Impact Evaluation of National Grid Rhode Island's Custom Refrigeration, Motor and Other Installations

National Grid

Final Report
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1 INTRODUCTION

This document summarizes the work performed by DNV GL during 2013 and 2014 to quantify the actual energy and demand savings due to the installation of six Custom Refrigeration, Motor and Other (RMO) measures installed through National Grid's Commercial and Industrial Retrofit and Commercial and Industrial New Construction energy efficiency programs in 2012 in Rhode Island (RI). This report also summarizes the sampling and analysis procedures used for developing the population level results, which are based on the combined results of the Rhode Island sites and a concurrent study of National Grid Custom RMO projects in Massachusetts.

1.1 Purpose of Study

The objective of this impact evaluation is to provide verification or re-estimation of electric energy and demand savings estimates for a sample of Rhode Island Custom RMO projects through site-specific inspection, monitoring, and analysis, and to develop new realization rates for the combined Custom RMO populations in Rhode Island. The results of the project studies are combined with the results from a concurrent study of National Grid Custom RMO installations in Massachusetts to determine appropriate population level realization rates for the combined Custom RMO populations in Rhode Island.

This impact study consists of the following four tasks:

1. Develop Sample Design
2. Develop Site Measurement and Evaluation Plans
3. Data Gathering and Site Analysis
4. Report Writing and Follow-up

1.2 Scope

The scope of work of this impact evaluation covered the 2012 Custom RMO end-uses, which include new equipment and/or control systems and strategies. This impact evaluation includes only measures which primarily reduce electricity consumption.

2 DESCRIPTION OF SAMPLING STRATEGY

The primary focus of the sample design task was to examine various precision scenarios for the Custom RMO programs in Rhode Island. Due to the fact that Custom RMO measure categories each account for a small proportion of RI's overall energy efficiency portfolio, the decision was made to combine them into one class to reduce the sample size requirements for this study. In addition to estimating realization rates for RI, the results obtained from the RI sample are combined with the MA results to determine a combined realization rate. Results from National Grid's Massachusetts Custom RMO evaluations were developed previously and are described in the final report for the MA-LCIEC Project 16[1].

[1] "Impact Evaluation of 2011 Custom Refrigeration, Motor and Other Installations", prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council, by KEMA, June 18, 2013.

The project populations for National Grid, based on projects completed in 2011 (MA) and 2012 (RI) are summarized in Table 2-1.

Table 2-1 RI & MA Population Statistics

Measure	State	Projects	Total Savings (kWh)	Average Savings	Minimum	Maximum
Refrigeration	MA	139	10,750,409	77,341	423	905,623
Motor	MA	15	1,692,613	112,841	5717	314,252
Other	MA	15	4,936,961	329,131	2380	3,849,196
Total MA (2011)		169	17,379,983	102,840	423	3,849,196
Refrigeration	RI	9	391,716	43,524	1536	118,451
Motor	RI	6	1,646,704	274,451	40891	541,086
Other	RI	6	999,750	166,625	65546	443,123
Total RI (2011)		21	3,038,170	144,675	1536	541,086
Total (MA+RI)		190	20,418,153			

The initial design approach was to support the estimation of annual kWh savings realization rates for National Grid's programs in Rhode Island. While annual kWh savings was the primary variable of interest, National Grid was also interested in achieving accurate results for coincident summer peak demand (kW), in order to meet the ISO-NE guidelines for ±10% precision with 80% confidence for their overall portfolio of programs.

The sample design and anticipated precision for annual kWh and summer kW is presented in the following section. The evaluation sample for this study was designed in consideration of the requirements for a 90% confidence level for energy (annual kWh) and an 80% confidence level for coincident peak summer demand (kW).

2.1 Annual kWh Sample Design

DNV GL presented several preliminary sample designs stratified by annual kWh for National Grid's Custom RMO programs in Rhode Island. The parameters considered in the sample design are the number of sample observations planned and the anticipated error ratio of the quantity being estimated which, in this case, is the realization rate for evaluated savings. The error ratio is a measure of the strength of the relationship between the known characteristic (i.e., tracking system savings) and the unknown population characteristic (i.e., evaluated savings).

