Impact Evaluation Analysis of the 2005 Custom SBS Program

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Introduction

This report provides estimates of the realization rates and statistical precision for the Custom SBS program measures installed in the year 2005 Small Business Services Program.

Purpose of this Study

This study has the following purposes:

1. To provide a statistical analysis of the engineering studies carried out for the Lighting, Refrigeration and Other categories of Custom SBS measures installed in year 2005 in the Small Business Services Program,
2. To assess the error ratios, i.e., the measures of variability, to be used in developing the sample designs for future studies, and
3. To draw together the results of the study to:
   - Provide unbiased estimates of the collective realization rate of all projects in the program population,
   - Summarize the overall savings,
   - Determine the statistical precision for all Custom SBS measures installed in year 2005 in the Small Business Services Program.

Scope

The scope of the analysis includes National Grid's four New England distribution affiliates: Massachusetts Electric Company, The Narragansett Electric Company, Granite State Electric Company, and Nantucket Electric Company[1].

[1] Granite State Electric Company did not participate in this study. However, if the population of SBS custom projects in New Hampshire is similar to the projects in Massachusetts and Rhode Island, the results from this study may be applied to Granite State custom projects as well.

Methodology

The population realization rate is the ratio of the evaluated savings for all population projects divided by the tracking estimates of savings for all population projects. Of course, the population realization rate is unknown, but it can be estimated by evaluating the savings in a sample of projects. The sample realization rate is the ratio between the weighted sum of the evaluated savings for the sample projects divided by the weighted sum of the tracking estimates of savings for the same projects. The sample realization rate is equivalent to the usual stratified ratio estimator of the population realization rate. The total tracking savings in the population is multiplied by the sample realization rate to estimate the total evaluated savings in the population.

When sample data are used to estimate the characteristics of a particular population, the accuracy of the results depends on the weights applied to each case in the sample. The case weight is defined to be the ratio between the number of projects in each stratum of the population divided by the number of projects in the corresponding stratum in the sample. As long as the sample projects are randomly selected from each stratum, the sample realization rate is a virtually unbiased estimator of the population realization rate.[2]

Model-based methods have been used to post-stratify the sample projects to reflect the 2005 population, to calculate the corresponding weights and realization rates, to estimate the statistical precision of the results, and to calculate new estimates of the error ratios. The error ratios are used to plan the sample sizes and to estimate the statistical precision to be expected from new studies as described in [1].

[2] Technically the ratio estimator is biased but in practice the bias is negligible with a properly stratified sample design.

The Population and Sample

Table 1 summarizes the 2005 tracking information used in the analysis. The table shows the gross first-year annual and on-peak energy savings in MWh, and the gross summer and winter demand savings in kW. The Refrigeration category had the most projects but the Lighting category the greatest savings. The Other category had only 24 projects but they were very large, yielding almost as much savings as the 92 Lighting projects.

Table 1: Tracking Statistics

Category	*Number of Projects*	*Gross Annual MWh*	*Gross On-Peak MWh*	*Onsite Summer kW Reduction*	*Onsite Winter kW Reduction*
Lighting	43	830	519	251	221
Refrigeration	92	461	170	94	94
Other	24	374	151	82	61
Total	159	1,664	840	427	376

Table 2 summarizes the number of sample projects used to develop the 2005 savings. This study made use of detailed engineering analysis of 20 evaluation projects. All projects were selected following statistical sampling plans as discussed in [1].

Table 2: Sample Sizes

Category	*Sample Size*
Lighting	10
Refrigeration	5
Other	5
Total	20

Case Weights

The sample projects were selected from the population of 2005 program participants. We extrapolated the results to the same population. We constructed new strata using a technique called balanced stratification.

In this technique, the projects in the sample were sorted in increasing order according to the value of tracking annual savings of each project and then divided equally among the strata. The stratum boundaries were calculated as the midpoint between the tracking

annual savings in adjoining strata. Then the stratum boundaries were used to tabulate the number of projects in each stratum in the 2005 population, and, finally, the case weight was calculated as the number of projects in the population divided by the number of projects in the sample in the stratum.

Table 3 shows the case weights that were used to extrapolate the available sample sizes to the 2005 population. For example, in stratum 1 of the lighting category, the stratum boundary was calculated as the midpoint between the tracking annual savings of the second and third projects in the sorted list. So stratum 1 consisted of all projects with tracking annual savings less than or equal to 10 MWh. The 2005 population contained 22 such projects and the sample two such projects so the case weight was 11.

