Revisiting Multifamily Retrofit Electricity Savings

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In 1990, Seattle City Light reported the initial round of findings about electricity savings from participants in the first two years of the Multifamily Conservation Program. Subsequently analysis continued, addressing issues surrounding the weather-normalization methodology and the cost-effectiveness of the current program.

This paper reports on outcomes from 111 buildings (1,449 units) that participated in the program during 1986 and 1987, providing comparisons with 95 pre-participant buildings (1,365 units) to derive estimates of net energy savings in 1987 and 1988. Extrapolations to impacts of the 1990 program are made to reflect ongoing changes in window technology.

In the final analysis, 1988 post-retrofit house-meter use dropped 21% in low-income buildings and 36% in standard-income buildings, due to common area lighting measures. Low-income tenant-meter use decreased by 10%, while standard-income tenant meter use decreased by 14%, due to window, shell insulation, and hot water measures. The whole-building net electricity savings estimates are identical, however, for both low-income and standard-income participants, averaging 1,440 kWh per dwelling unit in 1988.

By extrapolation, due to changes in window technology (dropping from an average post-retrofit heat-loss coefficient of $U=0.72$ in 1986-87 to $U=0.62$ in 1990), a dwelling unit weatherized in 1990 would save 1,640 kWh. Under newer building codes (requiring an average $U \leq 0.40$), in 1992 a dwelling unit is expected to save 2,040 kWh. The 1990 program under baseline conditions was found to be cost-effective to the region for standard-income participants (at 47 mills) and not so for low-income participants (at 78 mills).

Introduction

The purposes of this evaluation are: to estimate electricity savings for 1986 and 1987 participants in the Seattle City Light program; and to assess the cost-effectiveness of the program both in 1986-87 and in 1990. A comprehensive evaluation has been underway for several years, addressing issues of program process, administrative efficiency, electricity savings impacts, and economic impacts. Evaluation findings have been used in budget, load forecasting, and resource allocation decisions, as well as to identify operational and program design opportunities for improvement.

Program Description

The Multifamily Conservation Program entered its pilot phase in 1986. The program provides financial and technical help for conservation measures to owners of apartment buildings with five or more units and electric space heat. The multifamily buildings retrofitted through the program had fewer than four stories, wood or concrete frames, and primarily flat roofs. The program serves two distinct groups of buildings, one in which two-thirds or more of the tenants have low incomes, and the other comprised primarily of standard-income tenants.

The available conservation measures include: double-glazed replacement or conversion windows, storm windows, attic or flat roof insulation, under-floor insulation, wall insulation, caulking and weatherstripping, efficient flow showerheads, water heater wraps and temperature set-backs, pipe and duct wraps, additional cavity venting, and lighting modifications. Owners of buildings occupied by low-income tenants receive a full-cost grant, conditional upon agreement by the owner not to raise rents due to conservation measures for a period of five years. Owners of buildings with standard-income tenants qualify for a 10-year, zero-interest loan from the utility, with five-year deferred payment and a 50% discount for first-year payoff.

Methodology

The multifamily retrofit database prepared for this study (Okumo 1990a, 1990b, 1991) is the largest and most complete developed to date in the Pacific Northwest region. It contains electricity consumption and billing data from 1984 through 1988 for 206 existing apartment buildings comprising 2,814 dwelling units. Records for all 206 treatment and control buildings include basic structural characteristics, while records for the 111 retrofit buildings also include detailed audit and inspection data on additional building features pre- and post-retrofit.

Electricity Savings Overview

Four methods were established to estimate programmatic electricity savings. A quasi-experimental design with nonequivalent control groups was used. Comparisons were made between program participants and "pre-participants" selected from a waiting list. Pre- to post-retrofit gain scores and analysis of covariance were used to estimate electricity savings. First year savings were estimated for 1986 (Cohort I) and 1987 (Cohort II) participants, and the persistence of savings into a second post-retrofit year was examined. Standard-income buildings were analyzed separately from low-income buildings in a parallel design. In 1986 two groups of low-income buildings were studied: public housing (Cohort Ia) and privately-owned housing (Cohort Ib). All 1987 low-income treatment buildings were privately-owned (Cohort II).

