Persistence of Customized Commercial and Industrial Non-Lighting Energy Efficiency Installations

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ABSTRACT

This paper describes the methodology and results of a study of the persistence of savings from a large New England electric utilities' non-lighting customized energy efficiency installations. Measures, which were installed 2 to 3 years prior to the study, included commercial and industrial refrigeration, process, process cooling, HVAC, compressed air and comprehensive multi-end-use designs. Persistence was assessed through a review of billing records and program files, telephone interviews and on-site visits. Unlike most studies of persistence which assess persistence primarily through measure retention, this study paid particular attention to re-estimation of savings using the same algorithms as the original estimate of savings.

Results of a simple billing analysis were used to develop a telephone survey sample of 100 projects. To strengthen the information developed from the telephone surveys, on-site studies were conducted for 26 of the 100 phone surveyed sites. Results for these 26 sites were used to calibrate the results of the phone survey-based savings calculations using a double ratio method. The analysis option which showed the lowest relative precision produced realization rates of 1.024, 0.997 and 0.953 for kWh, summer kW and winter kW respectively. The relative precisions for these results ranged between 6 and 13 percent.

Lessons learned included the higher than expected persistence from larger, more complex efficiency measures, the cost savings and precision improvements associated with the use of less expensive phone surveys and a smaller number of more expensive on-site surveys and the importance of customer production output on savings persistence.

Introduction

In the spring of 1997, the NEES companies and RLW Analytics, Inc. conducted a persistence study of Custom measures installed through the utilities' retail affiliates' C&I New Construction and Retrofit programs. The goal of the study was to estimate persistence of energy and demand savings for the 262 non-lighting, non-drivepower Custom measures installed in 1994. Measures, which were installed 2 to 3 years prior to the study, included commercial and industrial refrigeration, process, process cooling, HVAC, compressed air and comprehensive multi-end-use designs. Eighty of these sites had an on-site evaluation in 1995. Persistence for these measures was assessed through a review of billing records, program file reviews, telephone interviews, and on-site visits. The study sought to compare results of a large number of phone surveys with a smaller number of on-site re-evaluations. A sample of 100 phone surveys and 25 on-sites was initially selected, with the on-site sample a subset of the phone sample.

Evaluation Design

The first step in the study was an analysis of 1994, 1995 and 1996 billing data of all 262 installations to determine which customers had large changes in usage and occupancy. The final sample was designed so that these customers had a higher probability of selection. In addition, the information on occupancy change and change in usage improved the telephone survey results by clueing the researchers into potential changes about which to query the customer. These changes might be indicative of an increase in the probability of poor persistence due to removal or inactivity of the installed measures.

The load was said to have changed if the average monthly usage increased or decreased by more than 20% from 1994 to 1995 or from 1995 to 1996. The occupancy was said to have changed if the account was closed or the tenant changed during these three years. In addition, each application was classified in terms of the prior on-site evaluation. The application was called a 'sample' application if it was included in the prior evaluation studies. Otherwise it was called an 'extrapolated' application because results of the prior on-site evaluations were extrapolated to those not evaluated sites.

Table 1 summarizes the results of the review of the billing records. All 262 applications were classified by the usage and occupancy changes and prior evaluation categories just described. The bottom row of the table shows that 176 applications had no change in load or occupancy. In developing the sample design, these 176 applications were put into class 1. By contrast, 51 applications had no change in occupancy but did have a 20% change in load, and 35 applications had a change in occupancy. These 86 applications were put into class 2. Table 1 shows similar counts for the 80 applications that were included in the first-year evaluation study, as well as the remaining 182 applications.

Table 1 also shows the total kWh savings in each category. This is the original gross kWh shown in the tracking system for each project. The largest total savings were in the no-change categories. Also the largest savings generally were in the 'sample' categories.

