Sample Design and Impact Evaluation
Analysis of the 2007 Custom Program

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Introduction

This report provides estimates of the realization rates and statistical precision for the Custom measures installed in the year-2007 Energy Initiative and Design 2000*plus* programs.

Purpose of this Study

This study has the following purposes:

1. To document the sample designs used to select the projects that were used to calculate the new realization rates for Process and HVAC measures. The samples were drawn from various program years, 2005 and 2006 for Process, and 2005 for HVAC,
2. To provide a statistical analysis of the engineering studies of 2005 and 2006 Process installations carried out for the evaluation of the Process category of Custom measures installed in year 2007 in the Energy Initiative and Design 2000*plus* programs,
3. To provide a statistical analysis of the engineering studies of 2005 Custom HVAC installations carried out for the evaluation of the HVAC category of Custom measures installed in year 2007 in the Energy Initiative and Design 2000*plus* programs,
4. Provide revised statistical analysis of the 2002 Comprehensive Design Approach (CDA) to match revised methodology implemented for the 2007 analysis,
5. To assess the error ratios, i.e., the measures of variability, to be used in developing the sample designs for future studies, and
6. To draw together the results from the new Process and HVAC studies, revised CDA study, and the previously reported Lighting[1] and study to:

[1] 2006 Lighting study methodology is consistent with the current methodology therefore no revisions to the Lighting study results are required

- Provide unbiased estimates of the collective realization rate of all projects in the program population,
- Summarize the overall savings, and
- Determine the statistical precision for all Custom measures installed in year 2007 in the Energy Initiative and Design 2000*plus* programs.

Scope

The scope of the analysis includes installations in the three New England states that National Grid offered electric efficiency measures in 2007: Massachusetts, Rhode Island and New Hampshire.

Methodology

For the last ten years or more, National Grid has used the model-assisted stratified ratio estimation methodology described in [1] and [2]. The key parameter of interest is the population realization rate, i.e., 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.

Sample Design

The sample designs guide the selection of the projects to be studied. This year's report differs from prior year's reports in that only the most recent Process and HVAC sample designs will be presented. The samples have been drawn from various program years, 2005 and 2006 for Process, and 2005 for HVAC.

Each of the sample designs was developed using the model-based methodology [1]. A statistical model was used to describe the relationship between the evaluated savings and tracking savings for all projects in the target population. The parameters of this model were combined with the information in the tracking system to develop an efficient sample design with the expected statistical precision that is desired. The key parameters of the model are the realization rate (defined above), the error ratio, and gamma. The error ratio is a measure of the project-to-project variation in the relationship between the evaluated savings and the tracking estimate of savings. The error ratio was used to choose the sample size and to estimate the expected statistical precision. Gamma describes how the residual standard deviation varies with the tracking estimate and was primarily used to stratify the population.

These parameters have been estimated as part of the analysis of many prior evaluation studies. Reference [3] provides an overview of the results found in earlier Custom studies carried out from 1994 through 1999. In these and other studies, we have found that the realization rate and error ratio vary from measure category to category and from one measure of savings to another. We have also found that the estimated value of gamma tends to vary randomly around 0.8. Therefore we currently use a simplified methodology to estimate the error ratio from sample data that assumes that the true value of gamma is 0.8.

We have also learned that it can be advantageous in recruiting and fieldwork to reduce the sampling fraction for the large projects. In particular, we have learned that reducing the set gamma moderately reduces the expected statistical precision very little but often yields more effective recruiting and field work. Therefore, it has become our standard practice to construct the sample designs with a set gamma of 0.5.

The sample designs used in the present studies reflect the values of tracking savings observed in the program-year population from which the measures were drawn, combined with the realization rates and error ratios found in the prior studies. This

information was used to choose the new sample sizes and to estimate the statistical precision to be expected from the new studies.

Analysis

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]

In prior analyses, samples were post stratified to the current year population which weighted sites based on the distribution of sites within strata for the current year. In the 2007 analysis, for the first time, the population that the sample was drawn from and the current year population were significantly different. The current year population did not contain any sites in the largest stratum of the original sample design. During the review of prior year data as well as future tracking data that is being compiled, it became clear that this variation in savings wasn't due to some fundamental shift in the magnitude of savings at sites, but was simply a result of what sites enrolled in the program within a given year. Using the current year post-stratification technique from prior analyses, all sites in the largest stratum would be given a case weight of 0, meaning that they represented no sites within the current population. Model-based stratification selects proportionately more sites within the largest savings stratum because sites with large savings have the largest amount of uncertainty associated with them. If populations vary year to year such that sample designed stratum cut points are not plausible for future year analysis populations, then it becomes desirable to extrapolate the sample back to the population from which it was originally drawn and then apply the realization rate to the current year population. Extrapolating back to the population from which it was drawn

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

allows use of all sites in the analysis. For the Process category where two years of samples were analyzed together, a simple average of measured savings of the two years was used to come up with an overall estimate of savings, an example of which is given after the Process PY2006 results section.

The Sample

The results presented in the main sections of this report are based on the new definitions of peak periods used in both this year's and last year's reports for Custom Process. For Custom Lighting the results are presented for this new definition as well as a definition being proposed for the ISO New England Forward Capacity Market (FCM). The results for the old definition of peak for Custom Process and the FCM definition are provided in a separate section after the main results[3]. Table 1 summarizes the number of sample projects used to develop the Program Year ("PY") 2007 savings estimates. The Custom HVAC study sites were all installed in program year 2005 while the Process sites were a combination of program year 2005 and 2006 install years. Detailed methodologies of sample selection for both categories are listed below.