Since the number of sample points that are required to achieve a desired level of precision depends upon the expected variability of the observed realization rates, DNV GL looked at prior custom measure evaluation studies to identify possible error ratios. Based on historical studies of custom measures in MA, the error ratios for realization rates for annual energy savings have ranged from about 0.3 to 0.5. For demand savings, error ratios tend to be slightly higher, ranging from about 0.6 to 0.9 for summer kW and 0.6 to 1.3 for winter kW. To be conservative and provide confidence that precision targets will be met, the sample designs presented here are based on error ratios of 0.4, 0.5 and 0.6 for annual kWh savings for Refrigeration, Motors and Other, respectively. The error ratios for summer and winter kW savings for Motors were assumed to be 0.6. For Custom Refrigeration, the kW error ratios were varied by season: 0.8 for summer and 1.3 for winter. For Custom Other, the kW error ratios were also varied by season: 0.9 for summer and 1.3 for winter. These are the same as the error ratios used for planning the 2011 MA statewide study.

The final annual kWh design, which served as the basis for the RI sample size of 6 sites, is shown in Table 2-2.

Table 2-2 Custom RMO Sample Design

Stratum	Maximum Savings	Projects	Total Savings (kWh)	Planned Sample	Inclusion Probabilities
1	224,085	17	1,162,229	3	0.1765
2	541,086	14	1,875,941	3	0.7500

Based on assumptions about error ratios, and the proposed sample sizes, an analysis of the anticipated precisions from this design was performed. Table 2-3 lists the calculated precision estimates for this scenario. The anticipated precisions are shown by measure, by state and overall for National Grid. When the RI sample is stratified optimally, the statewide precision of ±27.18% is reasonable. When combined with the MA anticipated results, the National Grid total would be expected to achieve a precision of ±12.01%.

Table 2-3 Custom RMO Anticipated Precisions for Annual kWh

State	Projects	Total kWh Savings	Error Ratio	Confidence Level	Sample	Anticipated Relative Precision	Error Bound
MA	169	17,379,983	0.5	90%	24	±13.29%	2,310,081
RI	21	3,038,170	0.5	90%	6	±27.18%	825,757
Total	190	20,418,153	0.5	90%	30	±12.01%	2,453,233

2.2 Summer kW Precision

In order to ensure that ISO-NE requirements for the Forward Capacity Market are met, it was useful to examine the estimated summer kW precision that could be achieved with a sample of this size. The error ratios for summer kW savings realization rates tend to be higher than those for annual energy savings, so the error ratios described above for summer kW were used. Given the ISO-NE requirement of ±10% precision at 80% confidence for each PAs total portfolio of resources, this analysis was run at an 80% confidence level. The results of this precision calculation are in Table 2-4. The anticipated precisions are somewhat higher than those for the annual kWh savings calculation because of the very conservative error ratio assumptions. Given that these measures represent such a small fraction of National Grid's Rhode Island's portfolio of programs, these are not expected to reduce their overall portfolio precision significantly.

Table 2-4 Anticipated Precisions for Summer kW

State	Projects	Summer kW Savings	Error Ratio	Confidence Level	Sample	Anticipated Relative Precision	Error Bound
MA	146	1,600	0.8	80%	24	±15.30%	245
RI	21	400	0.7	80%	6	±29.65%	119
Total	167	2,000	0.8	80%	30	±13.60%	272

2.3 Winter kW Precision

The calculation of anticipated precisions for winter KW is provided in Table 2-5. Due to the higher error ratios assumed for the winter kW design, the anticipated precisions are worse than those for summer kW.

