RHODE ISLAND SMALL BUSINESS ENERGY EFFICIENCY PROGRAM PRESCRIPTIVE LIGHTING STUDY

Final Report

National Grid

Prepared by DNV GL

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1 EXECUTIVE SUMMARY

National Grid Rhode Island commissioned a study to evaluate the prescriptive lighting (without controls) installed through their 2013 Small Business Energy Efficiency (SBS) Program. The main objectives of this study were to provide summer and winter coincidence factors, connected demand (kW), energy (kWh), annual hours of use (HOU) realization rates, percent on-peak energy savings, and summer and winter demand and energy HVAC interactive effects factors. These results are based on on-site measurement and verification (M&V) performed at a statistically selected sample of 30 sites.

1.1 Program Description and Program Activity Summary

National Grid's Small Business Energy Efficiency Program in Rhode Island offers rebates for energy efficient technologies such as lighting, lighting controls/sensors, custom measures, commercial refrigeration equipment, and walk-in cooler efficiency measures. Rebates of up to 70% of project costs can be provided to qualifying customers and National Grid further offers to finance the remaining 30% of project costs with a 0% interest loan for 2 years. To be eligible for the program, the business must have an average peak monthly demand of 200 kW or less.

There were 1,176 billing accounts with savings credited to the SBS program in the 2013 program year. The total tracked gross annual energy savings among all program participants was 22,019,804 kWh while the diversified peak demand kW savings were estimated at 4,414 kW. Table 1 below provides a measure level summary of the 2013 Small Business Energy Efficiency Program population. This summary includes the number of accounts with each measure type and their total savings. Since participating accounts can have more than one measure type installed, the number of accounts in the total line exceeds the total unique accounts that participated in 2013. We created subgroups with and without lighting control measures under the prescriptive lighting category to show the relationship between our suggested sample frame (prescriptive lighting without controls) relative to lighting installed with controls as well as the overall population. It is clear from this table that savings related to lighting measures overall accounts for the vast majority of program savings, with 94% of accounts installing either a lighting measure or lighting control.

Table 1: 2013 Small Business Energy Efficiency Program Activity

	Participating Accounts		**kWh Savings**		**Peak Diversified kW Reduction**	
End Use	N (1,176)	%	kWh	%	kW	%
Prescriptive Lighting without Controls	842	56%	12,197,815	55%	2,585	59%
Prescriptive Lighting with Controls	180	12%	4,057,523	18%	886	20%
Custom Lighting	112	7%	2,855,136	13%	675	15%
Lighting Controls	181	12%	536,889	2%	107	2%
Non-Lighting	185	12%	2,372,442	11%	162	4%
Total	**1,500**	100%	**22,019,804**	100%	**4,414**	**100%**

1.2 Sampling Methodology

DNV GL used Model-Based Statistical Sampling (MBSS) methodologies to inform the design of the SBS evaluation sample. This methodology allows us to develop a sample design that targets ±10% relative precision at the 90% confidence interval around energy savings, which we understood to be the primary outcome of interest to this study. To develop a sample design of this nature, however, it was necessary to estimate the study error ratio. Error ratios are typically estimated based upon previous experience with similar evaluations. This is because the actual error ratio for the study is not known until the actual variation observed between the final sample points and the tracking data has been assessed.

Based on previous experience and input from National Grid, we decided to target 30 sites in this study as indicated in Table 2. This table also includes estimates of the precisions that were anticipated at the time of this design, assuming an error ratio of 0.31.

Table 2: Prescriptive Lighting Sample Design

Measure Type	Projects	Total Savings (kWh)	Assumed Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
Lighting Systems	842	12,197,815	0.31	90%	30	±9.0%

1.3 On-Site Visit Methodology and Data Analysis

During each site visit, DNV GL field staff verified the type and quantity of installed fixtures by consulting with the site contact and comparing their specifications (including locations when available) to those reported in the tracking system. Interviews were conducted with the appropriate site personnel to gather information on holidays, operating hours, seasonal variations in schedules, business cycles or functional area use patterns that could be utilized to annualize the short-term monitoring. When possible, DNV GL field staff verified pre-existing or baseline conditions with site personnel to help with the accuracy of the savings calculations. HVAC equipment was documented to calculate interactive savings and ISO-NE Manual M-MVDR compliant lighting loggers were installed for a minimum of four weeks.

The data gathered from the on-sites were compiled into spreadsheets for analysis using the methods found in Appendix B. To summarize this approach; the savings were calculated as line-by-line comparisons of pre- and post-retrofit electrical use. Pre- and post-retrofit energy estimates were developed for each line item within each measure. Interactive cooling and heating effects of the installed measures were also calculated, when appropriate, utilizing engineering algorithms. All analyses were conducted in a manner that allowed for the provision of discrepancies between the tracked and gross savings according to each adjustment phase[1]. Final results were expanded to reflect population level impacts through case weighting, with precisions provided around all results. The results that follow cover all lighting types combined, but due to the large proportion of exterior fixtures rebated through the program, results are split by interior versus exterior fixtures in Appendix C.

[1] Documentation, technology, quantity, operation, and interactive adjustments.

1.4 Results

Table 3 summarizes the results of this analysis, which was based on 30 sampled sites. The realization rate for was found to be 102.4% with a precision of ±11.4% at the 90% confidence interval. Note that gross tracking savings do not include HVAC interactive effects. The error ratio was found to be 0.35, which is higher than the 0.31 assumed in the sample design.

Table 3: Summary of On-Site Savings Adjustments

Parameter	kWh	% Gross
Gross Savings (Tracking)	12,197,815	
Documentation Adjustment	51,511	0.4%
Technology Adjustment	4,447	0.04%
Quantity Adjustment	-159,458	-1.3%
Operational Adjustment	-58,367	-0.5%
HVAC Interactive Adjustment	456,740	3.8%
Adjusted Gross Savings	12,492,687	102.4%
Gross Realization Rate	102.4%	
Relative Precision	±11.4%	
Confidence Interval	90%	
Error Ratio	0.35	

Table 4 summarizes the savings factors resulting from our analysis. All relative precisions were calculated at the 80% confidence level[2]. The connected kW realization rate was 97.8%, with a relative precision of ±1.6%. The on-peak summer coincidence factor was 29.9%, with a relative precision of ±27.0%. The on-peak winter coincidence factor was 64.9%, with a relative precision of ±13.8%. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, connected kWh realization rate, kWh HVAC interactive effect, hours of use realization rate and percent on-peak kWh. The heating HVAC interactive effect is lower than we typically see in small business evaluations due to the relatively large proportion of exterior lighting installations. Installations of this nature impact both the electric and non-electric interaction; as well as the summer coincidence factor.

[2] These results are reported at the 80% confidence interval to be consistent with ISO-NE requirements for peak demand results.