Table 3: Case Weights

Category	*Stratum*	*Maximum Annual MWh*	*Total Annual MWh*	*Population*	*Sample*	*Case Weight*
Lighting	1	10	51	22	2	11
Lighting	2	22	122	7	2	3.5
Lighting	3	38	170	6	2	3
Lighting	4	56	187	4	2	2
Lighting	5	100	300	4	2	2
Refrigeration	6	3	52	27	1	27
Refrigeration	7	4	72	21	1	21
Refrigeration	8	5	87	18	1	18
Refrigeration	9	8	93	15	1	15
Refrigeration	10	37	157	11	1	11
Other	11	8	44	9	1	9
Other	12	14	58	5	1	5
Other	13	22	81	4	1	4
Other	14	30	78	3	1	3
Other	15	40	113	3	1	3

As shown in Table 3, both the number of projects in the population and the case weights tended to decrease from stratum to stratum in all categories.

Results

Table 4 summarizes the estimated realization rates obtained from the statistical analysis. The top row of the table shows the estimated realization rates for the Lighting category. The next two rows show the estimated realization rates for the Refrigeration category and the Other category. The final row shows the overall realization rate for the three measure categories taken together. We estimated the annual MWh realization rate to be 103.6% for Lighting and 159.6% for Refrigeration and 81.3% for Other. Combining the three categories, we estimated a realization rate of 114.1% for the annual MWh savings of all 2005 projects in all categories. This indicates that the annual savings would be found to be about 14% greater than the gross savings from the tracking system if all 2005 projects were to be evaluated. The percentage on-peak realization rates are also presented in the final column of Table 4.

Table 4: Realization Rates

Category	***Gross Annual MWh***	***Gross On-Peak MWh***	***Onsite Summer kW Reduction***	***Onsite Winter kW Reduction***	***Percent On-Peak***
Lighting	103.6%	110.0%	107.1%	115.0%	106.2%
Refrigeration	159.6%	178.8%	149.4%	69.4%	112.0%
Other	81.3%	61.6%	76.7%	52.6%	75.8%
Total	114.1%	115.3%	110.6%	93.4%	101.1%

If the realization rate is greater than one, the total evaluated savings estimated in the population is greater than the total tracking savings for the corresponding category. This occurred, for example, with the annual energy savings for Lighting and Refrigeration where the realization rates were 103.6% and 159.6% respectively. In contrast, the realization rate was only 81.3% for the Other category. The realization rates for the on-peak MWh savings were roughly similar to the realization rates for the annual savings. However the realization rates for the on-peak MWh savings were somewhat higher for the Lighting and Refrigeration categories and somewhat lower for the Other category.

The realization rates spanned a wider range for the demand impacts compared to the energy savings. For example, the realization rate was only 52.6% for Other winter demand reduction whereas it was 149.4% for summer Refrigeration demand reduction.

Figure 1 shows the sample data underlying the realization rate for the annual savings in the Lighting category. The figure has been obtained by multiplying both the tracking and measured savings of each sample project by the case weight associated with the project and then creating a scatter plot of the results. We have also plotted the line through the origin with slope equal to the realization rate estimated from the sample projects. If each of the sample projects had the same realization rate, then all of the points would lie along this line.

In the case of Lighting, Figure 1 shows that most of the ten sample points were rather close to the line, indicating that the realization rate was rather consistent from project to project.