Table 2-5 Anticipated Precisions for Winter kW

State	Projects	Total kWh Savings	Error Ratio	Confidence Level	Sample	Anticipated Relative Precision	Error Bound
MA	146	1,462	1.2	90%	24	±22.95%	336
RI	21	385	0.9	90%	6	±38.13%	147
Total	167	1,847	1.1	90%	30	±19.83%	366

2.4 Final Samples

Based on these stratified designs, random samples of projects were selected from the tracking system data. Table 2-6 presents the list of six projects selected as the final sample for RI Custom RMO projects. Note that two sites (1745819 and 1864209 and shaded gray in the table below) were ultimately dropped and replaced as they were unable to be successfully recruited into the evaluation.

Table 2-6 RI Final Sample Selection

Stratum	Application ID	Measure Type	Total Gross kWh Savings	Summer kW Savings	Winter kW Savings	Description
1	824282	Motors/Drives	113,224	19.16	1.45	Exhaust fan is used to automatically control using a VFD to maintain a SP set point in the bag house. Dampers are locked out to 100% open or removed.
1	1438841	Refrigeration	52,044	5.94	5.94	Installation of 58 more efficient ECMs.
1	1794980	Refrigeration	84,389	10.94	8.63	Glass doors with LED lighting added to existing cases.
2	2099672	Motors/Drives	409,041	67.09	67.6	Recirculation Fans speeds will be controlled by weight or differential pressure across the material to be dried. Exhaust fan speed will also be adjusted by weight of material being dried.
2	2202620	Motors/Drives	482,691	79.2	79.8	Backup-Recirculation Fans speeds will be controlled by weight or differential pressure across the material to be dried. Exhaust fan speed will also be adjusted by weight of material being dried.
1	1310864	Other	86,630	0.0	0.0	Backup-CAIR to bearings only when edge grinders operate.
2	1745819	Other	443,123	50.59	50.6	Dropped-Customer Unresponsive
2	1864209	Motors/Drives	541,086	57.03	69.76	Dropped-Customer Unresponsive

3 DESCRIPTION OF METHODOLOGY

3.1 Measurement and Evaluation Plans

Following the final sample selection of 2012 Custom RMO applications and prior to beginning any site visits, DNV GL developed detailed measurement and evaluation plans for each of the 6 applications. The plans outlined on-site methods, strategies for monitoring equipment placement, calibration and analysis plans. National Grid provided comments and edits to clarify and improve the plans prior to them being finalized.

The site evaluation plan played an important role in establishing approved field methods and ensuring that the ultimate objectives of the study were met. Each site visit culminated in an independent engineering assessment of the actual (e.g. as observed and monitored) annual energy, on-peak energy, summer on-peak and seasonal demand, and winter on-peak and seasonal demand savings associated with each project.

3.2 Data Gathering, Analysis, and Reporting

Data collection included physical inspection and inventory, interview with facility personnel, observation of site operating conditions and equipment, and long-term metering of usage or specific parameters needed to calculate usage. At each site, DNV GL performed a facility walk-through that focused on verifying the installed conditions of each energy conservation measure (ECM). Evaluators viewed EMS screens to verify schedules and operating parameters where applicable. Power meters and Time-Of-Use (TOU) current loggers were installed to monitor the usage of the installed equipment and associated affected spaces.

Collected data were analyzed to verify implementation of each ECM, and savings analyses were performed to estimate hourly energy use and diversified coincident peak demand. Each site report details the specific analysis methods used for each project including algorithms and assumptions.

DNV GL submitted draft site reports to National Grid upon completion of each site evaluation, which after review and comment resulted in the final reports found in Appendix A. This executive summary provides a concise overview of the evaluation methods and findings.

3.3 Analysis Procedures

In order to aggregate the individual site results from the RI RMO samples, DNV GL applied the model-assisted stratified ratio estimation methodology.[2,3] 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. This rate is estimated for the Rhode Island populations only, as well as for National Grid’s combined populations of Rhode Island and Massachusetts. 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 statistical precisions and error ratios are calculated for each level of aggregation.

The results presented in the following section include realization rates (and associated precision levels) for annual kWh, % kWh on-peak and demand (kW) savings during winter and summer on-peak periods, as defined by the ISO-NE Forward Capacity Market (FCM). All coincident summer and winter peak reductions were calculated using the following FCM definitions:

- Coincident Summer On-Peak kW Reduction is the average demand reduction that occurs over all hours between 1 PM and 5 PM on non-holiday weekdays in June, July and August.