Methods I through III present a picture that progressively decreases known sources of error variance in electricity use change over time for the study groups. Method I introduces the pre-participation control group of buildings to adjust for changes across the study period due to economic and social effects in a presumably similar group of owners and tenants (i.e., due to a changing economy and electric rates, changing occupant demographics and living habits, tenant turnover, changes in ownership, and conservation actions taken by customers apart from program participation). Method II introduces an adjustment for annual variations in weather conditions across the study period, which affect primarily the space heating and secondarily the water heating portions of electricity use. Commercial house-meter consumption data were not weather-normalized.

Supportive analyses were performed to estimate the actual temperature sensitivities of buildings in the study groups, both before and after retrofit. (See Okumo 1991 for specifics on the weather normalization analyses.) We found that multifamily buildings are much less sensitive to fluctuations in outdoor temperatures than predicted by simple regressions of consumption against heating degree-days. It was established that the electricity consumption of these multifamily buildings actually varied by 0.57 kWh/HDD*dev* in standard-income buildings and 0.53 kWh/HDD*dev* in low-income buildings. The discrepancy between earlier Seattle City Light estimates and the findings of this study is due to the seasonality of non-space-heating loads, which are greater in the cooler months but do not vary with precisely the same cycle as space heat loads. In these analyses it was also found that post-period treatment building temperature sensitivities were reduced by a factor of 0.46 (-54%) for standard-income building units and 0.77 (-23%) for low-income building units. These reductions are significantly greater than expected from our experience with HELP (Home Energy Loan Program) single-family homes, which informed initial analyses of electricity savings in the multifamily retrofit buildings.

Method III introduces a final correction for the correlation of pre- to post-period consumption and the contribution of this correlation to the error variance. Each residential unit was represented by one annual building-average unit score (1987 or 1988). The post-period unit scores were regressed against a single pre-period score for each unit (covariate 1984/1985 average) and a program participation indicator (bivariate). Method IV then summarizes the savings results across years and groups, incorporating the variance corrections of Method III. Each residential unit was represented by four or five annual building-average unit scores (1984 through 1988). The post-period unit scores were regressed against a single pre-period score for the units (covariate 1984) and a program participation indicator (bivariate). This method allowed for greater generalization of the study findings across the two major groups of program participants: all standard-income and all low-income buildings. Net electricity savings per residential unit were also estimated for the program as a whole.

Electricity Savings

Method I: Unadjusted Use Gain Scores

Significant program effects were seen in the average house-meter savings for program participants, attributable mainly to common area lighting measures in the second year of the program (Cohorts II). These participants saved sizeable net amounts: 34% of pre-period use among standard-income buildings and 22% among low-income buildings. The weighted average of savings across the two building types in Cohort II was 447 kWh per unit-year in 1988 (547 from the standard-income group and 350 from the low-income group), as expressed in terms of the total number of study group units. This represents 50% (61% standard-income, 39% low-income) of the typical multifamily building's lighting energy consumption, according to the DeLaHunt et al. (1985) estimate of 900 kWh per unit annually going to this end use in Seattle. DeLaHunt also predicted 45% savings from lighting retrofit measures.

Method II: Weather-Normalized Use Gain Scores

Significant program effects are also seen in the weather-normalized electricity savings findings from the average building-level gain score per dwelling unit, weighted by units. The net savings percentage for standard-income buildings in Cohort I was 9% in 1987 and 10% in 1988, indicating good persistence of savings across years. Cohort II in 1988 saved 11% of pre-period use. Average absolute savings were between 745 and 823 kWh per unit. The weighted average net savings across these three cohort-years is 792 kWh per unit, or 10%.

The net weather-normalized savings for low-income buildings rose from 10% in 1987 to 12% in 1988 for Cohort Ia public housing. Savings also rose between years from 13% to 14% in private low-income housing from Cohort Ib, again indicating persistence of savings across years. Low-income Cohort II buildings (also privately-owned housing) saved 7% of pre-period use in 1988. Average absolute savings were between 1,179 and 1,464 kWh per unit among public housing buildings, and between 736 and 1,812 kWh per unit among privately owned low-income buildings. The weighted average net savings across these three cohort-years is 1,150 kWh per unit, or 10%. Pre-period differences between treatment and control groups of low-income buildings render these comparisons vulnerable to correlation effects, however.