Table 1: Number of Applications and MWh Savings by Change Category and Prior Evaluation

		Applications				Annual MWh Savings			
Prior \Change	None	Load	Occupancy	Total	None	Load	Occupancy	Grand Total
Sample	48	21	11	80	18,545	9,712	1,773	30,031
Extrapolated	128	30	24	182	8,403	1,934	2,571	12,908
Grand Total	176	51	35	262	26,948	11,646	4,344	42,939

In order to develop an efficient sample design and to calculate its expected statistical precision, it was necessary to make assumptions about the variability in the target population. Table 2 summarizes the parameters assumed to develop the sample design for the telephone survey. In this application, beta, denoted, is the current savings as a proportion of the first-year savings. In other words, it is the retained savings in percentage terms. In class 1, we assumed that 90% of the savings would be retained, whereas in classes 2 we assumed that 70% of the savings would be retained. The error ratio is a measure of the variability between the retained savings of each application and the first-year savings. The error ratio was calculated from the equation:

$$ErrorRatio = \sqrt{\frac{1-\beta}{\beta}} \quad (1)$$

where β = estimate of persistence

Table 2: Modeling Assumptions for Telephone Survey

Class	Description	β	Error Ratio
1	No Change	.9	.3333
2	Change	.7	.6547

Using these parameters together with the tracking estimates of savings of the 262 applications, we used the Model-Based Statistical Sampling (MBSS™) sample design software to construct several different sample designs for the telephone survey. The planned sample size varied from 100 applications down to 18 applications, and the number of strata was either 5 or 3 within each of the two classes. Table 5 shows the expected statistical precision of each sample design. For example, for a sample of 100 of the 262 applications, we expected the relative precision to be about 2.9%. This means that, at the 90% level of confidence, we expected the survey estimate of current savings to be within 2.9% of the value that would have been obtained by telephone surveying all 262 customers. It does not mean that the survey is expected to be within 2.9% of the true value of current savings since a telephone survey is not a very reliable way to measure actual savings.

Table 3 shows how the expected statistical precision deteriorates as the sample size drops or the number of strata is decreased from 5 to 3. The results for samples of 25 and 18 were included because they were indicative of the precision that was expected from an on-site study unsupported by the telephone survey. For example, for a sample of 25 on-site studies with 5 strata, we expected the statistical precision to be about 18%.

Table 3: Expected Relative Precision of Alternative Survey Designs

Sample Size	Number Strata	Expected Relative Precision
100	5	0.029
100	3	0.053
60	5	0.079
60	3	0.108
25	5	0.185
18	3	0.275

Sample Design for the On-Site Studies

This section discusses the sample designs for the on-site studies, assuming nesting of the on-site sample within the larger telephone sample. For the applications with no change indicated in the billing data, i.e., applications in class one, we assumed the telephone survey would find that 90% persist and the remaining 10% were removed. Among the applications found to persist in the telephone survey, we expected 95% to persist in the on-site evaluations. By contrast, among the measures reported removed in the telephone survey, we expected 50% to actually be found to persist in the on-site evaluations. This estimate turned out to be high, as the final telephone survey and on-site estimates were relatively close.

In the case of the applications shown to have changed load or occupancy in the billing data, we assumed somewhat lower probabilities of persisting. For example, among the measures reported removed in the telephone survey in this group, we expected only 25% to actually be found to persist in the on-site evaluations. Again, this estimate turned out to be high.

In the case of the on-site audits, we developed sample designs using sample sizes from 25 to 18 and either 5 or 3 strata as before. We chose combinations of sample size and number of strata that allowed a balanced allocation of the sample to each stratum within each of the two classes. Table 4 summarizes the results. In this case, the expected statistical precision was the component of precision uniquely associated with the on-site sample. In other words, it was the precision that would have been expected by combining the on-site sample with a telephone survey of all 262 applications. As we decrease the sample size or the number of strata, the statistical precision tends to decrease. The sample of 25 on-site evaluations was predicted to substantially better statistical precision.

Table 4: Expected Relative Precision of Alternative On-Site Designs

Design	Sample Size	Number Strata	Expected Relative Precision
1	25	5	0.151
2	24	3	0.183
3	20	5	0.180
4	18	3	0.221

The statistical precision that was expected from various combinations of survey and on-site study sample size was then studied. Practically speaking, it was best to use the same number of strata in each of the two sample designs. Results indicated there was little improvement in going from an 80-application telephone survey to an 100-application telephone survey. In practice, however, reducing the telephone survey from 100 applications to 80 applications would have decreased the cost very little since much of the expense is in planning, training, and set up. Moreover, an 100-application survey provided an additional level of comfort with the evaluation. The 5 strata 100 telephone, 25 on-site survey provides a three percentage point higher precision than the survey with only 20 on-site and thus was selected. A total of 26 on-site surveys were actually completed.