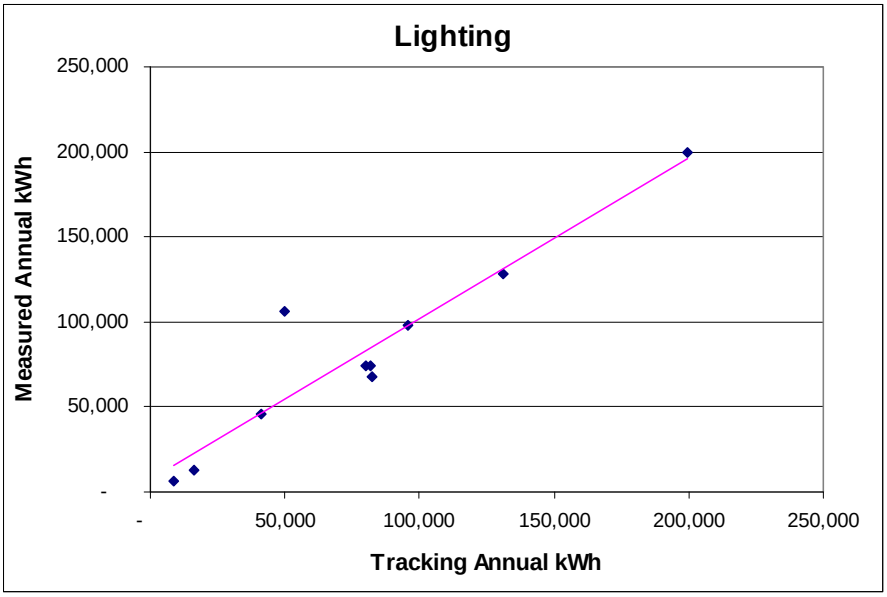

Figure 1: Measured vs. Tracking Weighted Annual Savings for Lighting

Figure 2 shows a similar graph for the Refrigeration sample. In this case the points were less scattered around the line, again indicating that the realization rate was rather consistent from project to project.

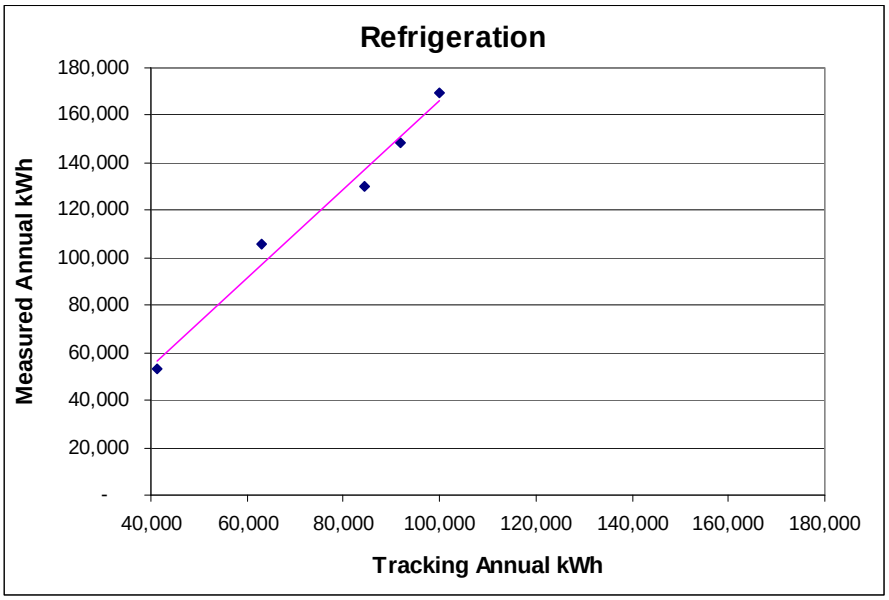

Figure 2: Measured vs. Tracking Weighted Annual Savings for Refrigeration

Figure 3 shows a similar graph for the five projects in the Other sample, but the points were more scattered around the line, indicating that there was higher variation in the realization rate from project to project.

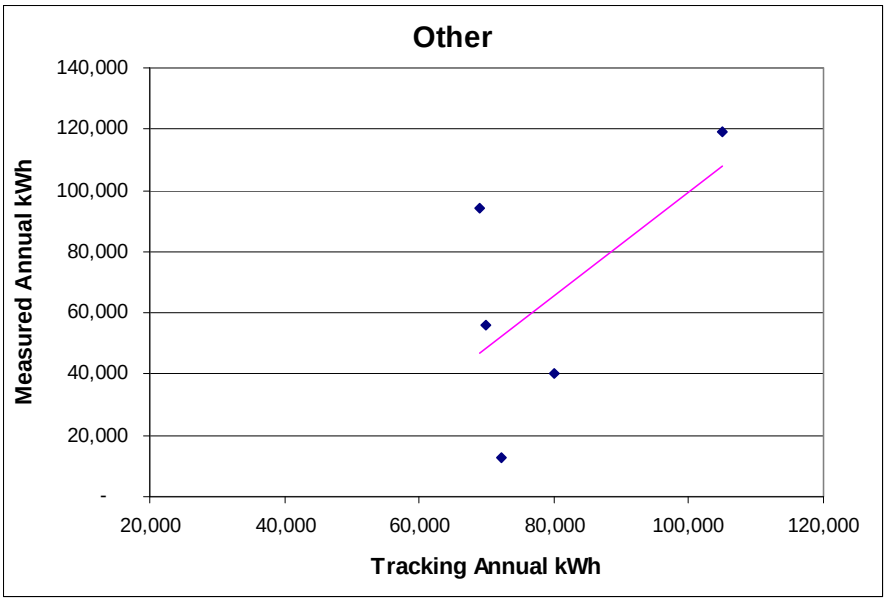

Figure 3: Measured vs. Tracking Weighted Annual Savings for Other

Statistical Precision

Table 5 reports the relative precision obtained for each measure of impact for each category and over all three categories taken together, calculated at the *90%* level of confidence. The overall relative precision for annual savings was ± 7.2%. The overall relative precision for the on-peak energy impacts and the summer and winter demand impacts was in the range ±13.7% to ± 22.7%.