Table 4: Summary of Savings Factors

Savings Factors and Realization Rates at 80% Confidence	Value	Precision
kW Factors		
Connected kW Realization Rate	97.8%	±1.6%
Summer Coincidence Factor	29.9%	±27.0%
Winter Coincidence Factor	64.9%	±13.8%
Summer kW HVAC Interactive Effect	111.5%	±5.4%
Winter kW HVAC Interactive Effect	99.4%	±0.8%
kWh Factors		
Connected kWh Realization Rate	98.7%	±0.9%
kWh HVAC Interactive Effect	102.0%	±8.5%
Hours of Use Realization Rate	96.3%	±10.7%
% On-Peak KWh	44.0%	[3]
Non-Electric		
Heating HVAC Interactive Effect (MMBtu/kWh)	-0.000526	

1.5 Conclusions and Recommendations

Overall, the prescriptive lighting measures installed through National Grid Rhode Island's SBS program are performing well relative to tracking estimates and generating substantial savings. The primary driver for the higher evaluated gross savings estimates is the HVAC interactive adjustment. The increase in savings due to documentation and technology adjustments are almost equally balanced by the decrease in savings due to the operational adjustment. HVAC interaction, which is not included in the tracking savings estimates, exceeds the reduction in savings due to the quantity adjustment, resulting in an increase in savings of 2.4% over the tracking system estimate.

The energy realization rate of 102.4% is similar to those from previous lighting impact evaluations, which are typically at or above 100%. The error ratio of 0.35 was somewhat higher than the assumed error ratio (0.31). This is an indication of greater variability in the evaluated savings estimates as compared to those from the tracking system. Future impact evaluations of lighting systems should consider increasing the planning error ratio to 0.35 or even 0.4 to further hedge against the possibility of yet higher levels of variability.

The following are some conclusions and recommendations specific to each of the adjustments presented above.

Documentation Adjustment

Conclusion: The overall documentation adjustment resulted in an increase in savings of ~0.4%. Twenty-six of the thirty sites in the sample (86.7%) had the documentation to support the savings estimates provided in the tracking system. Two other sites had documentation which provided savings estimates that were only slightly different (~0.1%) from those in the tracking system. The documentation from the two remaining sites provided a savings estimate that was approximately 6%

[3] The precision around the % on-peak kWh result could not be calculated due to the lack of tracking values for this factor.

higher than their tracking system counterparts. Overall, National Grid does a great job with the tracking database used for the SBS Program and with the documentation that supports those savings estimates.

Recommendation: We recommend that National Grid continue to track savings and supporting documentation consistent with its current system. Although there were a couple isolated discrepancies between tracking system and supporting documentation for one site, we do not believe this incident warrants an explicit recommendation at this time.

Technology and Quantity Adjustments

Technology Adjustment Conclusion: There was one site in the sample that experienced a minor technology change; from 12-watt LEDs (tracking) to 11-watt LEDs (evaluation). National Grid does a great job tracking what was actually installed.

Quantity Adjustment Conclusion: Five of the sites in the sample had at least one fixture that was reported as installed by the tracking system and not found onsite or was removed prior to the site visit.

Recommendation: We believe the current system National Grid is using to track the type and quantity of fixtures installed is sufficient. No change to that system is recommended.

Operational Adjustment

Conclusion: All thirty sampled sites experienced an operational adjustment, which is understandable given that tracking hours of use are estimated by vendors and/or customers based on building specific inputs. Eighteen sites had evaluation hours that were lower than the tracking estimates and twelve had evaluation hours that were higher but when combined they accounted for only a 0.5% reduction in savings.

Recommendation: Overall, the tracking system hours of use estimates appear to be very accurate. While there were discrepancies between the tracking and evaluation hours for every site, the average tracking hours were very close to the average evaluation hours. Given the time sensitive nature of program installations and for lack of a more accurate cost-effective way to estimate hours, we recommend that National Grid continue to use the hours of use estimates provided by the vendors/customers.

HVAC Interactive Adjustment

Conclusion: HVAC interaction accounted for the largest adjustment to the tracking savings at approximately 3.8%. The HVAC interactive adjustment in this study is small when compared to other similar studies due to the relatively large proportion of exterior lighting installations.

Recommendation: We recommend that National Grid consider including HVAC interaction in their tracking system savings estimates. While it was a relatively minor adjustment in this evaluation, interaction may become more influential on program savings should future program installations shift away from exterior fixtures and toward interior fixtures.

2 INTRODUCTION, STUDY OBJECTIVES, & PROGRAM SUMMARY

National Grid Rhode Island commissioned a study to evaluate the prescriptive lighting (without controls) installed through their 2013 Small Business Energy Efficiency (SBS) Program. The main objectives of this study were to provide summer and winter coincidence factors, connected demand (kW), energy (kWh), annual hours of use (HOU) realization rates, percent on-peak energy savings, and summer and winter demand and energy HVAC interactive effects factors. These results are based on on-site measurement and verification (M&V) performed at a statistically selected sample of 30 sites. Each result is defined in Appendix A.

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There are 1,176 billing accounts with savings credited to the SBS program in the 2013 program year. The total tracked gross annual energy savings among all program participants is 22,019,804 kWh while the diversified peak demand kW savings are estimated at 4,414 kW. Table 5 below provides a measure level summary of the 2013 Small Business Energy Efficiency Program population. This summary includes the number of accounts with each measure type and their total savings. Since participating accounts can have more than one measure type installed, the number of accounts in the total line exceeds the total unique accounts that participated in 2013. We created subgroups with and without lighting control measures under the prescriptive lighting category to show the relationship between the sample frame for this study (prescriptive lighting without controls) relative to lighting installed with controls as well as the overall population. It is clear from this table that savings related to lighting measures overall accounts for the vast majority of program savings, with 94% of accounts installing either a lighting measure or lighting control.

Table 5: 2013 Small Business Energy Efficiency Program Activity

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3 SAMPLING METHODOLOGY

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In a National Grid small business study we performed in Upstate NY recently, we experienced an error ratio around energy savings of 0.44. In a recent small business study in Connecticut, we used an error ratio of 0.35 around energy and 0.5 for summer peak demand. These assumptions resulted in energy savings results with a precision of ±7.8% at the 90% confidence interval and summer peak demand results with a precision of ±8.6% at the 80% confidence interval. In addition, we note that in a 2004 study of National Grid Small Business lighting, we experienced a precision of ±8.2% at the 90% confidence interval for energy based on 35 sites. Based on these experiences and input from National Grid, we decided to target 30 sites in this study as indicated in Table 6. This table also includes estimates of the precisions that were anticipated at the time of this design, assuming an error ratio of 0.31.

Table 6: Prescriptive Lighting Sample Design

Measure Type	Projects	Total Savings (kWh)	Assumed Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
Lighting Systems	842	12,197,815	0.31	90%	30	±9.0%

The stratified design for this study's sample of 30 is provided in the Table 7 below. The first three columns in the table provide the stratum number, the cut point used to allocate sites to the strata and the number of participating accounts with prescriptive lighting installed (without controls) in each stratum. The final three columns show the total tracking savings in each stratum, the number of sample points that were randomly selected from each stratum, and the probability of a site being included in the sample draw. This final column is the division of the sample size in each stratum by the number of accounts in that stratum. Reversing this calculation (dividing accounts in the strata by the accounts in the sample) provides the case weights that were used to expand the results back to the population. Note that in this sample design, we utilized account level activity as the sample unit as opposed to application level activity. This approach provided an opportunity to cover all lighting activity at each site visited as opposed to only evaluating portions of activity that might be reflected in a single application from a site.