Data Collection and Interpretation

Telephone Surveys

The telephone surveys were used to provide estimates of whether or not peak kW and annual kWh estimates had persisted ("0/1" estimates), as well as first-pass quantitative estimates, "detailed estimates", of the persisted peak kW and kWh savings. These detailed estimates incorporated a finer level of detail on changes to the equipment and its use. While these telephone survey-based savings estimates were recognized to have significant shortcomings, the intent was to provide a better estimate of persisting savings than was currently available for comparison to the results of the detailed on-site assessments. The 0/1 analysis was conducted to protect against the possibility that the detailed estimate based on the phone survey results produced a flawed re-estimate of savings due to lack of sufficient information. In addition, we wanted to test the accuracy of results using the less costly 0/1 approach.

The following describes how the phone survey responses were used to develop both 0/1 estimates of persistence, as well as more detailed estimates of peak kW and annual kWh estimates of persisted savings. For both analyses, any changes had to occur after the time of the mid-1995 impact evaluation. This rule was established to avoid double counting of changes in savings between the first-year impact evaluation in 1995 and this 1997 study.

0/1 Approach

In the 0/1 approach, the savings for an entire project or for a portion of a project were set to 0 or 100% of the 1995 valuation. A portion of a project was set to zero if an entire piece of equipment was no longer in use. For example, if two of three equal sized air compressors at a site were removed, the result was set to 33%. The result for a project or measure was set to zero if:

- The billing data, the telephone investigation, and/or a drive by on-site conducted revealed that the site was closed and that the equipment was not currently being used; or
- The customer reported: 1) measure was no longer in use; 2) hours were reduced to a negligible amount (set at 200/yr); or 3) measure conditions had reverted to the same or less efficient state than the base case.

Detailed Estimate

Under the detailed savings approach, additional adjustment beyond the 0/1 approach, were made to the evaluated savings based on the following:

- In general, any percent changes in hours reported were used to adjust peak demand and annual energy savings in a linear fashion. For example, if the hours during the summer peak period were reduced by 25% for a piece of manufacturing equipment, the summer peak demand savings were reduced by 25%. Where the documentation in the file review provided enough information to develop a more informed estimate based on differences in savings across the day, a detailed analysis of the savings during the specific hours of change were made and used as appropriate to increase or decrease the savings by the appropriate quantity. For example, if EMS setpoints were adjusted to further reduce cooling in evening hours, an attempt was made to determine the additional savings for these hours in particular.

- Savings were adjusted to reflect other changes described in the responses to the telephone survey provided the changes confirmed that it was after mid-1995, and that this condition was permanent <u>or</u> expected to last for an extended period (arbitrarily set at three months or more). For example, if the setpoints for an EMS system were changed, the site savings were adjusted based on engineering adjustments to the estimation approach found by reviewing each project file.

Summary of Telephone Survey Responses

In the telephone survey of 100 projects, surveyed participants were asked if the measures that they installed through program participation were still installed and operating. Of the 100 projects in the sample, 92 were still in use, 4 had all of the installed equipment out of service, and 4 had some of the installed equipment out of service. For those 8 measures that were not completely in use, participants were asked to give an explanation as to why. Of the eight measures, four customers had left the facility, three stated the measure did not work properly, and one moved equipment to another plant.

Many more sites made more subtle changes to existing measures. These changes were analyzed in the "detailed" analysis to estimate effects on energy and peak demand. Questions on changes in hours of use and changes in measure use informed this analysis. Survey responses indicated that for most sites, where hours of use had increased, the increase was due to an increase in production. For those sites where a decrease occurred, the explanation was often that the customer was trying to further reduce their electric bill by reducing the operation of the measure of the equipment the measure was installed with. The same held true for those explanations as to why measure use had changed. Again increase in production was the underlying factor. For all changes, participants were asked to indicate if the changes were temporary or permanent. Of the 34 changes, 17 were permanent increases, 6 were temporary decreases, and 11 were permanent decreases.