Method III: Analysis of Covariance

Covariance analyses were performed for both house-meter use and dwelling-meter use at the unit level. Goodness of fit ranged from $r^2=0.82$ to $r^2=0.96$ across analyses. Ninety-five percent confidence intervals are indicated following each estimate.

Common Area Savings. In Cohort II during 1988, standard-income buildings saved 36% of pre-period common area use, or 595 (±9%) kWh per unit-year; and low-income buildings saved 21%, or 469 (±18%) kWh per unit-year. The average of Cohort II savings in 1988, as expressed in terms of the total number of study group units, was 580 kWh per unit-year from the standard-income participants and 338 from the low-income participants (for a weighted average of 457 kWh per unit-year, overall).

When expressed only in terms of the total number of study group units in buildings having house meters, the 1988 house-meter electricity savings are estimated to have been 490 kWh per unit-year from the standard-income participants and 469 from the low-income participants (for a weighted average of 483 kWh per unit-year, overall). The Cohort II overall weighted average savings from house meters in 1988 were 540 kWh per unit, in buildings having house meters.

The results stated above have been rounded to conclude that program participants saved a mean of 520 (±14%) kWh per unit in common area electricity use annually, among buildings having house meters. No significant differences between standard-income and low-income buildings were observed in these pooled estimates. These analysis of covariance results are preferred for estimates of the common area savings on house meters, due to the great difference between program years in the implementation of efficient lighting retrofit measures. Thus the results of Method III for common area electricity savings were adopted in the load forecast models and the economic analysis of the Multifamily Conservation Program.

Dwelling Area Savings. All treatment groups experienced significant dwelling area savings. The net weather-normalized savings percentage for standard-income buildings declined slightly from 13% to 12% in Cohort I between post-retrofit years. Absolute savings dropped from 1,024 to 976 kWh per unit. Standard-income Cohort II buildings saved 1,048 kWh per unit, or 14%. The weighted average weather-normalized net savings across these three cohort-years is 1,024 kWh per unit, or 13%. As did Method II, analysis of covariance demonstrates the persistence of dwelling area savings from the standard-income buildings.

The first cohort of low-income buildings showed an unexplained rise in savings from first to second post-year. The net weather-normalized dwelling area savings rose from 4% to 9% (514 to 1,068 kWh per unit) in public housing and from 8% to 11% (981 to 1,378 kWh per unit) in private low-income housing from Cohort I. Low-income Cohort II buildings saved 751 kWh per unit (7%). The weighted average weather-normalized net savings across these five cohort-years is 885 kWh per unit, or 8%. Investigation ruled out any delay in the installation of measures, such as showerheads, that might have confounded first year effects. This group of buildings was atypical in pre-period electricity consumption levels, as well, and had a lower than average turnover rate (about half of the typical) among tenants over the study period.

Method IV: Linear Regression Analysis

Regression analyses were also performed for unit-level dwelling-area meter use. The net weather-normalized savings percentage for the dwelling area of standard-income buildings was 14%, while the low-income buildings saved 10% of pre-period electricity use. The average net savings across all building types was 11%. Absolute annual net savings (within a 95% confidence interval) were 1,078 (±4%) kWh among standard-income units, and 1,082 (±8%) kWh among low-income units. Combining standard-income and low-income buildings into one analysis, the absolute net dwelling-area electricity savings for the Multifamily Conservation Program in 1986-87 were estimated to be 1,036 (±5%) kWh per unit-year. This sort of regression average pools known sources of variability, but provides one more indicator that the average program effect was to save about 12% relative to the nonparticipant tenants' pre-period electricity consumption.

The results stated above have been rounded to conclude that, in a normal weather year, program participants saved a mean of 1,050 (±5%) kWh per unit in dwelling area electricity use annually. No significant differences between standard-income and low-income buildings were observed in these pooled estimates. The regression analyses reported here pool much of the variance that differentiates the Method III results for each post-period cohort-year. The results of Method IV for dwelling area electricity savings were adopted in the load forecast models and the economic analysis of the Multifamily Conservation Program.