Table 1: Sample Sizes

Category	*New Study*	*Install Year*	*Sample Size*
HVAC	Yes	PY2005	15
Lighting	No	PY2006	10
Process	Yes	PY2006	15
Process	No	PY2005	15
CDA	No	PY2002	3
Total			68

[3] From the sample data files, the following variables were assigned to the other and new peak definitions:
HVACPY05: *labeled as 'New', considered 'New Peak'; labeled as 'Old', included in 'Other Peak' section*
ProcessPY06: *labeled as 'New', considered 'New Peak'; labeled as 'FCM', included in 'Other Peak' section*
ProcessPY05: *labeled as 'New', considered 'New Peak'; labeled as 'Old', included in 'Other Peak' section*

Sample Designs

This section summarizes the sample designs used to select the Process and HVAC projects analyzed in this report. The Process sample design for PY2005 was documented in [4], while PY2006 for Process and the PY2005 HVAC sample design are documented in this report. Those reports as well as [1] provide more details about the methodology used to develop the sample designs described in the present report.

Table 2 summarizes the PY2005 Process sample design. The PY2005 Process tracking data were stratified by gross annual MWh savings into five strata as shown in the table. For example, stratum one consisted of all projects with tracking annual savings of 45 MWh or less. There were 44 projects in stratum one in the PY2005 population, with a total tracking annual savings of 1,045 MWh. Three projects were randomly selected from these 44 projects.

Table 2: PY2005 Process Sample Design

Stratum	Max Annual MWh	Projects in PY2005 Population	Total Annual MWh	Projects In Sample
1	45	44	1,045	3
2	80	27	1,760	3
3	155	20	2,208	3
4	272	14	3,257	3
5	2,732	7	7,399	3

Table 3 summarizes the PY2006 Process sample design. The PY2006 Process tracking data were stratified by gross annual MWh savings into five strata as shown in the table. For example, stratum one consisted of all projects with tracking annual savings of 64 MWh or less. There were 82 projects in stratum one in the PY2006 population, with a total tracking annual savings of 2,515 MWh. Three projects were randomly selected from these 82 projects.

Table 3: PY2006 Process Sample Design

Stratum	Max Annual MWh	Projects in PY2006 Population	Total Annual MWh	Projects In Sample
1	64	82	2,515	3
2	147	31	3,077	3
3	293	15	3,469	3
4	829	9	4,186	3
5	1,271	5	5,434	3

Taking the PY2005 and PY2006 samples together, a total of 30 Process sample projects were available for analysis.

Table 4 shows the assumptions that we used in the PY06 Process sample design. During the sample design process, it was assumed that the PY06 sample would be combined with the PY05 sample[4]. The table shows the number of projects and total savings from the PY05 tracking data, which differs from the data displayed for Process in the preceding section on PY06. The table also shows the realization rates and error ratios found in the PY06 evaluation of Process which analyzed projects from PY04 and PY05. These are the key parameters needed to plan new studies.

Table 4: PY06 Process Sample Design Assumptions

PY2006 Sample Design	*PROCESS*
Number of Projects	142
Planned Sample	15
Expected MWh	15,954
Expected Relative Precision	10.6%
Expected Error Bound	1,687
Gross Annual MWh	18,682
Realization Rate	0.85
Error Ratio	0.70

Table 5 summarizes the PY2005 HVAC sample design. The PY2005 HVAC tracking data were stratified by gross annual MWh savings into five strata as shown in the table. For example, stratum one consisted of all projects with tracking annual savings of 53

[4] During the planning stages it was assumed that there would be 15 sample sites in each of the two years, resulting in a total of 30 sample sites. The final sample for PY05 was 15 sites and for PY06 it was 15 sites.

MWh or less. There were 33 projects in stratum one in the PY2005 HVAC population, with a total tracking annual savings of 828 MWh. Three projects were randomly selected from these 33 projects.

Table 5: PY2005 HVAC Sample Design

Stratum	Max Annual MWh	Projects in PY2005 Population	Total Annual MWh	Projects In Sample
1	53	33	828	3
2	122	16	1,558	3
3	197	12	1,958	3
4	526	9	2,862	3
5	2,457	5	5,596	3

Table 6 shows the assumptions that we used in the sample design. The table shows the number of projects and total savings from the PY05 tracking data, as discussed in the preceding section. The table also shows the realization rates and error ratios found in recent evaluations of HVAC.

Table 6: HVAC Sample Design Assumptions

PY2005 Sample Design	*HVAC*
Number of Projects	75
Planned Sample	15
Expected MWh	12,507
Expected Relative Precision	18.2%
Expected Error Bound	2,281
Gross Annual MWh	12,802
Realization Rate	0.977
Error Ratio	0.480

Case Weights

As previously mentioned, the methodology for this year has been changed, and each of the samples were extrapolated back to the population from the year in which they were drawn. The stratum cut points that were used for the analysis were the same cut points created in the sample design. Weights were recalculated during the analysis to account for any changes to the sample due to replacing sample points with backup sites. The PY2005 and PY2006 samples were analyzed separately and extrapolated back to their respective population and ultimately the results were combined to come up with an

overall realization rate and relative precision for each program. Documentation of the methodology for combining multiple year results can be found in the Appendix.