Table 7: Small Business Energy Efficiency Program Sample Design

Stratum	Maximum	Accounts	Tracking Savings (kWh)	Sample	Inclusion Probability
1	8,592	402	1,817,765	6	0.015
2	15,135	189	2,154,277	6	0.032
3	23,610	127	2,367,585	6	0.047
4	45,143	82	2,653,913	6	0.073
5	178,547	42	3,204,273	6	0.142
	Total	842	12,197,815	30	N/A

4 ON-SITE VISIT METHODOLOGY

There were four primary steps undertaken in this study. They were file reviews and recruitment of the on-site sample, on-site visits with metering and verification, on-site analysis, and program level expansion. Each of these steps is discussed below.

4.1 File Reviews and Recruitment of the On-site Sample

After randomly selecting sites from within each stratum as the primary sample and receiving participant contact information and tracking system savings, calculations, and assumptions, file reviews were performed on each sample point. In these file reviews the DNV GL team recalculated the savings estimate for each sampled site.

The primary sample was then assigned to a team of site auditors, who scheduled their own visits. In order to minimize customer intrusion and maximize recruitment rates, the auditors were flexible with visit days and times are performed; including early morning, evening, and weekend visits as necessary. Additionally, each scheduled appointment was called approximately 48 hours before the visit to confirm the appointment.

Table 8 presents the final disposition of the recruitment calls made for the 30 on-site visits based on the disposition codes provided in The American Association for Public Opinion Research's (AAPOR) Standard Definitions.[4] Based on the algorithms provided in this document we calculate a 75% response rate and a 20% refusal rate. Based upon our experience, we believe these rates are reasonable for a study of this nature.

Table 8: Final M&V On-site Recruitment Disposition

Disposition Code	Disposition Description	Total
1.1	Completion	30
2.11	Refusal	8
2.21	Respondent Never Available	2
Total Customers Called		40

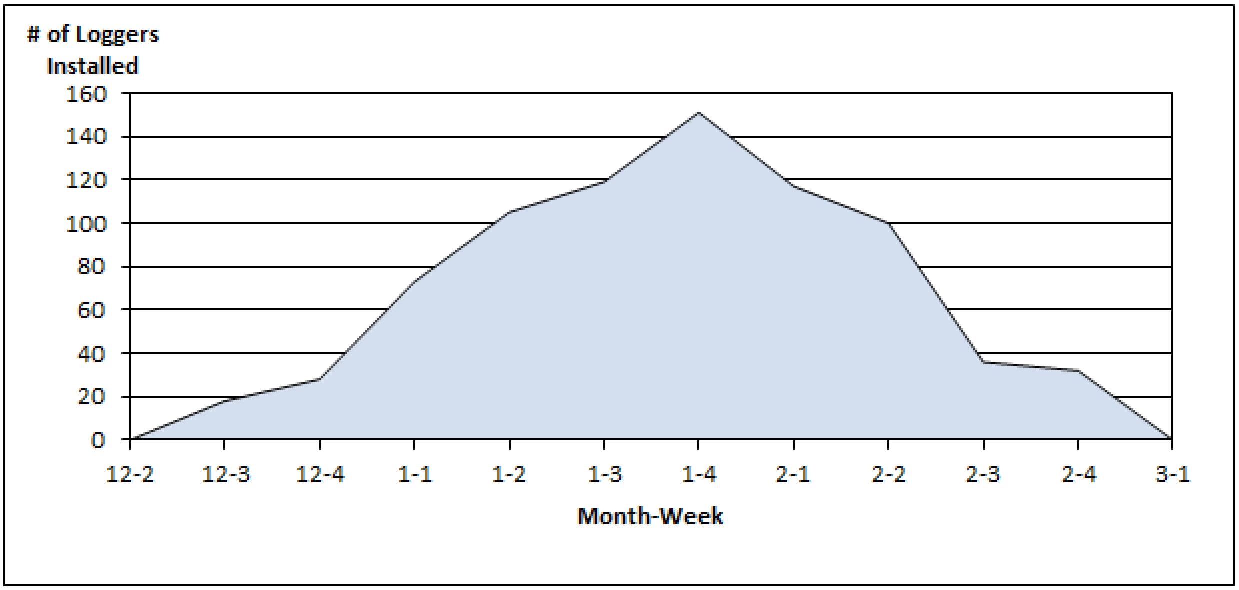
4.2 On-site Visits with Metering and Verification

During each site visit, DNV GL field staff verified the type and quantity of installed fixtures by consulting with the site contact and comparing their specifications (including locations when available) to those reported in the tracking system. Interviews were conducted with the appropriate site personnel to gather information on holidays, operating hours, seasonal variations in schedules, business cycles or functional area use patterns that could be utilized to annualize the short-term monitoring. When possible, DNV GL field staff verified pre-existing or baseline conditions with site personnel to help with the accuracy of the savings calculations. HVAC equipment was documented to calculate interactive savings and 151 ISO-NE Manual M-MVDR compliant lighting loggers were installed for a minimum of four weeks. As Figure 1 shows, the site work took place during the winter months.

[4] http://www.aapor.org/AAPORKentico/AAPOR_Main/media/MainSiteFiles/StandardDefinitions2011_1.pdf

This timing was ideal for the determination of coincident winter peak use (5 pm-7pm). However, logging in the winter did require annualization to assess summer coincidence and annual hours.

Figure 1: Logger Installation and Removal Timeline



In a recent study for National Grid on Small Business lighting in Upstate New York, DNV GL performed an analysis of annualized hours of use and summer coincidence factor estimates based upon the calculation of annualized three months of winter logging to a full year of logging[5]. Overall, the final 12-month estimate of lighting hours was 94.5% of that estimated based upon the winter logging period, but were statistically the same at the 90% confidence interval. The final estimate of summer coincidence (based on logging that occurred in the summer) was 59.1%, or roughly 6% higher than the estimate derived from the winter logging period (52.7%).

Our interpretation of these results is that lighting operation at the coincident peak hour for small business appears to be driven more by business hours of operation and perhaps seasonal activity than daylight or other external factors. Therefore, the summer coincidence factor was calculated using the logger data collected and adjusting for any seasonal effects (i.e., production or occupancy swings) reported by the site contact.

4.3 Data Analysis

Once the loggers were removed, the on and off transition data was downloaded from each logger and annualized/normalized to represent an entire year. In determining lighting schedules from time-of-use data, annual trends such as seasonal effects (e.g., daylight savings), production, and occupancy swings (such as vacations, business cycles, etc.) were accommodated to the extent supported by the data.