These analyses of covariance removed a large amount of error in the comparisons between low-income groups. Several other approaches were taken to help interpret the remaining error in the electricity savings estimates.

Showerhead Measure Discussion

Sumi (1990) conducted an evaluation of water conservation using a subsample of the multifamily retrofit buildings from this study. Using evaluation estimates of savings on water meters (from water billing histories) and engineering estimates of how much electricity it would take to heat this water, some implications were drawn for water heat end use savings from efficient showerhead measures. From Sumi (1990), we may infer per showerhead electricity savings, in buildings that received this measure, to be: Cohort I, 477 kWh per unit in 1987, 617 in 1988; Cohort II, 662 kWh in 1988. The actual measure penetration rates among standard-income Cohorts I and II were, respectively, 26% and 71%; among low-income cohorts, 50% and 24%.

To substantiate Sumi's findings, two analyses were performed in which the 1988 electricity use gain score for all standard-income buildings combined was regressed against indicators of window, shell insulation, and showerhead measure installations. One regression *(Model 1)*, using the square footage of existing glass as a covariate, yielded a coefficient per showerhead of 300 kWh (±94%) in gross electricity savings (r^2=0.76). The other regression *(Model 3)* yielded a coefficient per showerhead of 244 kWh (±31%) in gross electricity savings (r^2=0.36), in units receiving showerhead retrofits. These showerhead results are less than half of Sumi's findings.

The inference from these regression analyses is that showerheads contributed about 9% to 11% of the per-unit gross savings observed in the multifamily retrofit buildings, with an average saturation level of 41% of units receiving energy-efficient showerheads. The provisional, conservative conclusion at this point is that the energy efficient showerheads probably saved a mean of 240 (±30%) kWh per residential unit receiving this measure. Further research should be conducted to confirm this attribution of electricity savings to efficient showerheads.

An examination of correlations with building structural features revealed that, after glass square footage and showerhead retrofits, some additional correlation remained between the error term and the location of water heat tanks. Introduction of a variable for the presence of the tank in the residential unit, a closet, or the heated main body of the building reduced total annual building energy savings (by about 570 kWh per unit). A possible interaction effect between the incidence of showerhead retrofits and the internal location of water heat tanks could not be further tested due to the small number of cases. However, the data give the appearance of such an interaction, with the coefficient of annual savings per showerhead rising from about 240 kWh to around 625 kWh with the inclusion of the water heater location term (r^2=0.74). This result is intriguing in the light of Sumi's original findings.

Window Measure Discussion

Various estimates have been made of the electricity savings attributable to window measures, using multiple regression analysis. The findings were corroborated by two other studies that used end-use metering and engineering models. Five regression models were estimated to assess the contribution of window measures to overall program gross savings; the results of three are described here.

As mentioned above, *Model 1* regressed the 1988 gain score for all standard-income buildings combined against the square footage of existing window glass. In *Models 2 and 3*, 1988 gain scores were regressed against indicators of changes, due to retrofit measures, in the heat lost through windows and through areas receiving insulation. (See Okumo 1991 for specifics on the heat loss calculations.)

When analyzed from the building-level scores, regardless of which indices of window installations were used, similar results were obtained. Based on square footage of pre-existing glass, window retrofits captured 86% of the electricity savings observed. According to the heat-loss change variables, window retrofits were associated with 81% of electricity savings.

Analyzing the unit-level scores (weighted by number of units), somewhat different results were obtained by the various indices of window installations. According to the heat-loss change variables, combined with a variable indicating the number of energy efficient showerheads installed, window retrofits were associated with 62% (building scores) to 86% (unit scores) of the electricity savings observed. Showerheads were associated with 9% (building scores) to 10% (unit scores), or about 240 to 270 kWh, respectively. In the analysis of building scores, the absolute amount of savings associated with the remainder of measures (the constant) was around 350 kWh per residential unit. In the unit-score analysis, the coefficients were 24.1 kWh per btu/hour/°F for windows and 1.3 kWh for insulation measures. DeLaHunt et al. (1985), studying the multifamily conservation potential for this service area, predicted savings of 17.0 to 21.0 kWh/sq.ft. for windows and 1.4 to 5.4 kWh/sq.ft.for insulation measures.