In the case of Process, we used the stratum boundaries from the original sample design for each year. The final case weights for the Process PY05 and PY06 categories are shown in the final column of Table 7 and Table 8.

Table 7: Process PY2005 Case Weights

Category	Stratum	Maximum Annual MWh	Projects in PY2005 Population	Total Annual MWh	Sample	Case Weight
Process	1	45	44	1,045	3	14.7
Process	2	80	27	1,760	3	9.0
Process	3	155	20	2,208	3	6.7
Process	4	272	14	3,257	3	4.7
Process	5	2,732	7	7,399	3	2.3

Table 8: Process PY2006 Case Weights

Category	Stratum	Max Annual MWh	Projects in PY2006 Population	Total Annual MWh	Project In Sample	Case Weight
Process	1	64	82	2,515	3	27.3
Process	2	147	31	3,077	3	10.3
Process	3	293	15	3,469	3	5.0
Process	4	829	9	4,186	3	3.0
Process	5	1,271	5	5,434	3	1.7

HVAC also used the stratum boundaries from the original sample design. The final case weights for HVAC are shown in the final column in Table 9.

Table 9: HVAC PY2005 Case Weights

Category	Stratum	Max Annual MWh	Projects in PY2005 Population	Total Annual MWh	Project In Sample	Case Weight
HVAC	1	53	33	828	3	11.0
HVAC	2	122	16	1,558	3	5.3
HVAC	3	197	12	1,958	3	4.0
HVAC	4	526	9	2,862	3	3.0
HVAC	5	2,457	5	5,596	3	1.7

Process PY2005 Results

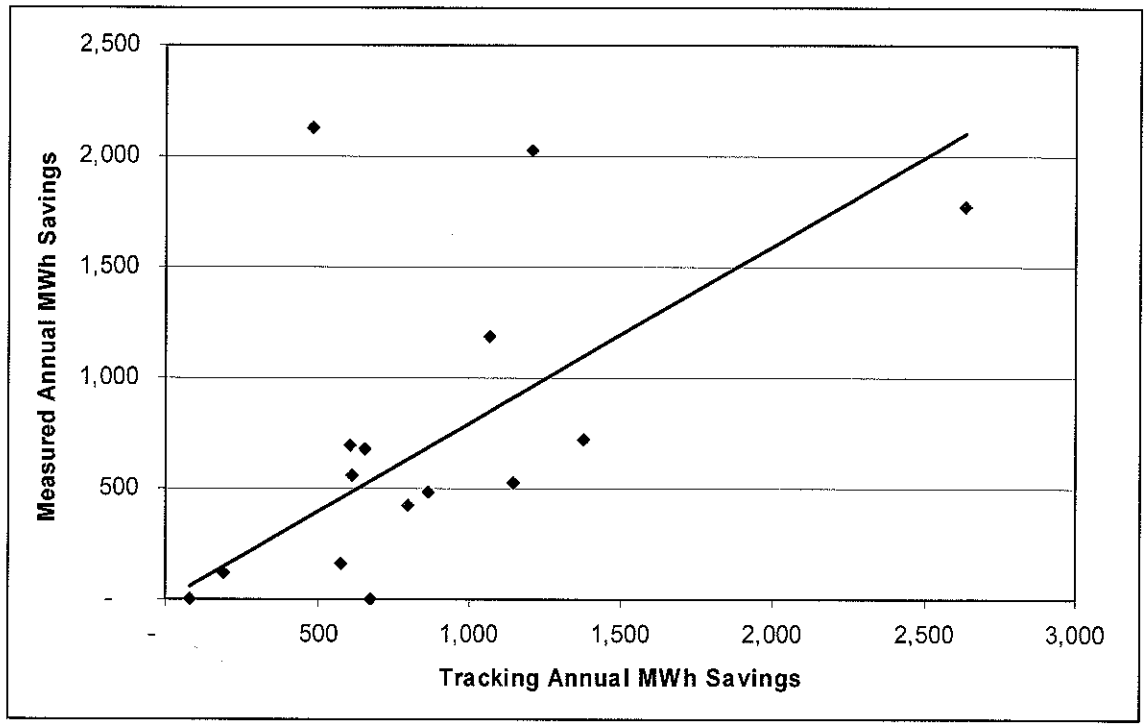
This section summarizes the primary results found from the analysis of the Process sample. Table 10 summarizes the results of the stratified ratio analysis of the Process sample. The table shows the results for each of the four measures of savings. In the case of Annual MWh savings, the realization rate for Process measures was found to be 88.2%. The relative precision was found to be ± 25.9% at the 80% level of confidence. The error ratio was found to be 0.83. Table 10 also shows the results for the on-peak savings, measured in MWh. The on-peak MWh savings is the percent on-peak times the annual MWh savings. Our analysis gave a realization rate of 110% for the on-peak MWh savings, meaning that the measured on-peak savings was about 110% of the tracking on-peak savings. Considering all projects taken together and using the percent on-peak found in the tracking system, 41% of the savings were on peak. The evaluation results indicate that 51% of all savings were on peak. The ratio between these two results is the realization rate for the percent on-peak savings, 124%.