On-Site Survey Data Analysis

To strengthen and validate the information collected as part of the phone surveys, 26 on-site evaluations were done. The 26 on-sites were all part of the original sample of 80 on-site evaluations done in 1995. In order for the on-site surveys to be a true determination of measure persistence and not simply a different calculation of savings by another engineer, all on-site evaluations were done by the same contractor who performed the original on-site evaluation in 1995. For the most part, the same methodology used in the original 1995 on-site evaluation was used again in the 1997 follow-up evaluation.

In the course of the 1997 on-site evaluations the contractors found errors in their original 1995 analyses. The impact of these errors, which were corrected in the 1997 analyses, was included in the calculated persistence realization rates. There were also a few instances when data on equipment loading available in 1997 was not available in 1995. The better loading information was used for the 1997 analysis and therefore also included in the calculation of the persistence realization rates. Though these realization rates are not necessarily related to persistence, their impact was included in the analysis to be conservative. The impact for most cases resulted in a decrease in the persistence realization rates.

Statistical Analysis and Findings

Analysis of the On-Site Data Standing Alone

Table 5 summarizes the data for the 26 sample sites. The "evaluated" statistics are based on the results of the first-year evaluation. The "on-site" results are based on the 1997 persistence on-sites. All statistics are calculated using case weights based on the sample design. The totals are extrapolated to the population of 262 sites.

The largest percent of the unweighted aggregate savings decreases were due to equipment removal and more accurate information on building loads. The largest percent increases in savings were due to increases in production, changes in setpoints for free cooling economizers, and changes in the door positioning of a fume hood ventilation system.

The on-site studies reported actual current MWh savings as well as summer and winter demand savings. Based on the on-site results, the population-level 1997 MWh savings estimates are actually slightly higher than the 1995 evaluated MWh savings. This trend indicates increased operating hours, increased production or the adoption of added measures since the original installation. The demand savings were slightly smaller.

Table 5: On-Site Sample Descriptive Statistics

Savings Variable	Total	Mean	Standard Deviation
Evaluated MWh	37,284	142.307	282.806
Evaluated summer kW	4,585	17.498	43.869
Evaluated winter kW	4,837	18.461	45.450
On-site MWh	37,275	142.271	302.344
On-site summer kW	4,404	16.808	40.035
On-site winter kW	4,736	18.076	42.534

Figure 1 shows the scatter plot of on-site MWh against 1st year evaluated MWh savings. The graph shows that there is a strong association between the two variables. The graph also shows that there is one exceptionally large project in the sample.

Figure 1: On-Site MWh vs. Evaluated MWh

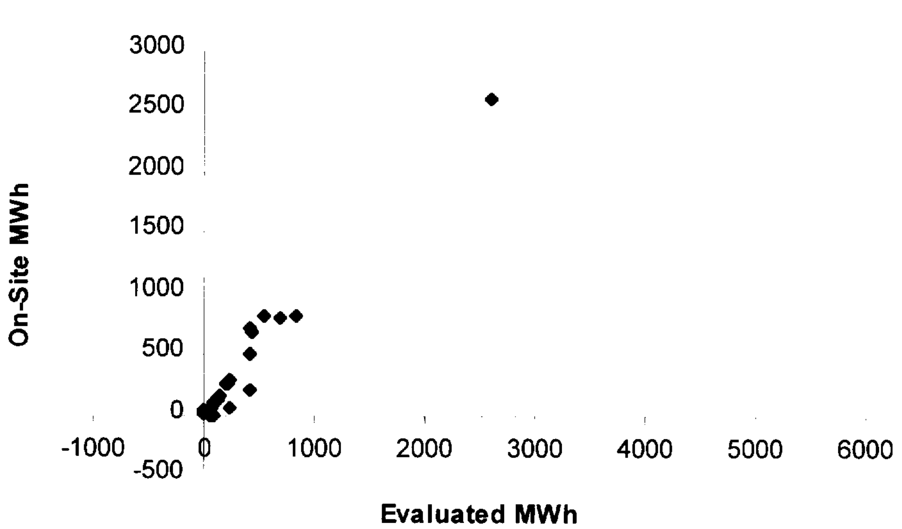

Table 6 shows the realization rates and relative precision based on the on-site results. The results show that the current on-site MWh savings are -.02% smaller than the 1st year evaluated MWh savings. Conversely, the summer and winter demand realization rates are 0.96 and 0.98 respectively, indicating that the current on-site demand savings are 4% and 2% smaller than the 1st year evaluated demand savings.