The preponderance of various estimates, from these models, of electricity savings attributable to window measures lies between 68% and 75% of the dwelling area total savings. Coates (1990), studying windows-only participants in the single-family Home Energy Loan Program, found energy savings equivalent to 71% of savings in homes receiving the full mix of measures (Sumi and Coates 1988). Taking into consideration these various findings, a conservative estimate of electricity savings attributable to window measures (that is, 70% of the total per residential unit) has been adopted in the estimation of parameters for the economic analysis of the program.

This estimate of the proportion of electricity savings attributable to window retrofits may be corroborated by some findings of University of Washington researchers regarding the relationship between glass U-value and space heat savings.[1] In the U.W. study, single-family homes were monitored and subsequently simulated with engineering models. In their research, it was found that reducing the U-value of the glass by 0.1 was associated with savings of 2.35 kWh per square foot of glass area. In another engineering study (DeLaHunt et al. 1984), simulations were performed of gross energy savings in multifamily buildings that yielded an index of 2.8 kWh per square foot of glass for each 0.1 reduction in U-value.[2]

A similar index may be calculated for the multifamily retrofit buildings using the general proportion of dwelling area electricity savings (70%) estimated above to be associated with window measures. The calculation is based on four assumptions: a general U-value before retrofit of 1.10; a weighted average U-value after retrofit of 0.72; an average glass retrofit area of 106 square feet per unit; and estimated net dwelling area electricity savings of 1,050 kWh per year. The sensitivity of these savings to the glass U-value is conservatively estimated to be 1.83 kWh per square foot of glass area for each 0.1 reduction in U-value. (The building-level estimate of window savings, 86% of the dwelling area total, would yield a U-value sensitivity of 2.24.)

It seems reasonable that a lower value would be obtained in multifamily buildings than in the monitored and simulated single-family buildings. Multifamily buildings are less sensitive to external temperatures, and it is believed that they also experience lower infiltration rates than single-family buildings. As a result of these analyses, the value of 2 kWh per square foot of window area per 0.1 change in U-value has been adopted for the 1990 economic analysis of the Multifamily Conservation Program.

Lighting Measure Discussion

Two types of actions were taken with respect to common areas. A small amount of water heater conservation should have reduced the electricity consumption of common laundry facilities. A larger amount of conservation should have been derived from the installation of energy efficient lighting and controls. Buildings with lighting retrofits received compact fluorescent fixtures and lamps (interior or exterior) as well as exterior high-intensity discharge (high pressure sodium) lighting, as appropriate.

An analysis was performed to differentiate the electricity savings occurring in buildings with or without lighting fixture and lamp retrofits. The treatment buildings were separated into these two groups, and net electricity per-unit scores were derived using the single non-retrofit control group, to indicate the specific effects of lighting retrofits. Standard-income buildings were examined separately from low-income buildings.

Significant levels of savings were found accruing from the house meters which serve common areas of the multifamily buildings and surrounding grounds. It was found that 74% of the house-meter savings were generated by actual lighting retrofit measures, while 26% of the savings occurred in buildings that did not receive lighting retrofits. It is unlikely that building owners decided to retrofit lighting after program participation, due to previous inactions and the favorability of program financing. The major alternate hypothesis for these significant nonretrofit common-area electricity savings is that owners acted on auditor recommendations regarding the proper seasonal adjustments of existing lighting control systems, which were not being optimized at the time of the initial audit. It is also possible that some tenant unit water heaters may actually be wired to commercial house meters.

Future research needs to be done to reconfirm the few parameters that can affect the performance of lighting measures; viz. control methods, hours of operation, and retention and upkeep of measures as installed. Improved information is also required on the installation of water heat measures, to confirm which tanks are on residential versus commercial meters, and what conservation measures are applied within these categories. The interaction of showerhead measure outcomes with the location of water heaters--in heated or unheated spaces, before and after weatherization--should also be determined.

