by HELP participants. These differences between the two groups were primarily due to the greater use of heat pumps by 1985 HELP participants.

There was considerable correspondence between the participant and non-participant groups in the age of their homes. For both groups, more than two-thirds of the homes were built prior to 1960 with only one home built after 1980.

The square footage for the six participant groups and the non-participants are provided in Table 1. The average home size for the 1981-1984 HELP participants and the non-participants are similar. In contrast, the homes of the 1985 and 1986 program participants are somewhat larger than those of the non-participants.

Table 1

Mean Square Footage for Home Energy Loan
Program Participants and the Non-participants

Group	N	Square Footage
1981	59	1589
1982	66	1702
1983	58	1530
1984	57	1645
1985	122	1867
1986	77	1808
Non-participants	227	1673

Overall, then, the HELP participant cohorts and the non-participants appear similar in the age of the home, the utilization of an electric furnace for space heating and, for 1981-1984 participants only, the square footage of the home. The differences between the two groups center on the 1985 and 1986 participants. The square footage of the homes of these groups are larger than the non-participants and the 1985 participants have a greater utilization of heat pumps for space heating.

Energy Consumption And Savings For PRISM Weather-adjusted Data

Stage 1: Weather Normalization Results. PRISM method results indicated that total electricity use was approximately equally split between heating and base level purposes for all groups. There is considerable variation in annual consumption, with PRISM estimates of

Normalized Annual Consumption (NAC) showing average standard errors, by group/year, from 3.3% to 5.9% of the mean NAC. Overall, the fit between the electricity billing data and the PRISM model is very good. The average R-squared value across the household/years is about .94 and the median R-squared is typically .98.

TABLE 2

Mean Annual Kilowatt-Hour Consumption By Group and Year (PRISM Method)

Group (N)	1980	1981	1982	1983	1984	1985	1986	1987*
NP (229)	24,720	25,140	23,184	23,232	21,555	20,710	21,863	22,743
1981 (132)	25,873	program	21,532	21,453	19,957	19,544	20,728	21,137
1982 (116)	25,212	25,948	program	21,933	20,255	19,906	20,688	20,770
1983 (111)	26,044	26,717	24,399	program	20,584	20,295	21,357	22,045
1984 (108)	25,961	26,421	24,754	24,932	program	19,885	21,429	22,813
1985 (285)	27,656	28,508	26,408	26,864	25,180	program	23,176	23,723
1986 (278)	26,541	27,137	25,102	25,593	23,843	22,769	program	22,562

* The N of cases is reduced for each group in the 1987 consumption data by an average of 6.6% due to attrition (account change and/or bill history data problem). The 1987 group N's with % decrease in parentheses are: NP=223 (2.6%); 1981=119 (9.8%); 1982=102 (12.1%); 1983=103 (7.2%); 1984=96 (11.1%); 1985=276 (3.2%); 1986=no change.

The pre-program electricity use for program participants ranges from 6% higher (in 1980) to nearly 14% higher (1984) than the non-participant households (Table 2). It is interesting to note that these differences in consumption increase steadily across the study period, reflecting the somewhat sharper decline in consumption shown by the non-participant group.

Reductions in electricity use during the first six years of the decade for non-participants, and, to a slightly lesser extent for participants (pre-program), are likely due in part to some significant increases in electricity prices during this period. Other factors may also have affected household electricity use (e.g., public awareness of energy issues, changes in household income, knowledge of the potential for bill reductions through installation of conservation measures). Table 2 provides evidence for all cohorts (program and non-participant) that this decline has ended, and that consumption has increased in the 1986-87 period. These results differ slightly from those obtained with the heating degree day weather-adjustment method, which showed consumption increases for 1986 but slight decreases in 1987.

The weather-adjusted, net first year energy savings using the PRISM output for the six HELP participant groups are presented in Table 3, and reflects a simple comparison of differences in means. As shown in this table, there was some variability in the energy savings for these cohorts, where first post-program year savings ranged from 2,107 annual kilowatt-hours to 2,805 kilowatt-hours (weighted mean equals 2,341 kilowatt-hours). This represented, on average, 9.5% of their mean pre-program consumption.

The same comparison of means method, for estimating net first year savings, was also applied to program cohorts employing change scores for subsequent program participants ("wait list" groups) in place of the non-participant comparison group (Table 3). This method yielded first year savings for the 1981 through 1984 cohorts only, as the design matrix "runs out" of subsequent program participant change scores corresponding to the appropriate pre- and post-program data years. As shown in Table 3, the first year savings with the wait list group approach are slightly higher than those shown by the non-participant group approach.

TABLE 3

Means: First year Energy Savings by Group
(PRISM Method)

Group	Total First Year Savings	NP Group Change	NP Net First Year Savings	Wait List Cohort Change	Wait List Net First Year Savings
1981	4,341	- 1,536	2,805	- 1,645	2,696
1982	4,015	- 1,908	2,107	- 1,489	2,526
1983	3,815	- 1,629	2,186	- 1,228	2,587
1984	5,047	- 2,522	2,525	- 2,824	2,223
1985	2,004	+ 308	2,312	NA	NA
1986	207	+ 2,033	2,240	NA	NA

Stage 2: Time-Series, Cross-Sectional Models. Results of the stage 1 weather adjustments, specifically the PRISM Normalized Annual Consumption estimate (NAC) for each household per year, were then used as the dependent variable to estimate time-series, cross-sectional regression models (TSCSREG procedure in SAS, 1986). This procedure accounts for the correlation among the eight annual consumption estimates for each household (i.e., it exlicitly recognizes that the observations are not independent of each other for each household), and is therefore preferable to simpler ordinary least squares methods.