[5] Final Report, Impact Evaluation of New York Small Business Services Energy Efficiency Program, 2010 and 2011 Program Years, National Grid USA Prepared by DNV GL, Inc., August, 2014

The data gathered from the on-sites were compiled into spreadsheets for analysis using the methods found in Appendix B. The savings were calculated as line-by-line comparisons of pre- and post-retrofit electrical use. Pre- and post-retrofit energy estimates were developed for each line item within each measure. Interactive cooling and heating effects of the installed measures were also calculated, when appropriate, utilizing engineering algorithms. The on-site savings calculations included all relevant information gathered during the on-site. All analyses were conducted in a manner that allowed for the provision of discrepancies between the tracked and gross savings according to each adjustment phase. This approach is consistent with that taken in all of the C&I lighting studies that DNV GL has performed for National Grid in Massachusetts and elsewhere. Overall program savings impacts are provided for each level of adjustment, including:

- *Documentation Adjustment:* The Documentation Adjustment reflects any change in savings due to discrepancies in project documentation. Evaluators recalculated the tracking estimates of savings using all quantities, fixture types/wattages, and hours documented in the project file. All tracking system discrepancies and documentation errors are reflected in this adjustment.
- *Technology Adjustment:* The Technology Adjustment reflects the change in savings due to the identification of a different lighting technology (fixture type and wattage) at the site than represented in the program data estimate of savings; provided that this technology was rebated by the program.
- *Quantity Adjustment:* The Quantity Adjustment reflects the change in savings due to the identification of a different quantity of lighting fixtures installed at the site than presented in the program data system estimate of savings.
- *Operation Adjustment:* The Operation Adjustment reflects the change in savings due to the observation or monitoring of different lighting operating hours at the site than represented in the program data system estimate of savings.
- *Interactive/Heating and Cooling Adjustment:* The Heating and Cooling Adjustments reflect changes in savings due to interaction between measures and other systems in the building. These effects take into account the effect of the energy efficient lighting measures on their corresponding heating and cooling systems. Energy efficient lighting serves to reduce the heat gain to a given space and accordingly reduces the load on cooling equipment. But this reduced heat gain has the added consequence of increasing the load on the heating system.

As discussed above, evaluators interviewed facility personnel during the on-site visit to ascertain the cooling and heating fuel, system type, and other information with which to approximate the efficiency of the HVAC equipment serving the space of each lighting installation. The DNV GL team expresses HVAC system efficiency in dimensionless units of Coefficient of Performance (COP), which reflects the ratio of work performed by the system to the work input of the system. Table 9 details the COP assumptions for general heating and cooling equipment types encountered in this study. Where site-specific information yields improved estimates of system efficiency, these were used in place of the general assumptions below.

Table 9: General Heating and Cooling COP Assumptions

Cooling System Type	COP
Packaged DX	2.9
Window DX	2.7
Chiller <200 Ton	4.7
Chiller >200 Ton	5.5
Air to Air Heat Pump	3.9
Water to Air Heat Pump	4.4
Refrigerated Area (high temp)	1.4
Refrigerated Cases (low temp)	1.9

Heating System Type	COP
Air to Air Heat Pump	1.5
Electric Resistance	1
Water to Air Heat Pump	2.8

Electric interactive effects are calculated only at sites where heating and/or cooling systems are in use at the same time the lighting project provides savings. Leveraging the 8,760 profile of hourly demand impacts, the DNV GL team computes electric interactive effects during the hours that lighting and HVAC are assumed to operate in unison.

DNV GL utilizes Typical Meteorological Year 3 (TMY3) hourly dry-bulb temperatures for Providence, RI as the balance point criteria in this analysis. For each hour in a typical year, DNV GL computes HVAC interaction according to the following equations:

Cooling kW Effects = 80% * Lighting kW Savings / Cooling System COP

Heating kW Effects = -80% * Lighting kW Savings / Heating System COP

The 80% values represent the assumed percentage of the lighting energy that translates to heat which either must be removed from the space by the air conditioning system or added to the space by the heating system during the aforementioned HVAC hours. The HVAC hours account for when the heating or cooling system is on, and when the outdoor air temperature exceeds a certain point, typically 55°F. This assumption is consistent with those established and employed in previous impact evaluations of prescriptive lighting measures. Heating factors are negative because heating interaction erodes gross lighting savings, while cooling interactive boosts it.

4.4 Program Level Expansion

After calculating all site level results, DNV GL combined the data gathered during the site visit with the program population data provided by National Grid to estimate gross savings realization rates for annual kWh, kW, and summer peak diversified kW. DNV GL also used the combined data to estimate gross savings results for winter peak diversified kW and percent energy on-peak. The results in the following section cover all lighting types combined, but due to the large proportion of exterior fixtures rebated through the program, results are split by interior versus exterior fixtures in Appendix C.

To perform the expansion, case weights for the overall population were utilized per the sample design presented earlier. All reporting at the program level has been sample weighted and is statistically representative of the population. Final results include the precisions associated with each level of disaggregation.

5 RESULTS

The results presented in this section include realization rates (and associated precision levels) for annual kWh savings, percent on-peak kWh savings, and on-peak demand (kW) coincidence factors at the times of the winter and summer peaks, as defined by the ISO New England Forward Capacity Market (FCM). All savings results are defined in Appendix A of this report.

Figure 2 presents a scatter plot of evaluation results versus tracking savings for annual energy savings (kWh). A one-to-one reference line is plotted as a bolded line on the diagonal of the figure. The annual kWh realization rate is 102.4%.

Figure 2: Scatter Plot of M&V On-Site Evaluation Results for Annual kWh Savings

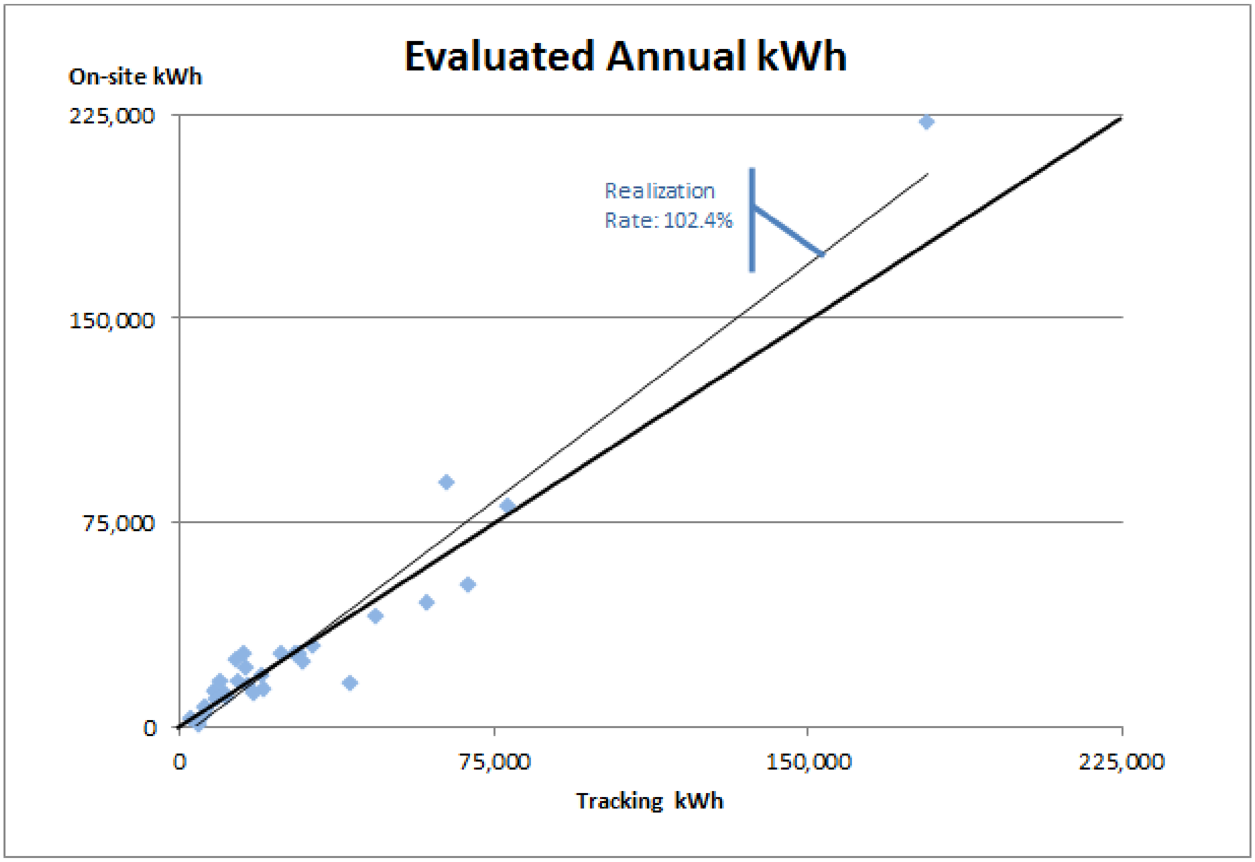


Table 10 summarizes the results of this analysis, which was based on 30 sampled sites. The realization rate for was found to be 102.4% with a precision of ±11.4% at the 90% confidence interval. The error ratio was found to be 0.35, which was higher than the 0.31 assumed in the sample design.