It is worth noting that the buildings receiving lighting retrofit measures attained nearly 80% of the electricity savings expected, based on an engineering estimate considering the pre- and post-retrofit wattages of lamps (bulbs) and ballasts. This difference between estimated and actual savings may be due to deviations from expected hours of operation. Actual operating hours should be reconfirmed by follow-on research to improve on the ability of auditors to accurately estimate electricity savings outcomes from lighting retrofit measures.

Summary of Measured Electricity Savings

Projected out into levelized savings streams, the net present values for 1986-87 participants are 5,556 megawatt-hours from standard-income buildings in Cohort I and 13,217 megawatt-hours from Cohort II. Similar projections for low-income buildings would be 1,975 megawatt-hours from Cohort Ia and 3,901 megawatt-hours from Cohort Ib (for a Cohort I low-income total of 5,876 megawatt-hours), and 9,334 megawatt-hours from Cohort II. The load reduction achieved in 1988 by these study buildings was 0.217 average megawatts.

Economic Analysis

Economic Analysis Overview

The present value of energy savings is computed from the electricity savings over the lifetime of the measures times the avoided cost of new resources as of 1986 (or 1990) in 1990 dollars. The net present value adds other economic benefits (such as increased comfort, reduced operating and maintenance costs, and reduced private investment due to the program), and subtracts the costs of the program (for measure installation, administration, and taxes). The net present value is computed as the sum of all economic benefits minus the sum of all economic costs. Those benefits and costs that occur over many years are computed as present values using a 3% real discount rate.

The levelized cost is defined at the constant unit value ascribed to the electricity savings in each time period such that the benefits are just equal to the costs. It is computed by dividing the present value of all economic costs by the present value of the electricity savings. Economic benefits accruing to customers and credits for conservation are excluded from this calculation. It should be kept in mind that, over the lifetime of the measures, the avoided cost of new resources is expected to continue to rise for the utility. Thus net benefits would tend to become more positive over time, and the levelized cost for the program participants would decline in future years.

A forecast model was used to project electricity savings, net of price overlap, through the year 2010 (for the 1990 program), beyond which electricity savings were assumed to maintain their 2010 value for the remaining life of the installed measures. The levelized cost to the Seattle City Light service area is defined as the regional cost minus any Bonneville Power Administration reimbursements through the Energy Buy-Back program.

A complete economic analysis was performed for the 1986-87 program years to provide background for the 1990 program economic analysis presented in Seattle City Light (1991). Separate levelized costs were calculated for the common area house-meter savings (lighting efficiency measures) and for the dwelling area tenant-meter savings (window, insulation, and water efficiency measures). For both the 1986-87 and the 1990 program economic analyses, comparison values were calculated from present values of electricity savings based on program-wide parameters that are not specific to each cohort's individual savings estimates.

Cost-Effectiveness of the 1986-87 Program

An economic analysis of the Multifamily Conservation Program was performed from the regional perspective.[3] All savings and costs are represented in 1990 dollars as of 1986. The load forecast model assumptions for this analysis were: measure lifetimes of 16 years for lighting and 30 years for all other measures; dwelling area savings of 1,050 (±5% error) net kWh per dwelling unit; common area savings of 520 (±15% error) net kWh per dwelling in buildings with house meters (or, 390 kWh per unit across all units, since about 75% of the units are in participant buildings installing common area measures); and electricity savings discounted at 3% per annum over the first 20 years. These assumptions add a degree of stability to estimates of the present value of energy savings for the low-income buildings, about which the evaluation findings leave some uncertainty. Thus the average level of savings for the entire program was 1,440 kWh per dwelling unit in 1988.

The 1986-87 standard-income study buildings had an estimated net present value to the region of ($-215,500), while the 1986-87 low-income study buildings had a net present value to the region of ($-980,600). The levelized cost of programmatic conservation for the standard-income study buildings was estimated to be 63 mills per kWh, while for the low-income buildings it was 81 mills. The avoided cost of production in 1986, for comparison, was 39 mills. The net benefits were ($-330) for standard-income and ($-821) for low-income buildings. These findings represent only the first two cohorts retrofitted during the pilot phase of the Multifamily Conservation Program.