[2] 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.

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

- Coincident Winter On-Peak kW Reduction is the average demand reduction that occurs over all hours between 5 PM and 7 PM on non-holiday weekdays in December and January.

Relative precision levels and error bounds are calculated at the 80% confidence level for demand values, since that is the requirement for portfolios participating in the ISO-NE Forward Capacity Market. For all kWh realization rates, the standard 90% confidence level is used.

4 CUSTOM REFRIGERATION, MOTOR, AND OTHER RESULTS

Evaluated savings data for the Rhode Island sample points were analyzed to develop Rhode Island realization rates, and then combined with National Grid Massachusetts results (previously reported as discussed above) to represent overall results for use in Rhode Island.

In preparation for analyzing the evaluation results collected for the RI sample points, the original 2012 population distribution was used to calculate case weights for each observation in the Rhode Island sample. These weights reflect the number of projects that each sample point represents and allow for the aggregation of results across strata. Since two sample sites were dropped from the study, the case weights are different than those in the original design. The case weights for this study are shown in the last column in Table 4-1.

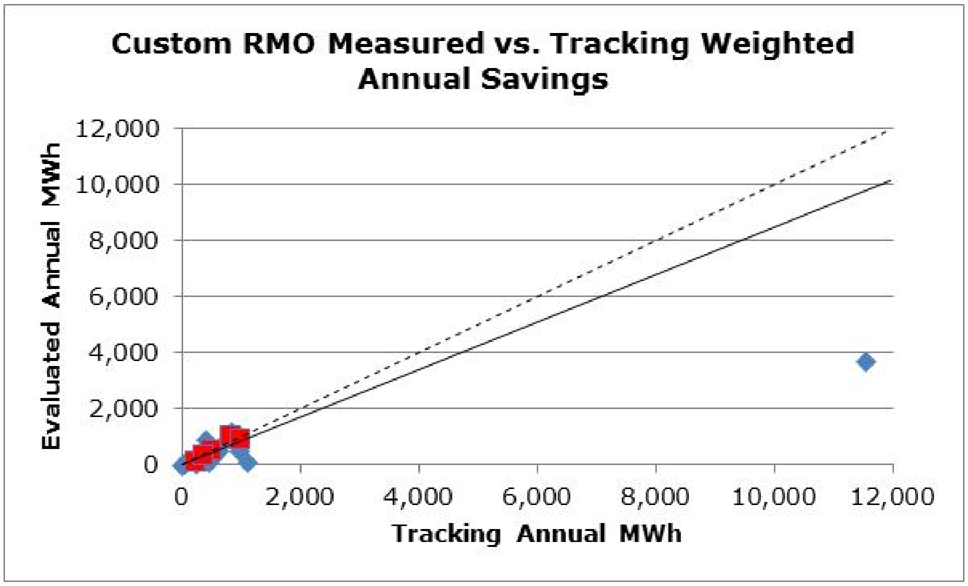
Table 4-1 RI Custom RMO Case Weights

State	Stratum	Maximum KWh Savings	Total Projects	Total Annual MWh	Projects in Sample	Case Weight
Rhode Island	1	224,085	17	1,162,229	4	4.25
Rhode Island	2	541,087	4	1,875,941	2	2

4.1 Major Findings and Observable Trends

Figure 4-1 presents a scatter plot of evaluation savings for the six Rhode Island sample points combined with the Massachusetts sample points. Each point has been weighted by the number of population projects that it represents. The dashed line represents a realization rate of one. The slope of the solid line in this graph is an indication of the realization rate, and can be seen to be less than one. However, the six Rhode Island sample points, as indicated by the six square points in the graph, were mostly close to one.

Figure 4-1 Scatter Plot of RI and MA Evaluation Results for Annual MWh Savings



4.2 Presentation of Results

Table 4-2 presents a summary of the site level results for this impact evaluation.