Table 10: Summary of PY2005 Process Results

Statistic	Annual MWh	On-Peak MWh	Summer kW	Winter kW	Percent On-Peak
Total Tracking Savings	15,669	6,455	2,109	2,153	41.2%
Realization Rate	88.2%	109.7%	100.8%	85.9%	124.3%
Relative precision	25.9%	28.4%	26.5%	28.4%	
Total Measured Savings	13,828	7,080	2,125	1,848	51.2%
Error bound for Measured Savings	3,577	2,013	563	524	
Error ratio	0.83	0.90	0.91	0.90	

Figure 1 shows the sample data underlying the realization rate for the annual savings in the Process 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.

Figure 1: Custom Process PY2005 Measured vs. Tracking Weighted Annual Savings



Process PY2006 Results

This section summarizes the primary results found from the analysis of the Process sample. Table 11 summarizes the results of the stratified ratio analysis of the Process sample. The table shows the results for each of the four measures of savings. In the case of Annual MWh savings, the realization rate for Process measures was found to be 87%. The relative precision was found to be ± 21.9% at the 80% level of confidence. The error ratio was found to be 0.66. Table 11 also shows the results for the on-peak savings, measured in MWh. The on-peak MWh savings is the percent on-peak times the annual MWh savings. Our analysis gave a realization rate of 126% for the on-peak MWh savings, meaning that the measured on-peak savings was about 126% of the tracking on-peak savings. Considering all projects taken together and using the percent on-peak found in the tracking system, 41% of the savings were on peak. The evaluation results indicate that 60% of all savings were on peak. The ratio between these two results is the realization rate for the percent on-peak savings, 145%.

Table 11: Summary of PY2006Process Results

Statistic	Annual MWh	On-Peak MWh	Summer kW	Winter kW	Percent On-Peak
Total Tracking Savings	18,682	7,674	2,242	2,306	41.1%
Realization Rate	87.1%	126.2%	119.2%	91.4%	144.8%
Relative precision	21.9%	21.6%	32.4%	40.0%	
Total Measured Savings	16,276	9,683	2,673	2,108	59.5%
Error bound for Measured Savings	3,563	2,090	865	842	
Error ratio	0.66	0.65	0.97	1.17	

Figure 2 shows the sample data underlying the realization rate for the annual savings in the Process 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.

Figure 2: Custom Process PY2006 Measured vs. Tracking Weighted Annual Savings

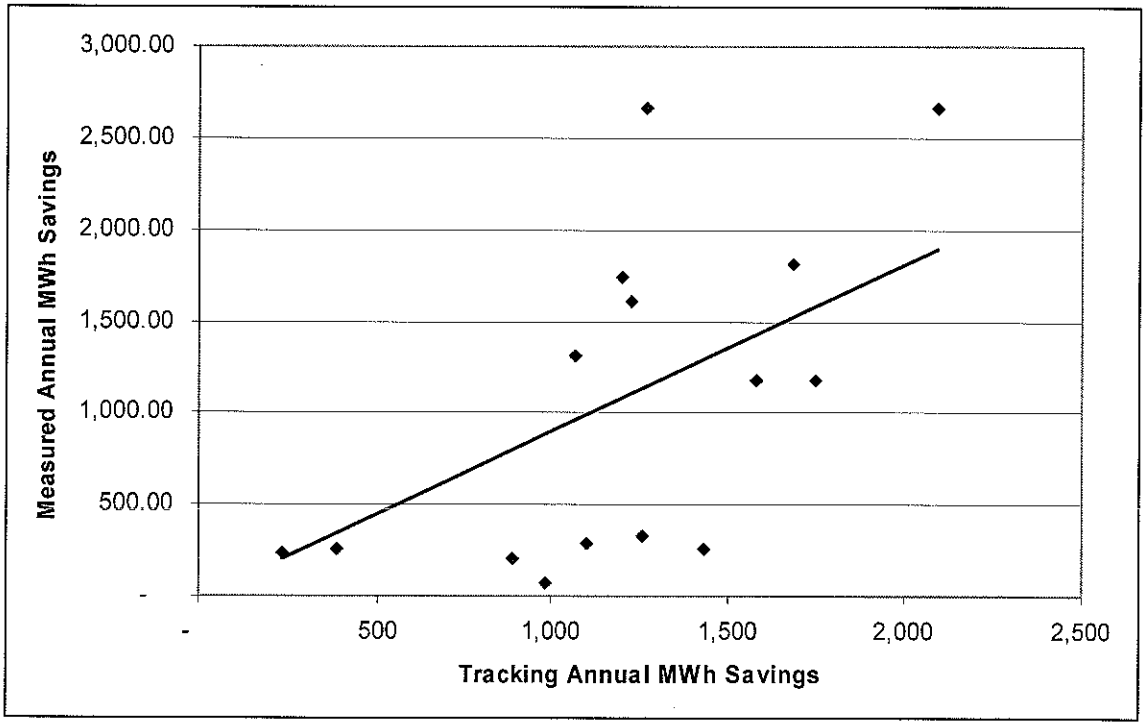


Table 12 shows the realization rates for the Process category for PY2005 and PY2006. The overall realization rate was calculated as the simple average of the realization rate from each program year.