Table 10: Summary of On-Site Savings Adjustments

Parameter	kWh	% Gross
Gross Savings (Tracking)	12,197,815	
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HVAC Interactive Adjustment	456,740	3.8%
Adjusted Gross Savings	12,492,687	102.4%
Gross Realization Rate	102.4%	
Relative Precision	±11.4%	
Confidence Interval	90%	
Error Ratio	0.35	

Table 11 summarizes the savings factors resulting from this analysis. All relative precisions were calculated at the 80% confidence level. The connected kW realization rate was 97.8%, with a relative precision of ±1.6%. The on-peak summer coincidence factor was 29.9%, with a relative precision of ±27.0%. The on-peak winter coincidence factor was 64.9%, with a relative precision of ±13.8%. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, connected kWh realization rate, kWh HVAC interactive effect, hours of use realization rate and percent on-peak kWh. The heating HVAC interactive effect is lower than we typically see in small business evaluations due to the relatively large proportion of exterior lighting installations. Installations of this nature impact both the electric and non-electric interaction; as well as the summer coincidence factor.

Table 11: Summary of Savings Factors

Savings Factors and Realization Rates at 80% Confidence	Value	Precision
kW Factors		
Connected kW Realization Rate	97.8%	±1.6%
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kWh Factors		
Connected kWh Realization Rate	98.7%	±0.9%
kWh HVAC Interactive Effect	102.0%	±8.5%
Hours of Use Realization Rate	96.3%	±10.7%
% On-Peak KWh	44.0%	[6]
Non-Electric		
Heating HVAC Interactive Effect (MMBtu/kWh)	-0.000526	

[6] The precision around the % on-peak kWh result could not be calculated due to the lack of tracking values for this factor.

6 CONCLUSIONS AND RECOMMENDATIONS

Overall, the prescriptive lighting measures installed through National Grid Rhode Island's SBS program are performing well relative to tracking estimates and generating substantial savings. The primary driver for the higher evaluated gross savings estimates is the HVAC interactive adjustment. The increase in savings due to documentation and technology adjustments are almost equally balanced by the decrease in savings due to the operational adjustment. HVAC interaction, which is not included in the tracking savings estimates, exceeds the reduction in savings due to the quantity adjustment, resulting in an increase in savings of 2.4% over the tracking system estimate.

The energy realization rate of 102.4% is similar to those from previous lighting impact evaluations, which are typically at or above 100%. The error ratio of 0.35 was somewhat higher than the assumed error ratio (0.31). This is an indication of greater variability in the evaluated savings estimates as compared to those from the tracking system. Future impact evaluations of lighting systems should consider increasing the planning error ratio to 0.35 or even 0.4 to further hedge against the possibility of yet higher levels of variability.

The following are some conclusions and recommendations specific to each of the adjustments presented above.

Documentation Adjustment

Conclusion: The overall documentation adjustment resulted in an increase in savings of ~0.4%. Twenty-six of the thirty sites in the sample (86.7%) had the documentation to support the savings estimates provided in the tracking system. Two other sites had documentation which provided savings estimates that were only slightly different (~0.1%) from those in the tracking system. The documentation from the two remaining sites provided a savings estimate that was approximately 6% higher than their tracking system counterparts. Overall, National Grid does a great job with the tracking database used for the SBS Program and with the documentation that supports those savings estimates.

Recommendation: We recommend that National Grid continue to track savings and supporting documentation consistent with its current system. Although there were a couple isolated discrepancies between tracking system and supporting documentation for one site, we do not believe this incident warrants an explicit recommendation at this time.

Technology and Quantity Adjustments

Technology Adjustment Conclusion: There was one site in the sample that experienced a minor technology change; from 12-watt LEDs (tracking) to 11-watt LEDs (evaluation). National Grid does a great job tracking what was actually installed.

Quantity Adjustment Conclusion: Five of the sites in the sample had at least one fixture that was reported as installed by the tracking system and not found onsite or was removed prior to the site visit.

Recommendation: We believe the current system National Grid is using to track the type and quantity of fixtures installed is sufficient. No change to that system is recommended.

Operational Adjustment

Conclusion: All thirty sampled sites experienced an operational adjustment, which is understandable given that tracking hours of use are estimated by vendors and/or customers based on building specific inputs. Eighteen sites had evaluation hours that were lower than the tracking estimates and twelve had evaluation hours that were higher but when combined they accounted for only a 0.5% reduction in savings.

Recommendation: Overall, the tracking system hours of use estimates appear to be very accurate. While there were discrepancies between the tracking and evaluation hours for every site, the average tracking hours were very close to the average evaluation hours. Given the time sensitive nature of program installations and for lack of a more accurate cost-effective way to estimate hours, we recommend that National Grid continue to use the hours of use estimates provided by the vendors/customers.

HVAC Interactive Adjustment

Conclusion: HVAC interaction accounted for the largest adjustment to the tracking savings at approximately 3.8%. The HVAC interactive adjustment in this study is small when compared to other similar studies due to the relatively large proportion of exterior lighting installations.

Recommendation: We recommend that National Grid consider including HVAC interaction in their tracking system savings estimates. While it was a relatively minor adjustment in this evaluation, interaction may become more influential on program savings should future program installations shift away from exterior fixtures and toward interior fixtures.

A. Description of Results and Factors

This section presents a listing of realization rate and savings factors that were produced as part of this study. Each entry contains a description of that savings variable.

A.1 Realization Rates

Annual KWh – This result is the gross annual kWh realization rate including additional savings due to HVAC interactive effects. This realization rate is the evaluation gross annual kWh savings divided by the tracking gross annual kWh savings.

Connected KW – This result is the gross connected kW realization rate, which includes any documentation, quantity, and technology adjustments. This realization rate is the evaluation gross connected kW savings divided by the tracking gross connected kW savings.

Connected kWh – This result is the gross connected kWh realization rate, which includes only the documentation, quantity, and technology adjustments. This realization rate is the evaluation gross connected kWh savings divided by the tracking gross connected kWh savings.

Hours of Use – This result is the hours of use realization rate, which represents the evaluation estimate of hours of use divided by the tracking estimate of hours of use.

A.2 Savings Factors

Summer Coincidence Factor – Diversity x Coincidence. This is the percentage of the connected kW savings coincident with the summer on-peak period (1pm-5pm on non-holiday weekdays in June, July, and August).