Table 4-2 RI Custom RMO Detailed Site Results

		Tracking Estimated Savings				Evaluation Savings			
Stratum	Site ID	kWh/yr	On-Peak %	On-Peak Summer kW	On-Peak Winter kW	kWh/yr	On-Peak %	On-Peak Summer kW	On-Peak Winter kW
1	824282	113,224	40%	19.2	1.5	117,651	54.4%	20.3	0.9
1	1438841	52,044	47%	5.9	5.9	30,289	46.4%	3.4	3.5
1	1794980	84,389	46%	10.9	8.6	76,958	46.8%	8.9	8.9
2	2099672	409,041	57%	67.1	67.6	530,778	47.1%	61.9	62.0
2	2202620	482,691	67%	79.2	79.8	446,462	72.5%	96.4	95.3
1	1310864	86,630	0%	0.0	0.0	76,719	45.3%	8.3	8.5

Table 4-3 summarizes the savings realization rates and primary reasons for discrepancies between the tracking and evaluation estimates of annual energy savings for the six RI sites. The site energy savings realization rates ranged from a low of 58% to a high of 130%.

Table 4-3 RI Custom RMO Realization Rates and Primary Site Discrepancies

Stratum	Site ID	Realization Rates kWh/Yr	On-Peak %	On-Peak Summer kW	On-Peak Winter kW	Primary Reasons for Discrepancies
1	824282	104%	136%	106%	65%	Annual fan operation was found to be 1,100 hours as compared to tracking estimate of 808 hours.
1	1438841	58%	99%	58%	58%	The reduction in savings is due to differences in wattage of the existing ECMs.
1	1794980	91%	102%	82%	103%	Savings variance due to differences in space temperatures, case temperatures and refrigeration compressor efficiency.
2	2099672	130%	83%	92%	92%	The increase in savings is due to extended annual operation and lower average operating kW.
2	2202620	92%	108%	122%	119%	The fan operates approximately 2,100 hours less than tracking estimates. Partially offset by lower average operating kW.
1	1310864	89%	N/A	N/A	N/A	Monitoring data found that the shutoff period is approximately 11% shorter than tracking estimates.

The site-level evaluation results for Rhode Island were aggregated using stratified ratio estimation. The Massachusetts results from separate Custom RMO samples were combined to determine a MA realization rate. Then the Rhode Island and Massachusetts realization rates were applied to their respective total tracking savings to estimate each state's total evaluated savings. The National Grid combined realization rate is the ratio of the total evaluated savings to the total tracking savings, each of which is calculated by summing across the two states. Table 4-4 summarizes the RI results and Table 4-5 shows the aggregation of the previously reported MA results to a combined Custom RMO category. Finally, Table 4-6 provides a summary of the aggregated National Grid results. Since the design criteria for the demand realization rates were different than those for the annual kWh (80% vs. 90% confidence levels), the precisions are reported only in the appropriate rows in these tables.

Table 4-4 Summary of RI Custom RMO Results

Rhode Island	Annual MWh	On-Peak MWh	% On-Peak kWh	On-Peak Summer kW	On-Peak Winter kW
Custom RMO					
Total Tracking Savings	3,038	1,382	51%	400	385
Total Measured Savings	3,028	1,587	71%	455	449
Realization Rate	100%	115%	139%	114%	117%
Relative Precision at 90% Confidence	11.0%	20.6%	-	N/A	N/A
Error Bound at 90% Confidence	332	327	-	N/A	N/A
Relative Precision at 80% Confidence	N/A	N/A	-	15.0%	16.5%
Error Bound at 80% Confidence	N/A	N/A	-	68	74
Error Ratio	0.20	0.33	-	0.31	0.34

Table 4-5 Summary of MA Custom RMO Results

Massachusetts	Annual MWh	On-Peak MWh	% On-Peak kWh	On-Peak Summer kW	On-Peak Winter kW
Custom RMO					
Total Tracking Savings	17,380	7,059	40%	2,329	2,009
Total Measured Savings	14,293	6,531	43%	2,056	1,727
Realization Rate	82%	93%	109%	88%	86%
Relative Precision at 90% Confidence	20.6%	19.8%	-	N/A	N/A
Error Bound at 90% Confidence	2,943	1,291	-	N/A	N/A
Relative Precision at 80% Confidence	N/A	N/A	-	18.7%	17.5%
Error Bound at 80% Confidence	N/A	N/A	-	385	302
Error Ratio	0.65	0.66	-	0.73	0.74