At the 90% level of confidence, the relative precision of the energy savings result was 12.6%. In the case of summer and winter demand savings, the relative precision was 7.5% and 13.4%, respectively.

Table 6: On-Site Survey Estimates of Current Savings

On-Site Savings Variable	Realization Rate	Relative Precision	Estimated Total
MWh	.9998	0.126	40,497
Summer kW	.9606	0.075	7,463
Winter kW	.9791	0.134	**5,261**

Analysis of the On-Site Data with the Telephone Survey Data

The experimental design included a telephone survey of 100 sites selected from the population of 262 sites, following a stratified sampling plan. The survey was designed to provide two types of estimates of the current savings of each project in the sample: the 0/1 approach and the detailed estimate approach, both discussed earlier. The survey data was combined with the on-site information collected for the 26 on-site sample sites using double ratio estimation. This was a two-step approach. In the first step, the ratio was calculated between the survey estimate of current savings, using the data from the 100-site phone survey sample, and the first-year evaluated savings for the same sites. In the second step, the ratio was calculated between the on-site estimate of current savings and the phone survey estimate of current savings, using the data from the 26-site on-site sample. The final realization rate was obtained as the product of the two ratios. This analysis was carried out using both the 0/1 survey results and the detailed survey assessments.

0/1 Result

Table 7 reports the sample descriptive statistics. Statistics are reported for both the first-year evaluated savings and the 0/1 estimates of the current savings.

Table 7: 0/1 Telephone Survey Sample Descriptive Statistics

Savings Variable	Total	Mean	Standard Deviation
Evaluated MWh	41,311	157.676	492.544
Evaluated Summer kW	7,251	27.674	106.591
Evaluated Winter kW	4,954	18.908	50.029
Telephone 0/1 MWh	39,477	150.675	493.004
Telephone 0/1 Summer kW	7,105	27.117	106.636
Telephone 0/1 Winter kW	4,531	17.295	50.141

The following figure shows a scatterplot relating 0/1 measures of current kWh and first-year evaluated savings. The graph shows a very high correlation between 0/1 current savings and first-year savings. The graph also shows that the only projects with zero current savings were very small.