Winter Coincidence Factor – Diversity x Coincidence. This is the percentage of the connected kW savings coincident with the winter on-peak period (5pm-7pm on non-holiday weekdays in December and January).

Summer kW HVAC Interactive Effect – This is an adjustment factor applied to the gross connected kW savings that are due to interactive effects during the summer on-peak period.

Winter kW HVAC Interactive Effect – This is an adjustment factor applied to the gross connected kW savings that are due to interactive effects during the winter on-peak period.

KWh HVAC Interactive Effect – This is an adjustment factor applied to the gross kWh savings that are due to interactive effects.

% On Peak KWh – This is the percentage of energy savings that occur during on-peak hours (non-holiday weekdays from 6am-10pm).

Table 12: Summary of Results and Factors

Tracking System Values		Evaluation Values	
(a)	Annual kWh	(j)	Annual kWh
(b)	kWh HVAC Factor	(k)	kWh HVAC Factor
(c)	On-Peak % Annual kWh	(l)	On-Peak % Annual kWh
(d)	Connected kW	(m)	Connected kW
(e)	Summer kW Coincidence Factor	(n)	Summer kW Coincidence Factor
(f)	Summer kW HVAC Factor	(o)	Summer kW HVAC Factor
(g)	Winter kW Coincidence Factor	(p)	Winter kW Coincidence Factor
(h)	Winter kW HVAC Factor	(q)	Winter kW HVAC Factor
(i)	Average Hours of Use	(r)	Average Hours of Use

Realization Rates	
(s)	Annual kWh
(t)	Connected kW
(u)	Connected kWh
(v)	Hours of Use

Savings Algorithms	
Evaluated Annual kWh Savings	(a) x (s) or (a) x (u) x (v) x (k)
Evaluated Connected kW	(d) x (t)
Evaluated Summer Peak kW Reduction	(d) x (t) x (n) x (o)
Evaluated Winter Peak kW Reduction	(d) x (t) x (p) x (q)

A.3 Calculation Methods

This section serves as a detailed example that illustrates the calculation of all savings and adjustment factors. DNV GL used a single line item from a lighting project to serve as an example of the calculation methods. Table 13 presents a summary of all savings parameters for this particular example.

Table 13: Calculation Example Result Summary

Parameter	Annual KWH	Difference %	Connected kW	Difference %
Gross (TRACKING) kWh/Connected kW Savings	3,690	N/A	0.74	N/A
Adjustment - Documentation Change	0	0%	0.00	0%
Adjustment - Technology Change	0	0%	0.00	0%
Adjustment - Quantity Change	-410	-11%	-0.08	-11%
Adjustment - Operation Change	543	15%	N/A	N/A
Non-Interactive Savings	3,823	104%	0.66	89%
Adjustment - Cooling Interaction	314	9%		
Adjusted Gross (ONSITE) Savings	4,136	112%		

Parameter	On-Peak Summer kW	Difference %	On-Peak Winter kW	Difference %
Connected Demand Savings	0.66	N/A	0.66	N/A
Adjustment - On-Peak Coincidence	-0.12	-18%	0.00	0%
Non-Interactive Savings	0.54	82%	0.66	100%

Parameter	On-Peak Summer kW	Difference %	On-Peak Winter kW	Difference %
Non-Interactive Savings	0.54	N/A	0.66	N/A
Adjustment - HVAC Interaction	0.14	27%	0.00	0%
Adjusted Gross (ONSITE) Savings	0.68	127%	0.66	100%

Table 14 presents the pre-retrofit condition for this space as outlined in the application documentation. The pre-retrofit condition included (18) 2F40SSS fixtures rated at 94 watts each. The application also assumed 5,000 annual operating hours.

Table 14: Tracking Pre-Retrofit Condition

Qty	Lighting Fixture Code	Fixture Type	Fixture Description	W/Fixt	Hours of Operation per Year
18	2F40SSS	2L4' STD/STD	Four Foot T12 Systems	94	5,000

Table 15 represents the proposed condition according to the tracking system. In this case, the pre-retrofit fixtures were to be replaced with (18) 2F32EEE fixtures rated at 53 watts each. The hours of operation in the proposed condition were also 5,000 annual operating hours.

Table 15: Tracking Proposed Condition

Qty	Lighting Fixture Code	Fixture Description	Fixture Type	W/Fixt	Hours of Operation per Year
18	2F32EEE	2L4' T8EE/ELEE	Four Foot T8 HP/RW Systems	53	5,000

The first step of the savings analysis was to recreate the savings calculations based upon project documentation. This was done to isolate any documentation adjustments.

Documentation Adjustments

Documentation adjustments reflect any change in savings due to discrepancies in project documentation. Evaluators recalculated the tracking estimates of savings using all quantities, fixture types/wattages, and hours documented in the project file. All tracking system discrepancies and documentation errors are reflected in this adjustment. The documentation adjustments are calculated according to the following formulae:

DOC KWH ADJ = Recreated Tracking kWh Savings – Tracking kWh Savings = 3,690 - 3,690 = 0 kWh

DOC KW ADJ = Recreated Tracking kW Savings – Tracking kW Savings = 0.74 – 0.74 = 0 kW

Hours of Use and Coincidence

The first on-site task was establishing the customer's holiday and vacation/shutdown schedule. Table 16 shows the input for the site holiday analysis. In this particular case, the site contact informed the evaluating engineer that the facility was closed during six major holidays. He also stated that the facility does not have any long shutdowns.

Table 16: Input for Site Specific Holidays

Holiday	Date	Site Observed Holidays
New Year's Day	1/1/2014	Yes
Martin Luther King Day	1/20/2014	No
Presidents Day	2/17/2014	No
Good Friday	4/18/2014	No
Memorial Day	5/26/2014	Yes
Independence Day	7/4/2014	Yes
Labor Day	9/1/2014	Yes
Columbus Day	10/13/2014	No
Veteran's Day	11/11/2014	No
Thanksgiving Day	11/27/2014	Yes
Day After Thanksgiving	11/28/2014	No
Christmas Eve	12/24/2014	No
Christmas Day	12/25/2014	Yes

To determine the annual operating hours from monitoring lighting logger data, engineers examine the hourly percent run time across the entire monitoring period.

For the logger data analysis, an 8x24 profile (Monday through Friday plus Holiday by hour-of-day) is generated using a computer program to represent the average percentage of time that the fixture operated during the monitoring study. Table 17 presents the profile of the logger used for this example.

Table 17: Logger Profile Summary

Hour Ending	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Hol
1	33	36	49	45	46	53	45	57
2	34	36	42	47	41	49	46	51
3	32	36	50	39	42	39	41	50
4	32	36	41	36	35	37	37	50
5	57	39	40	36	34	37	49	50
6	34	57	54	53	84	50	35	50
7	34	75	89	66	94	66	39	50
8	35	99	100	100	99	99	47	52
9	37	100	100	100	100	100	51	57
10	38	100	100	100	100	100	58	50
11	35	100	100	100	100	100	53	50
12	37	100	100	100	100	100	53	50
13	36	98	100	100	100	100	45	50
14	35	99	100	100	99	100	43	50
15	34	100	100	100	100	100	48	50
16	37	94	92	94	92	90	43	50
17	34	92	86	84	86	81	42	50
18	36	100	100	100	100	100	37	50
19	37	100	100	100	100	100	35	50
20	34	95	89	93	94	97	35	50
21	32	98	96	95	97	97	37	50
22	33	96	92	88	87	73	35	50
23	32	49	43	40	33	37	34	50
24	33	45	42	40	40	49	42	50

This analysis concluded that this fixture operates 5,827 hours per year, of which 67% of these operating hours occur coincide with the defined on-peak period definition. The on-peak summer and winter coincidence factors are 82% and 100%, respectively.