In [1] it was estimated that the sample designs would yield an overall relative precision of ± 17% for annual energy savings, assuming an error ratio of 0.5 for all measures. So the achieved relative precision was higher than what was assumed during the planning stage.

Table 5: Relative Precision at the 90% Level of Confidence

Category	***Gross Annual MWh***	***Gross On-Peak MWh***	***Onsite Summer kW Reduction***	***Onsite Winter kW Reduction***
Lighting	10.0%	20.9%	19.2%	30.3%
Refrigeration	4.7%	6.9%	8.6%	25.8%
Other	33.1%	58.7%	67.0%	38.2%
Total	7.2%	13.7%	14.3%	22.7%

The statistical precision was generally better for the total impact than for individual categories. This is because the error of estimation is independent from one category to another. Therefore when the results are pooled across categories, underestimates in some categories will tend to be offset by overestimates in other categories.

The statistical precision was generally good for Lighting and Refrigeration, and was higher for Other measures. The statistical precision reflects the variation displayed in the scatter plots shown in Figure 1 through Figure 3 as well as the sample sizes shown in Table 2. In the Lighting category, the relative precision was about ±10% whereas the precision was expected to be about ±23% in the sample design. In the Refrigeration category, the relative precision was about ±5% whereas the precision was expected to be about ±36% in the sample design. This accounts for much of the drop in the overall precision below expectation.

The precision was generally better for annual energy savings and summer demand savings than for on-peak savings and winter demand savings. The poorest relative precision was ± 67% for the summer demand impacts for the Other category.

Considering the total savings of all measures, the statistical precision was very good for annual energy savings and the worst for winter demand savings. This indicates that the tracking estimates are more accurate for annual energy savings than for the remaining categories of savings. This may be due to unavoidable uncertainty about the time of use or operating schedule of some of the measures at the time that the tracking estimate of savings was developed. However the statistical precision of the summer demand savings and the gross on-peak savings were reasonable.

Table 6 reports the relative precision obtained for each measure of impact for each category and over all three categories taken together, calculated at the *80%* level of confidence.

Table 6: Relative Precision at the 80% Level of Confidence

Category	*Gross Annual MWh*	*Gross On-Peak MWh*	*Onsite Summer kW Reduction*	*Onsite Winter kW Reduction*
Lighting	7.8%	16.3%	15.0%	23.6%
Refrigeration	3.6%	5.4%	6.7%	20.1%
Other	25.8%	45.7%	52.2%	29.8%
Total	5.6%	10.7%	11.2%	17.7%

Estimated Savings

The estimated realization rates, Table 4, can be multiplied by the tracking estimates of savings reported in Table 1. This yields an estimate of the actual energy and demand savings for each measure category and in total. The corresponding error bound can be obtained by multiplying the estimated savings by the relative precision shown in Table 5. If desired, a 90% confidence interval can be obtained as the estimated savings plus or minus the error bound. It is useful to look at the estimated evaluated savings and error bounds in order to understand the contribution of each measure category to the total savings and combined error bound

Table 7 shows the results. In terms of evaluated annual savings, the largest category is Lighting, which is estimated to contribute over 860 MWh of annual savings. Refrigeration also contributes substantial added savings. The largest error bound comes from the Other category, with an error bound of ± 93 MWh. The Lighting category also has a large error bound of ± 86 MWh. These categories with relatively large error bounds contribute the most to uncertainty about the overall savings and the realization rate of the program.