Figure 2: 0/1 Telephone MWh vs. Evaluated MWh

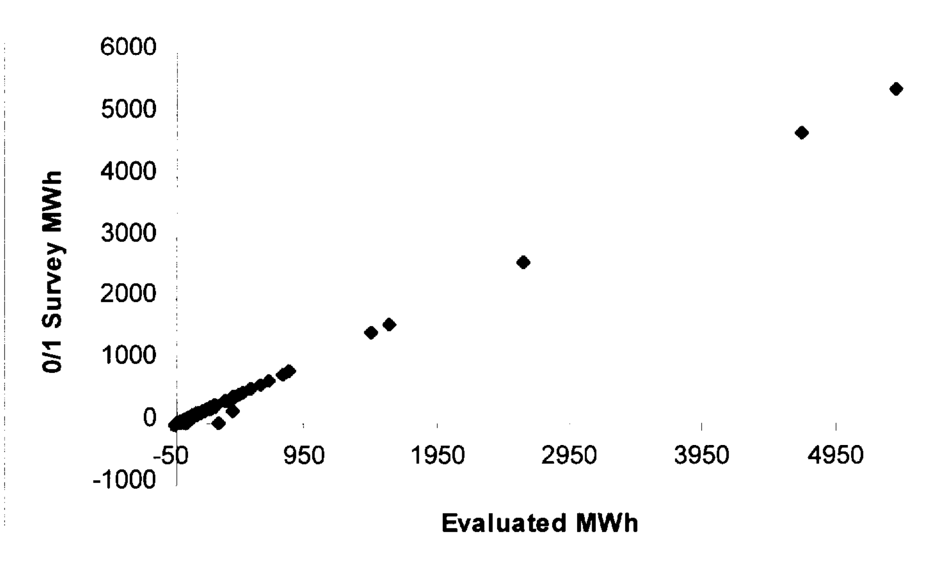

Table 8 shows the first-stage estimates of total current savings as well as the corresponding error bounds, relative precision and realization rates. The results depict the first-stage realization rates relating 0/1 survey estimates to the first-year evaluated savings. These rates are 96% for MWh, 98% for summer demand, and a somewhat lower 91% for winter demand. Note that the relative precision for summer kW, which is less than 8%, is excellent, while relative for MWh and winter kW at less than 14% is good.

Table 8: 0/1 First Stage Estimates of Current Savings

0/1 Savings Variable	Relative Precision	Realization Rate	Estimated Total
MWh	2.4	0.9556	38,709
Summer kW	1.5	0.9799	7,613
Winter kW	5.9	0.9147	4,915

The next step in the analysis was to combine the survey and on-site data. Table 9 shows the descriptive statistics for the 0/1 survey estimates using the on-site sample of 26 sites.

Table 9: 0/1 Descriptive Statistics for the On-Site Sample of 26

0/1 Savings Variable	Total	Total	Mean	Standard Deviation
Telephone 0/1 MWh	34,770	34,770	132.708	280.866
Telephone 0/1 Summer kW	4,332	4,332	16.534	43.791
Telephone 0/1 Winter kW	4,544	4,544	17.344	45.414

Scatterplots relating on-site measures of current kWh and summer kW savings with the corresponding 0/1 measure of current savings from the survey also show very high correlations. Table 10 shows the second-stage realization rates relating the on-site results to the 0/1 survey estimates for the 26 on-site applications. These realization rates can be calculated as the ratio between the on-site sample values reported in Table 9 and the survey-based values reported in Table 5. Results show that the current on-site MWh savings, summer kW and winter kW, are 7.2%, 1.7%, and 4.2% larger than the 0/1 estimates, respectively.

Table 10: 0/1 Second Stage Realization Rates

Savings Variable		Realization Rate
14	MWh	1.072
15	Summer kW	1.017
16	Winter kW	1.042

The overall realization rate can be calculated as the product of the first and second stage results reported above. Table 11 shows the results. Based on the 0/1 survey estimates combined with the on-site results, the overall realization rates are estimated to be 1.024 for MWh, 0.997 for summer kW and 0.953 for winter kW. Note that the relative precision is quite good for MWh, excellent for summer kW, and slightly poorer for winter kW.

Table 11: 0/1 Combining Stage 1 and Stage 2 Realization Rates

Savings Variable	1st Stage Realization Rates	2nd Stage Realization Rates	Combined Realization Rates	Combined Relative Precision
MWh	0.9556	1.0720	1.0244	.095
Summer kW	0.9799	1.0170	0.9966	.062
Winter kW	0.9147	1.0420	0.9531	.129

Detailed Assessment Results

A similar double ratio estimation analysis was carried out using the detailed survey estimates of current savings together with the on-site results. Table 12 shows the descriptive statistics for the detailed survey assessment of the 100 applications in the telephone survey.

Table 12: Detailed Assessment Survey Descriptive Statistics

Detailed Savings Variable	Total	Mean	Standard Deviation
MWh	39,952	152.487	512.255
Summer kW	7,144	27.266	106.811
Winter kW	4,571	17.446	**50.272**

Table 13 summarizes the first-stage analysis of the detailed survey data for the 100 applications for the telephone survey sample. The results depict the first-stage realization rates relating the detailed survey estimates to the first year evaluated savings, as well as the corresponding relative precision. Note that the relative precision is excellent for all three variables. These rates are 96.7% for MWh, 98.5% for summer demand, and a lower 92.3% for winter demand.