Table 4-6 Summary of Overall MA & RI National Grid Custom RMO Results

Massachusetts + Rhode Island	Annual MWh	On-Peak MWh	% On-Peak kWh	On-Peak Summer kW	On-Peak Winter kW
Custom RMO					
Total Tracking Savings	20,418	8,441	45%	2,728	2,393
Total Measured Savings	17,320	8,118	51%	2,511	2,176
Realization Rate	85%	96%	113%	92%	91%
Relative Precision at 90% Confidence	17.1%	16.4%	-	N/A	N/A
Error Bound at 90% Confidence	2,962	1,331	-	N/A	N/A
Relative Precision at 80% Confidence	N/A	N/A	-	15.6%	14.3%
Error Bound at 80% Confidence	N/A	N/A	-	391	311
Error Ratio	0.57	0.59	-	0.66	0.66

From the state-level results, we can observe that the Rhode Island realization rates are significantly higher than those estimated for Massachusetts for all savings variables analyzed. At 17.1%, the overall precision on the Annual KWh estimate is reasonable. All of the RI only precisions are better than expected due to the fact that error ratios were lower what was anticipated in the sample design.

4.3 Implications for Future Studies

From a statistical perspective, which is heavily dependent on Massachusetts results, it appears that the Custom RMO results are stable, and the variation across sample sites is about what was expected. The Rhode Island Custom RMO sites performed very well in comparison to MA. Unless the underlying causes of the variability change, future designs should assume similar error ratio values to determine sample size requirements.

5 CONCLUSIONS AND RECOMMENDATIONS

Despite the positive results of the Rhode Island sites, the National Grid Custom RMO custom measure category appears to be producing results that are lower than expected when combined with Massachusetts. Below are the DNV GL evaluation team findings and recommendations, which refer only to National Grid's Rhode Island sites. Additional recommendations, based on National Grid's Massachusetts sites, are available in the concurrent Massachusetts Custom RMO impact evaluation referenced previously.

- **Project Documentation.** The overall quality of the Rhode Island project files was very good. The measures studied included fans at an asphalt plant, VSDs on drying ovens, compressed air blow off, retrofitted refrigerated cases, and evaporator fan ECMs. There was no uniformity in the measure types, but the project documentation was very comprehensive, and provided all the details necessary to complete the site evaluations. Continue to collect and retain all relevant project files including applications, TA studies, analysis spreadsheets and specification sheets for all custom measures going forward.

- **Metering.** For some of the measures at the industrial facilities, it was found that production schedules and equipment operation were very diverse. For industrial type measures, it is sometimes difficult to assess the operational diversity with short term metering. DNV GL performed two distinct periods of metering at the asphalt plant since the first period did not appear long enough to assess the operational diversity. It is recommended that for measures which tend to have large production swings that National Grid considers doing some pre-installation metering, and also a minimum of 90 days of post-installation metering if evaluated. National Grid may also consider requesting a year of production records to aid in the development of tracking savings estimates.
- **Spreadsheet Tools.** National Grid utilizes spreadsheet tools for measures such as ECMs, which is intended to standardize the savings estimates of these types of high volume measures. However, these tools should incorporate the ability to adjust key saving assumptions if more specific information is available from the site. For example, site 1438841 was an ECM installation which used the spreadsheet tool to estimate tracking savings. However, a TA study had been done prior, which identified the actual wattages of the existing evaporator fan motors. The actual existing fan motors were of a lower wattage than the default wattages available in the spreadsheet tool, which resulted in lower evaluated savings estimates. If the spreadsheet tool were modified, the site wattages could have been used in place of the default wattages to arrive at a more accurate savings estimate.