Non-Interactive On-Site Savings

Table 18 represents the on-site installed condition as found the evaluation team. For this example, the evaluator identified (16) 2F32EEE fixtures, which was two fewer fixtures than in the project documentation. A schedule identification number ("1" in this example) maps the hours of operation and the summer and winter coincidences into this spreadsheet.

Table 18: On-Site Installed Condition

Qty	Lighting Fixture Code	Fixture Description	Fixture Type	W/Fixt	Schedule Number	Hours of Operation per Year	On-Peak Summer Coincidence	On-Peak Winter Coincidence
16	2F32EEE	2L4' T8EE/ELEE	Four Foot T8 HP/RW Systems	53	1	5,827	82%	100%

The on-site pre-retrofit condition, presented in Table 19, was established through review of project documents, discussion with facility personnel, and observational inference. This lighting fixture savings analysis presumes that the operating hours did not change between the pre- and post-retrofit conditions.

Table 19: On-Site Pre-Retrofit Condition

Qty	Lighting Fixture Code	Fixture Description	Fixture Type	W/Fixt	Hours of Operation per Year
16	2F40SSS	2L4' STD/STD	Four Foot T12 Systems	94	5,827

Table 20 presents the adjusted gross on-site savings for this example.

Table 20: Adjusted Gross On-Site Savings

kW Savings	kW Summer Savings	kW Winter Savings	kWh Savings
0.656	0.536	0.656	3,823

Heating and Cooling Interaction

Heating and cooling interaction was calculated for each line item where applicable based on the specific HVAC systems serving the space. When lighting equipment converts electrical energy to light, a significant amount of that energy is dissipated in the form of heat. Energy efficient lighting measures convert more electrical energy to light and less to heat. Since installing energy efficient lighting adds less heat to a given space, a complete estimation of energy savings considers the associated impacts on the heating and cooling systems or "interactive effects."

The interactive effects take into account the effect of the energy efficient lighting measures on their corresponding heating and cooling systems. Energy efficient lighting serves to reduce the heat gain to a given space and accordingly reduces the load on cooling equipment. But this reduced heat gain has the added consequence of increasing the load on the heating system.

As part of the on-site methodology, evaluators interviewed facility personnel to ascertain the cooling and heating fuel, system type, and other information with which to approximate the efficiency of the HVAC equipment serving the space of each lighting installation. The DNV GL team expresses HVAC system efficiency in dimensionless units of Coefficient of Performance (COP), which reflects the ratio of work performed by the system to the work input of the system. Table 21 details the COP assumptions for general heating and cooling equipment types encountered in this study. Where site-specific information yields improved estimates of system efficiency, these were used in place of the general assumptions below.

Table 21: General Heating and Cooling COP Assumptions

Cooling System Type	COP
Packaged DX	2.9
Window DX	2.7
Chiller <200 Ton	4.7
Chiller >200 Ton	5.5
Air to Air Heat Pump	3.9
Water to Air Heat Pump	4.4
Refrigerated Area (high temp)	1.4
Refrigerated Cases (low temp)	1.9

Heating System Type	COP
Air to Air Heat Pump	1.5
Electric Resistance	1
Water to Air Heat Pump	2.8

Electric interactive effects are calculated only at sites where heating and/or cooling systems are in use at the same time the lighting project provides savings. Leveraging the 8,760 profile of hourly demand impacts, the DNV GL team computes electric interactive effects during the hours that lighting and HVAC are assumed to operate in unison.

DNV GL utilizes Typical Meteorological Year 3 (TMY3) hourly dry-bulb temperatures for Providence, RI as the balance point criteria in this analysis. For each hour in a typical year, DNV GL computes HVAC interaction according to the following equations:

Cooling kW Effects = 80% * Lighting kW Savings / Cooling System COP

Heating kW Effects = -80% * Lighting kW Savings / Heating System COP

The 80% values represent the assumed percentage of the lighting energy that translates to heat which either must be removed from the space by the air conditioning system or added to the space by the heating system during the aforementioned HVAC hours. The HVAC hours account for when the heating or cooling system is on, and when the outdoor air temperature exceeds a certain point, typically 55°F. This assumption is consistent with those established and employed in previous impact evaluations of custom lighting measures. Also, heating factors are negative because heating interaction erodes gross lighting savings, while cooling interactive boosts it.

B. Site Level Results

Table 22: Sample Tracking System Savings Estimates

DNVGL ID	Facility Type	Annual kWh	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW	Summer kW Coincidence Factor	Summer kW HVAC Factor	Winter kW Coincidence Factor	Winter kW HVAC Factor	Average Hours of Use
DNV0101	Office	4,509	0%	N/A	2.05	74%	N/A	74%	N/A	2,202
DNV0103	Office	6,412	0%	N/A	1.47	100%	N/A	100%	N/A	4,368
DNV0104	Restaurant	5,951	0%	N/A	2.21	72%	N/A	72%	N/A	2,699
DNV0106	Restaurant	6,251	0%	N/A	2.08	73%	N/A	73%	N/A	3,001
DNV0107	Other	8,363	0%	N/A	2.54	72%	N/A	72%	N/A	3,287
DNV0108	Medical (Hospital)	2,752	0%	N/A	0.79	69%	N/A	69%	N/A	3,484
DNV0201	Restaurant	8,685	0%	N/A	2.39	69%	N/A	69%	N/A	3,640
DNV0202	Medical (Hospital)	10,838	0%	N/A	4.82	100%	N/A	100%	N/A	2,249
DNV0203	Grocery	13,855	0%	N/A	2.64	74%	N/A	74%	N/A	5,240
DNV0204	Retail	9,987	0%	N/A	2.53	69%	N/A	69%	N/A	3,943
DNV0205	Office	11,007	0%	N/A	2.52	69%	N/A	69%	N/A	4,368
DNV0206	Retail	13,548	0%	N/A	3.95	74%	N/A	74%	N/A	3,433
DNV0301	Other	19,739	0%	N/A	4.52	69%	N/A	69%	N/A	4,368
DNV0302	Retail	15,610	0%	N/A	6.00	69%	N/A	69%	N/A	2,600
DNV0303	Retail	15,838	0%	N/A	5.44	69%	N/A	69%	N/A	2,912
DNV0305	Grocery	16,188	0%	N/A	3.71	69%	N/A	69%	N/A	4,368
DNV0306	Other	20,313	0%	N/A	2.63	74%	N/A	74%	N/A	7,724
DNV0307	Restaurant	17,663	0%	N/A	4.56	69%	N/A	69%	N/A	3,875
DNV0401	Manufacturing	27,499	0%	N/A	6.70	74%	N/A	74%	N/A	4,107
DNV0404	Other	28,466	0%	N/A	6.52	69%	N/A	69%	N/A	4,368
DNV0405	Grocery	24,556	0%	N/A	5.25	71%	N/A	71%	N/A	4,682
DNV0406	Restaurant	29,423	0%	N/A	6.74	69%	N/A	69%	N/A	4,368
DNV0408	Retail	40,670	0%	N/A	9.39	70%	N/A	70%	N/A	4,334
DNV0409	Office	31,755	0%	N/A	7.27	69%	N/A	69%	N/A	4,368
DNV0501	Warehouse	46,853	0%	N/A	22.30	74%	N/A	74%	N/A	2,101
DNV0502	Other	59,203	0%	N/A	25.26	69%	N/A	69%	N/A	2,343
DNV0503	Office	63,812	0%	N/A	17.06	73%	N/A	73%	N/A	3,741
DNV0505	Retail	178,547	0%	N/A	54.29	69%	N/A	69%	N/A	3,289
DNV0507	Retail	78,608	0%	N/A	15.46	70%	N/A	70%	N/A	5,085
DNV0510	Medical (Hospital)	68,899	0%	N/A	21.38	73%	N/A	73%	N/A	3,222