Table 12: Averaged Process Realization Rate

	Annual kWh	On-Peak kWh	Summer kW	Winter kW	Percent On-Peak
Process05 RR	88.2%	109.7%	100.8%	85.9%	124.3%
Process06 RR	87.1%	126.2%	119.2%	91.4%	144.8%
Combined	87.7%	117.9%	110.0%	88.7%	134.6%

HVAC Results

This section summarizes the primary results found from the analysis of the HVAC sample. Table 13 summarizes the results of the stratified ratio analysis of the HVAC sample. The table shows the results for each of the four measures of savings. In the case of Annual MWh savings, the realization rate for HVAC measures was found to be 75.7%. The relative precision was found to be ± 17.7% at the 80% level of confidence. The error ratio was found to be 0.48.

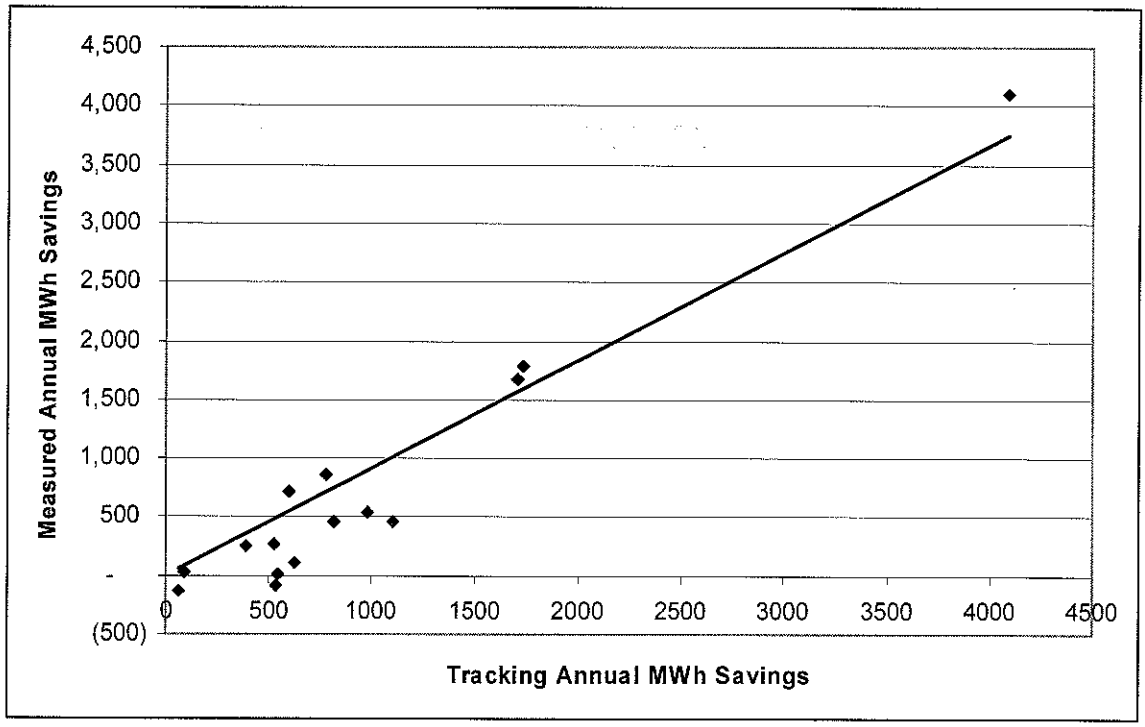
Table 13 also shows the results for the on-peak savings, measured in MWh. The on-peak MWh savings is the percent on-peak times the annual MWh savings. Our analysis gave a realization rate of 115.6% for the on-peak MWh savings, meaning that the measured on-peak savings was about 116% of the tracking on-peak savings. Considering all projects taken together and using the percent on-peak found in the tracking system, 35% of the savings were on peak. The evaluation results indicate that 54% of all savings were on peak. The ratio between these two results is the realization rate for the percent on-peak savings, 153%.

Table 13: Summary of HVAC Results

Statistic	Annual MWh	On-Peak MWh	Summer kW	Winter kW	Percent On-Peak
Total Tracking Savings	12,802	4,488	1,889	1,311	35.1%
Realization Rate	75.7%	115.6%	70.0%	106.1%	152.7%
Relative precision	17.7%	33.7%	36.3%	25.5%	
Total Measured Savings	9,687	5,186	1,323	1,392	53.5%
Error bound for Measured Savings	1,716	1,747	481	355	
Error ratio	0.48	0.78	1.22	0.81	

Figure 3 shows the sample data underlying the realization rate for the annual savings in the HVAC 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.

Figure 3: Custom HVAC Measured vs. Tracking Weighted Annual Savings



Application to the 2007 Population

Table 13 summarizes the PY2007 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 Process category had more projects, 138, and more savings, while HVAC had 56 projects and less savings.

Table 14: Tracking Statistics

	Annual MWh	*On-Peak MWh*	*Summer kW*	*Winter kW*	*Percent On-Peak*
HVAC	7,899	3,644	2,060	416	46.1%
Lighting	3,854	2,188	665	758	56.8%
Process	21,578	9,806	2,923	2,959	45.4%
CDA	5,904	2,566	1,755	476	43.5%
Total	39,235	18,205	7,403	4,608	46.4%

Combined Results

This section combines the new results for the Process and HVAC categories with the results from previous Lighting study and recalculated results of the CDA study in order to obtain results for all Custom Program measure categories taken together.