TABLE 4

Regression Results for Annual Kilowatt-Hour Energy Savings By Year Of Follow-Up And Group (PRISM Method)

	Energy Savings					
Group	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year
1981	2,505	2,836	2,650	2,302	2,261	2,145
1982	1,827	2,049	1,713	2,109	2,437	
1983	2,228	1,724	1,837	1,540		
1984	2,412	1,900	1,095			
1985	1,879	2,029				
1986	1,654					
All Cohorts	2,274	2,398	2,131	2,309	2,661	2,355
All Cohorts (no NP)	2,737	2,910	2,710	3,019	3,519	3,345

The regression procedure was used in testing the variations in comparison group methods. This meant that separate regressions were performed for: (1) each participant cohort with the non-participant group; (2) all participant cohorts with the non-participant group; and, (3) all participant cohorts without the non-participant group. Table 4 presents the time-series, cross-section regression results and includes the follow-up year energy savings coefficients obtained for each of these three variations in the pooling of participant and non-participant groups.

First year savings estimates by cohort, from Table 4, range from 1,654 annual kilowatt-hours to 2,505 kilowatt-hours when each of the six cohorts was compared separately to the non-participant group. Follow-up year estimates (beyond first post-program year) ranged from 1,095 annual kilowatt-hours to 2,836 kilowatt-hours, varying by cohort and follow-up year. All cohorts showed considerable persistence in the energy savings across the post-program year, and all follow-up year savings coefficients were statistically significant at the .001 level or beyond according to the t-test output from the regression analyses.

Table 4 also gives savings estimates for regressions which combined all participant cohorts and the non-participant group. These savings results have a narrower range: from 2,131 annual kilowatt-hours (in the third post-program year) to 2,661 kilowatt-hours (in the fifth year). The highest savings coefficients were produced by combining all participant cohorts without the non-participant group (employing the "wait list" cohorts to statistically control for the non-programmatic savings trend over time). Table 4 presents these savings as ranging from 2,710 annual kilowatt-hours (for the third post-program year) to 3,519 kilowatt-hours (for the fifth year).

Again, two primary findings are: the persistence of energy savings attributable to the HELP program for this time period was found to be consistently high across the various analytic methods; and, the variation in savings observed across the analytic methods reflects the differences in consumption trends over time between program participants and the non-participant group. Because the non-participant group exhibited a slightly more marked decline in consumption over the study period, analyses which include non-participants tend to show lower savings than analyses which exclude them. This is the case whether the procedure for calculating net savings (net of non-program induced savings trends) is a simple comparison of means or a time-series, cross-section regression.

DISCUSSION

It was found in this evaluation that the net (program-induced) electricity savings averaged about 2,300 annual kilowatt-hours across participant cohorts for the first year after weatherization. As a percentage of preprogram electricity use, these savings were about 9.5%. Net savings for subsequent follow-up years ranged from approximately 2,100 kilowatt-hours (third year) to 2,650 kilowatt-hours (fifth year), with sixth-year savings (the last follow-up year in the study) estimated at about 2,350 annual kilowatt-hours. These estimates were derived from a time-series, cross-section regression model which combined PRISM weather-adjusted consumption information from all participant cohorts and the non-participant group.

Non-participants (eligible households who did not participate) reduced their annual consumption over the first six years of the study period from a high of approximately 25,000 kilowatt-hours (in 1981) to a low of 20,700 (1985). Consumption for this group subsequently increased by 5.6% in 1986 and 4.0% in 1987.

The findings for persistence of electricity savings for the period 1981 through 1983 are very similar to those found during the same period by the BPA Residential Weatherization Pilot Program evaluation (Goeltz, Hirst, and Trumble, 1986). Also, the consumption trend observed for the non-participant group is very comparable to that observed in the Northwest by Horowitz (Horowitz, et al., 1987), where consumption increases coincided with recent years of flat or real declining rates.

Electricity savings attributable to conservation programs (whether first year or subsequent years) vary with changes in electricity prices, incomes (and elasticities for energy consumption with respect to income), and attitudes and awareness of energy issues. Thus, assumptions concerning persistence of these savings, or future program savings, into a forecast horizon must be tempered with updated information for the relevant economic and energy-related indicators.

Future savings can be expected to vary also as a function of program components (measures) installed in the weatherization program. For example, analysis for a sub-sample of HELP homes which received only new windows showed dramatically lower savings (about 500 annual kilowatt-hours). Future expected program savings would very likely increase if no "windows-only" option were offered.

The information provided on non-participant consumption over the period 1980 through 1987 is potentially valuable for load forecasting, as this group's energy use was strongly correlated with City Light aggregate measures of single-family, electrically heated houses in the service area. Additional independent corroboration of the consumption increases observed for 1986 and 1987 would strengthen these findings.

We have not tested for attrition bias. Due to problems in reconstructing billing histories (for changed accounts), the lack of complete data on structure characteristics and the absence of household survey data, examination of attrition bias has not been undertaken. Thus, while adequate sample sizes were available for the longitudinal analysis, we cannot speculate as to differences between people who moved and those who did not move (i.e., differences that may be correlated with energy conservation behaviors) and we cannot assume random attrition. The study does include comparisons of participant cohort and non-participant group profiles using structural characteristics data available on about one-half of the households.

Few studies have examined the dynamics of program-induced energy savings and little is known about the generalizability of results with respect to region or to trends in electricity price and incomes. Additional evidence obtained from analysis of longitudinal data is required to further support the role of conservation programs as energy resources.

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