Common-area efficient lighting was a very cost-effective measure to be added to the program mix, costing Seattle City Light only ten to twelve mills per kilowatt-hour (or $10 to $12 per mWh). With the switch to separate-ballast compact fluorescents in later years, this measure should become very cost-effective in terms of operations and maintenance (O&M) costs as well. There was no difference between standard-income buildings and low-income buildings in the cost-effectiveness of lighting retrofits. Likewise there was no difference between standard-income and low-income buildings in the cost-effectiveness of window measures.

The showerhead measure introduced gradually into the program appears to have provided extremely cost-effective savings. Efficient-flow showerheads presented a negligible cost in all years; when provided directly by the program they increased administrative supply expenditures by only $4 apiece. Sumi (1990) estimated for this same study group that the showerheads should provide about 480 to 660 kWh per unit-year of electricity savings in units where they were installed. Even at half this savings level (as the current electricity evaluation study suggests), showerheads remain very cost-effective.

Program Changes from 1986-87 to 1990

Seattle City Light also performed an analysis of the cost-effectiveness of the Multifamily Conservation Program, applied to program operations for the calendar year 1990. The two program elements--the grant program for low-income households and the loan program for standard-income buildings--were analyzed separately. From 1986 through 1990 there were 202 standard-income buildings and 264 low-income buildings served by the Multifamily Conservation Program. The total cost of the program from 1986 through 1990 was 4.6 million dollars for the standard-income portion and 7.4 million dollars for the low-income portion.

In 1990, the standard-income program served 1,020 households and the low-income program served 868 households. The cost of measures installed in 1990 was $1,803 (±18%) per standard-income dwelling unit, and $1,174 (±27%) per low-income unit. Administration costs and taxes were $540 (±6%) per standard-income unit and $254 (±11%) per low-income unit, in 1990 dollars. Other customer benefits, including thermostat setting "takeback" and reduced lighting operations and maintenance costs, were calculated at $236 per dwelling unit.

The most significant change affecting energy savings for the Multifamily Conservation Program in 1990 has been the changing market for retrofit windows over the five-year period. Since 1986 there has been a significant movement away from air-filled aluminum-framed windows (dropping from 82% of square footage in 1986 to 31% in 1990) and towards air-filled vinyl-framed windows (rising from 9% of square footage in 1986 to 55% in 1990). This shift has increased the overall energy efficiency of windows installed under the program (from an estimated average U-value of 0.72 to an estimate of 0.62 in 1990). Energy savings for 1990 have been increased by 200 (±100% error) kWh per unit to reflect these more energy-efficient windows. This adjustment is a result of multiplying an engineering estimate of energy savings of 2 kWh per square foot of window area per

0.1 drop in U-value by an average of 100 square feet of glazing area retrofitted per apartment unit.

Thus the energy savings estimates are the same for both portions of the program, averaging 1,640 (±19% error) kWh per dwelling unit (including both residential meter and commercial meter savings). The economic performance of both portions of the program may improve with the revised building code requirement to install more energy efficient windows (U-value ≤ 0.40) beginning in July 1991.

Cost-Effectiveness of the 1990 Program

The results of the analysis indicate that the loan program had a net present value to the region of $202,000, while the grant program has a net present value to the region of ($-614,000). These estimates have an accuracy of plus or minus $500,000. The likelihood that the true performance of the program provides a positive economic benefit is 70% for the standard-income portion and less than 1% for the low-income portion. A positive economic benefit indicates that the program may be providing electricity savings more cheaply than other alternative investment actions that could be undertaken.

The levelized cost of the loan program is estimated to be 47 mills under baseline assumptions, ranging from 38 mills under optimistic conditions to 60 mills under pessimistic conditions. The levelized cost of the grant program is estimated to be 78 mills under baseline assumptions, ranging from 64 mills under optimistic conditions to 94 mills under pessimistic conditions. The likelihood that the true levelized cost of the program is less than the avoided cost to Seattle City Light (41 mills in 1990) is only 17% for the standard-income portion and less than 1% for the low-income portion. These results indicate that there is a high likelihood that the electricity saved from the 1990 program participants is more expensive than other alternative actions that could be undertaken.