Table 15 summarizes the estimated realization rates obtained from the statistical analysis. The first four rows of the table show the estimated realization rates for the four measure categories. The final row shows the overall realization rate for the four measure categories taken together. Considering Annual MWh savings as an example, we estimated the realization rate to be 76% for HVAC and 88% for Process. Combining the new results from these two categories with the previous results for Lighting and CDA, we estimated an overall realization rate of 91% for the annual savings of all 2007 projects in the four categories. This indicates that the annual savings would be found to be about 9% smaller than the gross savings from the tracking system if all 2007 projects were to be evaluated.

Table 15: Realization Rates

Category	*Annual MWh*	*On-Peak MWh*	*Summer kW*	*Winter kW*	*Percent On-Peak*
HVAC	75.7%	115.6%	70.0%	106.1%	152.7%
Lighting	117.2%	126.8%	109.7%	113.6%	108.1%
Process	87.7%	117.9%	110.0%	88.7%	105.9%
CDA	104.2%	87.2%	103.4%	105.5%	83.6%
Total	90.7%	114.2%	97.3%	96.1%	126.0%

The first four columns of Table 15 show the realization rates for each type of savings: Annual MWh, On-peak MWh, Summer kW, and Winter kW. These results are the ratio between the case-weighted sum of the evaluated savings divided by the case-weighted sum of the tracking savings, summed across all projects in the sample. 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 measures, where the realization rate was about 118%.

The last column of Table 15 shows the realization rates for the percent on-peak energy savings. This is the realization rate for the estimate of the percent on-peak energy savings found in the tracking system for each measure category. The same results for on-peak energy savings can be obtained in either of two ways:

1. Multiply the annual kWh savings found in the tracking system by the percent on-peak found in the tracking system, and multiply the results by the on-peak energy realization rate, or
2. Multiply the percent on-peak found in the tracking system by the percent on-peak realization rate to get an adjusted percent on-peak. Then multiply the annual savings found in the tracking system by the annual energy realization rate, and multiply this adjusted annual energy savings by the adjusted percent on-peak.

Table 16 reports the relative precision obtained for each measure of impact for each category and over all measures taken together. The results are calculated at the 80% level of confidence. The overall relative precision for annual savings was ±9.7% at the 80% level of confidence. The overall relative precision for the on-peak energy impacts and the summer and winter demand impacts was in the range ±10.3% to ± 15.0% at the 80% level of confidence.

Table 16: Relative Precision at 80% Level of Confidence

Category	Annual MWh	On-Peak MWh	Summer kW	Winter kW
HVAC	17.7%	33.7%	36.3%	25.5%
Lighting	12.2%	15.3%	20.5%	33.7%
Process	17.0%	17.6%	21.3%	24.8%
CDA	12.0%	22.4%	9.1%	9.6%
Total	9.7%	12.3%	10.3%	15.0%

Usually, the relative precision is 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.

Table 17 shows the estimated measured savings for PY2007. The savings estimates for the 2007 population were calculated by multiplying the realization for each program category by the 2007 tracking estimates of savings.

Table 17: 2007 Estimated Measured Savings

Category	Annual MWh	On-Peak MWh	Summer kW	Winter kW	Percent On-Peak
HVAC	5,977	4,211	1,443	441	70.5%
Lighting	4,518	2,774	730	860	61.4%
Process	18,921	11,564	3,216	2,623	61.1%
CDA	6,153	2,237	1,815	502	36.4%
Total	35,569	20,787	7,203	4,427	58.4%

Table 18 show the error bounds associated with the total measured savings. These results are equal to the square root of the sum of the squared error bounds of all categories. For example, for the total Annual MWh savings of all categories, the error bound is 3,449 MWh and the 80% confidence interval for the total Annual MWh savings is 35,569 ± 3,449 MWh. The overall error bound is calculated by taking the square root of the sum of the squared error bounds. The overall relative precision shown in Table 16

can be obtained from these results. For example, the relative precision for the total Annual MWh savings is 3,449 / 35,569 = 9.7%.

Table 18: Error Bounds at 80% Level of Confidence

Category	Annual MWh	On-Peak MWh	Summer kW	Winter kW
HVAC	1,716	1,747	480.6	355.2
Lighting	548	428	142	215
Process	2,553	1,471	511.8	489.9
CDA	1,462	1,091	192	166
Total	3,449	2,567	742	663

The information developed in the present study can be used to help plan future studies of the Custom program. Some important insights can be drawn from Table 18. The measure categories with the largest error bounds, e.g., Process in the case of Annual MWh savings, contribute the greatest uncertainty to the overall program impact. This suggests that added attention should be given to these categories.

To quantify the expected statistical precision of a new study and to choose new sample sizes, it is necessary to estimate the variability in the population. For stratified ratio estimation the appropriate measure of variability is a population parameter 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 entire population, but it is reflected in the sample scatter plot shown in Figure 1 for Process. If the error ratio is close to zero then the points are expected to lie close to the line. It the error ratio is larger, then the points are expected to be more widely scattered around the line.

The error ratio can be regarded as a measure of the quality of the tracking estimates for the population of individual projects. Error ratios less than 0.5 are desirable. An error ratio of 0.5 would indicate that for the majority of projects the evaluated savings are within ± 50% of the savings recorded in the tracking system after adjustment for the

realization rate. When the error ratio is greater than one, 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.

Although the true error ratios are always unknown, the error ratios can be estimated from the sample data. Error ratios were estimated for the Process category based on the PY05 and PY06 sample data, for the HVAC category based on the PY05 data, and for the CDA category based on the PY02 sample data. The Lighting error ratios are from the PY06 report [4]. Table 19 shows the results.