Table 7: Estimated Evaluated Savings and Error Bounds

Category	*Gross Annual MWh*	*Error Bound*	*Gross On-Peak MWh*	*Error Bound*	*Onsite Summer kW Reduction*	*Error Bound*	*Onsite Winter kW Reduction*	*Error Bound*
Lighting	860	86	571	119	269	52	254	77
Refrigeration	735	34	305	21	141	12	65	17
Other	282	93	93	54	63	42	32	12
Total	1,899	137	969	133	472	68	351	80

Table 7 also shows the total estimated savings of the three measure categories as a whole. In the case of total annual savings, the 90% confidence interval is 1,899 MWh ± 137 MWh. The error bound of the total program is substantially less than might be expected from the error bounds of the three individual categories. This is because the random sampling errors in the three categories are expected to balance out.[3]

Planning Future Studies

The information developed in the present study can be used to help plan future studies of the Custom SBS program. Some important insights can be drawn from Table 7. Those measure categories with the largest error bounds contribute the greatest uncertainty to the overall program impact. This suggests that added attention might be given to the Lighting and Other categories. In choosing the sample size for Lighting and Other, the company should balance the evaluation cost against the expected statistical precision.

The statistical precision of a new study is primarily determined by the new sample size together with the variability in the population. For stratified ratio estimation the appropriate measure of variability is a population parameter that is called the error ratio. In the context of impact evaluation, the error ratio is a measure of the variability between the evaluated savings and the tracking estimate of savings adjusted for the realization rate of the category. The error ratio is a statistical measure of the variability in the scatter plots shown in Figure 1 through Figure 3. The error ratio will be close to zero if the points lie close to the line. The error ratio will be larger if the points are more scattered around the line.

Error ratios were calculated for the Lighting, Refrigerator and Other categories. Table 8 shows the results. The error ratio can be regarded as a measure of the quality of the tracking estimates. Error ratios less than 0.5 are desirable. When the error ratio is greater

[3] Since the samples are statistically independent from one measure category to another, the error bound of the total savings is the square root of the sum of the squared error bounds of the savings in the four categories. The relative precision of the total savings, reported in Table 5, is the error bound of the total savings divided by the total evaluated savings.

than 1, it indicates that the measured savings are poorly related to the tracking estimates of savings. In such instances, it may be productive to seek improvements in the procedures for determining the tracking savings.

Table 8: Estimated Error Ratios

Category	*Gross Annual MWh*	*Onsite Summer kW Reduction*	*Onsite Winter kW Reduction*
Lighting	0.26	0.51	0.76
Refrigeration	0.07	0.12	0.35
Other	0.50	1.04	0.60
Total	0.23	0.46	0.67

The annual savings error ratios shown in Table 8 are generally 0.5 or smaller. This indicates that the tracking estimates of annual savings provide fairly accurate estimates of the evaluated savings after adjustment for the realization rates shown in Table 4. In the case of annual energy savings, the larger error ratios are found in the Other and Lighting categories, reflecting the difficulty of estimating savings for these categories. Nevertheless, the error ratio of 0.5 for Other measures indicates that the evaluated annual savings are generally within ± 50% of the annual savings recorded in the tracking system, after adjustment for the realization rate.

The error ratios for on-peak savings are generally similar to those of annual energy savings. However, the error ratios are generally larger for the demand savings than annual energy savings. This is another indicator of the difficulty of estimating the demand savings of many projects, especially in the Other category.

Conclusions and Recommendations

The following conclusions and recommendations are offered:

- Realization rates have been estimated for the Lighting, Refrigeration and Other categories based on these studies. These results are believed to provide the best available estimates of the realization rates of these three measure categories.

- The error ratios are lower than the assumed error ratios used in the sample design. This indicates that the tracking information is more accurate than planned, especially for Refrigeration.
- Formal sample designs were used to select the projects for evaluation. This minimized the opportunity for selection bias and made it possible to attach statistical precision to the finding for each category. This practice should be continued in future studies.
- The error ratios reported in this study should be used to design new evaluation studies in order to better estimate the relative precision at the planning stage.

Using the Results in the Savings Calculations

The realization rates developed in this study will be applied to calculate post-evaluation energy and demand savings.

The 2005 Impact evaluation [2] identified a systemic discrepancy in the refrigeration motor measure tracking savings estimates. According to the evaluation team, the direct motor savings calculated by the tracking system savings methodology was understated by about 60%[4]. If the Company adjusts the program tracking savings upward, future studies would observe a lower measure realization rate, closer to 100%, down from the current estimate of 160% for Refrigeration. As an example, if the Company adjusts the savings by 40%, and the understatement is 60%, then the future realization rate would approximate 114% (160%/140%).

Reference

[1] *Sample Designs for the Custom SBS Evaluations*, Prepared for National Grid by RLW Analytics, March 20, 2006.

[2] *Small Business Services Custom Measure Impact Evaluation*, Prepared for National Grid by RLW Analytics, March 23, 2007.

[4] Page 32