The evidence, then, indicates that in 1990 the loan portion of the program was cost-effective to the region under most circumstances; however, the grant portion was not. The primary reason for the difference in performance is that the grant portion is more costly (measures installation and administration) but delivers about the same level of energy savings as the loan portion. Possible reasons for higher costs include the required effort to determine if the applicant's tenants meet the income guidelines of the program, the need for more extensive rehabilitation of the structures for low-income participants, less flexibility in the choice and specifications of conservation measures, and differences in the method of obtaining competitive contractor bids.

Many of the benefits of the program accrue to customers throughout the Bonneville Power Administration region, more so than to those within Seattle City Light's service area. Participating customers are clearly better off in both programs. Net benefits per participating household from the standard-income portion of the 1990 program are $969, while for low-income households the net benefits are $1,648 in 1990 dollars. Meanwhile, net benefits per household in the service area are ($-326) for standard-income and ($-920) for low-income customers. Ratepayers in the region as a whole receive positive net benefits from the loan portion of the program, at $198 per participating household, while the net benefit of the grant portion of the program remains negative at ($-707) per household.

Conclusion

One purpose of this evaluation was to estimate the electricity savings for 1986 and 1987 participants in the Seattle City Light Multifamily Conservation Program. In the final analysis, house-meter use dropped 21% in low-income buildings and 36% in standard-income buildings, due to common area lighting measures. Low-income tenant-meter use decreased by 10%, while standard-income tenant meter use decreased by 14%, due to window, shell insulation, and hot water measures. The whole-building net electricity savings estimates were identical, however, for both low-income and standard-income participants, averaging 1,440 kWh per dwelling unit in 1988. By extrapolation, due to changes in window technology, a dwelling unit weatherized in 1990 would save 1,640 kWh. Under newer building codes, effective in mid-1991, a dwelling unit retrofitted in 1992 is expected to save 2,040 kWh.

In both absolute kilowatt-hour and percentage terms, the electricity savings measured for the Multifamily Conservation Program from buildings retrofitted in 1986 and 1987 represent a significant improvement over those measured for participants in the 1985 research and demonstration (R&D) project that preceded implementation of this program. Sumi and Newcomb (1987) found only 5% net savings, using several methods based on comparisons of means. Comparisons of median consumption scores yielded 6% to 10% savings estimates. Sumi and Newcomb had noted that, considering the small samples included in their study (15 treatment buildings and 9 controls), the comparisons of medians may have been a more reliable measure of typical building savings. For the Multifamily Conservation Program, we find that the low-income buildings performed at the level that Sumi measured, while the standard-income buildings saved more, especially the 1987 participants. These increased savings should be attributed to program improvements, such as the addition of efficient lighting and showerhead measures as the program has evolved.

The total measured electricity savings accumulated by the study participants were 497 megawatt-hours in 1987 and 1,900 megawatt-hours in 1988. These savings estimates under-represent the performance of the program as a whole. The study group participants (111 buildings, 1,449 units) comprise a subset of the total program participation (134 buildings, 1,846 units) during the program years 1986 and 1987.

The 1986-87 program was not found to be cost-effective to the region or the service area. However, it was determined that by 1990 the program was in fact cost-effective to the region for standard-income participants (at 47 mills) and not yet so for low-income participants (at 78 mills), under baseline conditions. Changing window technology, common-area lighting, and showerhead retrofits have been the primary drivers in improving the cost-effectiveness of this multifamily conservation program over the past five years.

Endnotes

1. See Emery et al. (1989). Also, related verbal communications from A. F. Emery and C. J. Kippenhan to Barbara Erwine, February 1991, regarding coefficient of heat transmission parameters.

2. See DeLaHunt et al. (1984). Also, related verbal communications from David Baylon to Barbara Erwine, 1991, regarding building simulation parameters; and calculations by Erwine, Seattle City Light.

3. Economic analyses were performed with the assistance of Allen F. Wilson, Energy Resource Planning and Load Forecasting Unit.

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