Table 19: Estimated Error Ratios

Category	Annual MWh	On-Peak MWh	Summer kW	Winter kW
HVAC	0.48	0.78	1.22	0.81
Lighting	0.31	0.41	0.58	0.83
Process05	0.83	0.90	0.91	0.90
Process06	0.66	0.65	0.97	1.17
CDA	0.16	0.30	0.12	0.13

The estimates of Process savings are not as accurate as estimates of savings for Custom Lighting and CDA projects. Process has more sampled sites due to the higher error ratio and the large amount of savings associated with this measure category.

For Lighting, the error ratios are generally 0.5 or smaller for energy. This indicates that in the Lighting category, the tracking estimates of energy savings provide fairly accurate estimates of the evaluated energy savings for the majority of Custom projects after adjustment for the realization rates. The Lighting error ratios for demand savings are higher.

Process Comparison with Prior Studies

This section compares the new Process results with the results from the preceding study.[5] Table 20 summarizes the results for the realization rates. The realization rates are a measure of the bias of the tracking estimates. For example, a realization rate less than 100% indicates that the tracking estimates tend to overstate savings across the projects in the category. Ideally, the realization rate should be close to 100%.

The realization rates found in the present Process study are similar to those found in most of the prior studies of this category with the exception of last year. These results continue to reverse the low values found in the PY2002-03 study.

Table 20: Custom Process New and Prior Realization Rates

Study	*Installed Year*	*Sample Projects*	*Annual MWh*	*On-Peak MWh*	*Summer kW*	*Winter kW*
New	PY2005-06	30	87.7%	117.9%	110.0%	88.7%
Prior	PY2004-05	34	108.5%	140.9%	109.7%	100.7%
Prior	PY2003-04	39	85.4%	80.6%	85.8%	72.1%
Prior	PY2002-03	40	68.1%	60.2%	68.1%	62.4%
Prior	PY2001-02	41	85.0%	85.2%	86.0%	75.9%
Prior	PY2000-01	41	87.8%	85.3%	81.2%	75.0%

Table 21 compares the error ratios found in the current and prior Process studies. With the new methodology of extrapolating each year of Process findings to the population from which it was drawn, an overall error ratio cannot be calculated. An error ratio for each analysis has been listed below. The error ratio for PY2006 falls in line with the PY2004-05 results with the exception of winter kW which experienced a substantial increase.

[5] These results are listed for illustration purposes only. The 2007 analysis is the first year implementing a new methodology so results are not directly comparable to prior year analyses. In this years analysis the sample data for each program year were expanded back to the population year from which they were drawn. In previous years analysis the sample data for each program year was expanded to the population of the current year to be evaluated.

Table 21: Custom Process New and Prior Error Ratios

Study	*Installed Year*	*Sample Projects*	*Annual MWh*	*On-Peak MWh*	*Summer kW*	*Winter kW*
New	PY2006	15	0.66	0.65	0.97	1.17
New	PY2005	15	0.83	0.90	0.91	0.90
Prior	PY2004-05	34	0.69	0.72	0.83	0.84
Prior	PY2003-04	39	0.70	0.85	1.16	1.26
Prior	PY2002-03	40	0.66	0.72	0.83	1.15
Prior	PY2001-02	41	0.62	0.75	0.63	0.90
Prior	PY2000-01	41	0.54	0.74	0.71	1.27

HVAC Comparison with Prior Studies

This section compares the new HVAC results with the results from the preceding HVAC study.[6] Table 22 summarizes the results for the realization rates. The realization rates are a measure of the bias of the tracking estimates. For example, a realization rate less than 100% indicates that the tracking estimates tend to overstate savings across the projects in the category. Ideally, the realization rate should be close to 100%.

The realization rates found in the present HVAC study are lower than those found in the prior studies, with the exception of On-peak MWh. Originally plans were made to combine PY2005 and PY2006 HVAC in the same way that Process is combined. The PY2006 HVAC sites were not completed in time to be included in this analysis.

[6] These results are listed for illustration purposes only. The 2007 analysis is the first year implementing a new methodology so results are not directly comparable to prior year analyses. In this years analysis the sample data for each program year were expanded back to the population year from which they were drawn.

Table 22: Custom HVAC New and Prior Realization Rates

Category	*Study*	*Installed Year*	*Sample Projects*	*Annual MWh*	*On-peak MWh*	*Summer kW*	*Winter kW*
HVAC	New	PY2005	15	75.7%	115.6%	70%	106.1%
HVAC	Prior	PY2003	10	97.7%	83.1%	106.4%	124.7%
HVAC	Prior	PY2001	10	94.9%	105.0%	72.7%	68.1%
HVAC	Prior	PY1999	15	94.0%	86.2%	85.0%	141.6%

Table 23 compares the error ratios found in the current and prior HVAC studies. In the HVAC category, the error ratios for Annual MWh are similar to past years with the exception of PY2003 in which there was an outlier that substantially impacted the error ratio.