Table 13: Detailed Assessment First Stage Estimates of Current Savings and Realization Rates

Detailed Savings Variable	Estimated Total	Relative Precision	Realization Rate
MWh	39,174	0.025	0.9671
Summer kW	7,655	0.015	0.9853
Winter kW	4,958	0.059	0.9227

The next step in the analysis was to combine the detailed survey and on-site results for the 26 applications in the on-site sample. Table 14 shows the descriptive statistics for the detailed survey estimates using the on-site sample. The results show that the current MWh savings based on the on-site results are about 6% larger than the detailed MWh savings based on the surveys. Conversely, the summer kW realization rate is 1.01, indicating that the current summer peak demand savings from the on-site studies are 1% higher than the detailed survey-based estimates.

Table 14: Detailed Assessment Second State Estimates of Current Savings and Realization Rates

Detailed Savings Variable	Estimated Total	Realization Rate
MWh	35,065	1.0630
Summer kW	4,360	1.0100
Winter kW	4,571	1.0360

The overall realization rate can be calculated as the product of the first and second stage results reported above. Results are shown in Table 15. Based on the detailed survey estimates combined with the on-site results, the overall realization rates are estimated to be 1.028 for MWh, 0.995 for summer kW and 0.956 for winter kW.

Table 15: Detailed Assessment Final Estimates of Current Savings

Savings Variable	1st Stages	2nd Stages	Realization Rates Combined	Relative Precision
MWh	0.9671	1.0630	1.0280	0.096
Summer kW	0.9853	1.0100	0.9952	0.061
Winter kW	0.9227	1.0360	1.0284	0.129

Comparing the Alternative Estimates

Table 16 shows the estimates of the total savings and corresponding error bounds using the three different approaches: (a) using the on-site data directly, (b) using the on-site data with the 0/1 results from the telephone survey, and (c) using the on-site data with the detailed results from the telephone survey. The most appropriate way to choose between these alternative approaches is to select the methodology that provides the smallest error bound. It is clear from the table that the use of either set of results from the telephone survey sample of 100 was effective in reducing the error associated with results based solely on the on-site sample of 26. The table results further indicate very little difference between the error bounds and savings estimates from the 0/1 survey and the detailed survey methods. Given the cost savings and reduction in customer effort associated with using a 0/1 type survey versus a more detailed survey with more complicated savings calculations, the 0/1 survey approach combined with the nested on-site sample was most cost-effective.

Table 16: Alternative Savings Estimates

Savings Variable	On-Sites Alone		0/1 Survey		Detailed Survey	
	Estimated Total	Error Bound	Estimated Total	Error Bound	Estimated Total	Error Bound
MWh	40,497	5,116	41,498	3,962	41,643	3,999
Summer kW	7,463	563	7,739	478	7,733	474
Winter kW	5,261	702	5,122	660	5,136	662

Summary

Table 17 summarizes the results of this study. The most reliable results were obtained by combining the 0/1 survey results from the telephone surveys for the stratified sample of 100 sites with the on-site assessments carried out for the subsample of 26 sites. The table shows the final estimate of the realization rate of the current savings relative to the first-year evaluated savings, and also the associated relative precision and 90% confidence interval for the realization rate, based on the relative precision.

The realization rates were estimated at 1.024 for MWh, 0.997 for summer kW and 0.953 for winter kW. The relative precision of these results was ±9.5%, ±6.2% and ±12.9%, respectively. The 90% confidence intervals all span the value 1.00. From this it can be concluded that there has been no statistically significant loss of savings relative to the first-year evaluated savings.

Table 17: Evaluation Results

	Realization Rate	Relative Precision	Lower Bound	Upper Bound
MWh	1.024	0.095	0.927	1.122
Summer kW	0.997	0.062	0.935	1.058
Winter kW	0.953	0.129	0.830	1.076

Lessons Learned

The primary lessons learned from this study are:

- Persistence of more complex customized energy-efficiency measures was very high due to high levels of measure retention and production increases.
- Moving from using measure retention alone as an indicator of persistence can be improved upon by using savings persistence;
- Using a double ratio estimation technique which involved a larger number of phone surveys calibrated with a smaller number of on-site visits significantly improved precision over the results using a small number of on-sites alone, and
- A brief phone survey assessing whether or not equipment was still in place and in use was sufficient. The more detailed analysis of the data from the phone survey sample of 100 added no increase in precision.