Table 23: Custom HVAC New and Prior Error Ratios

Category	*Study*	*Installed Year*	*Sample Projects*	*Annual MWh*	*On-peak MWh*	*Summer kW*	*Winter kW*
HVAC	New	PY2005	15	0.48	0.78	1.22	0.81
HVAC	Prior	PY2003	10	1.12	0.99	0.82	1.14
HVAC	Prior	PY2001	10	0.48	0.46	0.90	0.87
HVAC	Prior	PY1999	15	0.40	0.54	0.72	0.66

Other Peak Definitions

This section presents the results for the Process and HVAC peak summer and winter kW using 'Other Peak' definitions. From the sample data files, the following variables were assigned to the other and new peak definitions:

HVAC:

labeled as 'New', considered 'New Peak';

labeled as 'Old, included in 'Other Peak' section

Process PY05:

labeled as 'New', considered 'New Peak';

labeled as 'Old, included in 'Other Peak' section

Process PY06:

labeled as 'New', considered 'New Peak';

labeled as 'FCM, included in 'Other Peak' section

Table 24 through Table 27 present the realization rates, relative precision, measured savings, and the error bounds for the summer and winter kW estimates. Realization rates, relative precisions, and measured savings of the "other" definitions are calculated using methodology that is consistent with those explained in the previous section.

Table 24: Realization Rates

Category	Other Summer kW	Other Winter kW
HVAC	52.2%	101.1%
Process	105.9%	92.2%

Table 25: Relative Precision

Category	Other Summer kW	Other Winter kW
HVAC	45.0%	26.5%
Process	21.2%	23.4%

Table 26: PY2007 Estimated Measured Savings

Category	Other Summer kW	Other Winter kW
HVAC	1,076	420
Process	3,095	2,730

Table 27: Error Bounds

Category	Other Summer kW	Other Winter kW
HVAC	444	351
Process	488	483

Conclusions and Recommendations

The following conclusions and recommendations are offered:

- A new methodology of extrapolating samples back to the population from which they were drawn has been adapted for all categories.
- Realization rates have been estimated for the Process category by combining a new sample of PY2006 projects with a prior sample of PY2005 projects as done in the PY04-05 analysis. However, following the revised methodology, the sample for each year of Process was extrapolated back to the population from which it was drawn and then combined together to come up with an overall realization rate. These results are believed to provide the best available estimates of the realization rates of this measure category.
- CDA results were recalculated to conform with revised methodology
- The Company should continue to strive to improve the accuracy of the tracking estimates of savings, especially in the Process and HVAC categories.

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 for the 2007 program year.

References

[1] *The California Evaluation Framework,* prepared for Southern California Edison Company and the California Public Utility Commission, by the TecMarket Works Framework Team, June 2005, Chapters 12-13.

[2] *Model Assisted Survey Sampling,* C. E. Sarndal, B. Swensson, and J. Wretman, Springer, 1992.

[3] *Meta-Analysis of the Custom Evaluation Studies: 1994-1999,* Prepared for National Grid by RLW Analytics, February 12, 2001.

[4] *Sample Design and Impact Evaluation Analysis of the 2006 Custom Program,* Final Report, Prepared for National Grid by RLW Analytics, July 20, 2007.

Appendix

Combining Process Results Methodology

The following explains the methodology used to combine the results of two independent studies of a program in two program years, in this case, the combining of two years of studies for the Custom Process category.

Let R_1 and R_2 be the true realization rates of the program in the two program years. We want to estimate the average realization rate $w_1 R_1 + w_2 R_2$. As a matter of policy, we have agreed that $w_1 = w_2 = .5$ but the following method is applicable for any given weights. Let $\hat{R}_1$ and $\hat{R}_2$ be statistically independent, unbiased estimators of the true realization rates of the program in the two program years and let eb_1 and eb_2 be the error bounds of the two estimators, calculated at the chosen level of confidence using the same z coefficient for both years. Typically, $\hat{R}_1$, $\hat{R}_2$, eb_1 and eb_2 will be calculated using stratified ratio analysis of two statistically independent samples, one drawn from each year.

Then an unbiased estimator of the average realization rate is $w_1 \hat{R}_1 + w_2 \hat{R}_2$. The error bound of this estimator is $\sqrt{(w_1\, eb_1)^2 + (w_2\, eb_2)^2}$. The *rp* is $\sqrt{(w_1\, eb_1)^2 + (w_2\, eb_2)^2} \,/\left(w_1 \hat{R}_1 + w_2 \hat{R}_2\right)$.

When each individual study is analyzed, our standard practice is to estimate the error ratio measuring the variability between measured savings and tracking savings. Let these error ratios be denoted er_1 and er_2. These error ratios are of interest because they can be used to choose future sample sizes or to estimate the expected relative precision for a future study with a given sample size. Let rp_1 and rp_2 be the expected relative precisions of two future studies to be combined as described above. Then the expected *rp* of the average realization rate would be $\sqrt{(w_1 R_1 rp_1)^2 + (w_2 R_2 rp_2)^2} \,/\left(w_1 \hat{R}_1 + w_2 \hat{R}_2\right)$. If

we assume that $w_1 = w_2 = .5$ and $R_1 = R_2$ then the expected *rp* of the average realization rate is $0.5\sqrt{(rp_1)^2 + (rp_2)^2}$. If rp_1 and rp_2 are equal and their common value is denoted *rp* then the combined relative precision is $rp/\sqrt{2}$. If you let rp_c denote the desired value of the combined relative precision, you can choose the sample sizes for each individual study so that the expected relative precision of each individual study is equal to $\sqrt{2}\, rp_c$.