Table 23: Sample Evaluation Savings Estimates

DNVGL ID	Facility Type	Annual kWh	kWh HVAC Factor	On-Peak % Annual kWh	Connected kW	Summer On-Peak kW Coincidence Factor	Summer On-Peak kW HVAC Factor	Winter On-Peak kW Coincidence Factor	Winter On-Peak kW HVAC Factor	Average Hours of Use
DNV0101	Office	396	100%	34%	2.18	1%	100%	0%	100%	182
DNV0103	Office	6,002	100%	23%	1.47	0%	100%	100%	100%	4,089
DNV0104	Restaurant	6,717	107%	64%	2.14	70%	115%	5%	100%	2,927
DNV0106	Restaurant	3,772	107%	40%	2.08	19%	127%	37%	100%	1,695
DNV0107	Other	12,524	100%	48%	2.54	61%	100%	63%	100%	4,923
DNV0108	Medical (Hospital)	2,487	113%	77%	0.80	70%	127%	41%	100%	2,755
DNV0201	Restaurant	9,756	100%	23%	2.39	0%	100%	100%	100%	4,089
DNV0202	Medical (Hospital)	12,177	112%	47%	4.82	28%	127%	28%	100%	2,261
DNV0203	Grocery	16,222	112%	61%	2.64	86%	127%	87%	100%	5,463
DNV0204	Retail	16,047	107%	45%	2.53	67%	117%	63%	100%	5,911
DNV0205	Office	10,304	100%	23%	2.52	0%	100%	100%	100%	4,089
DNV0206	Retail	24,065	111%	55%	3.95	90%	124%	77%	100%	5,478
DNV0301	Other	18,478	100%	23%	4.52	0%	100%	100%	100%	4,089
DNV0302	Retail	26,532	100%	25%	6.38	3%	127%	100%	100%	4,237
DNV0303	Retail	21,591	113%	61%	4.66	90%	127%	79%	100%	3,940
DNV0305	Grocery	15,153	100%	23%	3.71	0%	100%	100%	100%	4,089
DNV0306	Other	13,175	111%	51%	2.63	60%	127%	60%	100%	4,493
DNV0307	Restaurant	12,161	91%	51%	3.37	42%	120%	53%	63%	3,657
DNV0401	Manufacturing	26,366	107%	64%	6.70	64%	117%	49%	100%	3,672
DNV0404	Other	26,647	100%	23%	6.52	0%	100%	100%	100%	4,089
DNV0405	Grocery	26,308	104%	34%	5.25	22%	127%	98%	100%	4,818
DNV0406	Restaurant	23,304	100%	43%	6.74	1%	100%	69%	100%	3,460
DNV0408	Retail	15,942	101%	49%	9.39	8%	117%	1%	100%	1,676
DNV0409	Office	29,726	100%	23%	7.27	0%	100%	100%	100%	4,089
DNV0501	Warehouse	40,482	111%	75%	21.33	35%	90%	35%	100%	1,729
DNV0502	Other	45,213	100%	54%	25.10	23%	100%	40%	100%	1,803
DNV0503	Office	89,697	104%	53%	17.06	72%	109%	70%	100%	5,033
DNV0505	Retail	221,997	100%	23%	54.29	0%	100%	100%	100%	4,089
DNV0507	Retail	80,925	102%	30%	16.36	16%	116%	100%	100%	4,834
DNV0510	Medical (Hospital)	51,960	111%	75%	19.53	50%	42%	41%	100%	2,475

Table 24: Sample Realization Rates and Primary Reasons for Discrepancies

DNVGL ID	Facility Type	Annual kWh	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
DNV0101	Office	4,509	9%	106%	8%	Evaluation hours of use are 91% lower than assumed in the tracking system savings estimate.
DNV0103	Office	6,412	94%	100%	94%	Evaluation hours are 6% less than hours assumed in the tracking system.
DNV0104	Restaurant	5,951	113%	97%	108%	One 2L4'T8 fixture that was reported in the tracking data was not found onsite. Evaluation hours of use are 8% greater than assumed in the tracking system savings estimate. Cooling interaction increases savings by an additional 8%.
DNV0106	Restaurant	6,251	60%	100%	56%	Evaluation hours of use are 44% lower than assumed in the tracking system. Cooling credit increased savings by 4%.
DNV0107	Other	8,363	150%	100%	150%	Evaluation hours of use are 50% higher than those assumed in the tracking savings estimate.
DNV0108	Medical (Hospital)	2,752	90%	101%	79%	Evaluation hours of use are 21% lower than assumed in the tracking system estimate. Cooling interaction increases savings by 11%.
DNV0201	Restaurant	8,685	112%	100%	112%	Evaluation hours are 12% higher than hours assumed in the tracking system.
DNV0202	Medical (Hospital)	10,838	112%	100%	101%	Evaluation hours of use are 1% higher than assumed in the tracking system estimate. Cooling interaction increases savings by an additional 12%.
DNV0203	Grocery	13,855	117%	100%	104%	Evaluation hours of use are 4% higher than assumed in the tracking system estimate of savings. Cooling interaction increased savings by an additional 13%.
DNV0204	Retail	9,987	161%	100%	150%	Evaluation hours of use are 50% higher than those assumed in the tracking system estimate. Cooling interaction increased savings by an additional 11%.
DNV0205	Office	11,007	94%	100%	94%	Evaluation hours are 6% less than hours assumed in the tracking system.
DNV0206	Retail	13,548	178%	100%	160%	Evaluation hours of use are 60% higher than assumed in the tracking system estimate. Cooling interaction increases savings by an additional 18%.
DNV0301	Other	19,739	94%	100%	94%	Evaluation hours are 6% less than hours assumed in the tracking system.
DNV0302	Retail	15,610	170%	106%	163%	Evaluation hours of use are 63% higher than assumed in the tracking savings estimate. Cooling interaction increases savings by an additional 1%.
DNV0303	Retail	15,838	136%	86%	135%	Twenty-one fixtures were found to have died or had already been replaced; causing a 15% decrease in savings. The evaluation hours of use are 35% higher than assumed in the tracking system. A cooling credit increase savings by an additional 15%.
DNV0305	Grocery	16,188	94%	100%	94%	Evaluation hours are 6% less than hours assumed in the tracking system.
DNV0306	Other	20,313	65%	100%	58%	Evaluation hours of use are 42% lower than assumed in tracking savings estimate. Cooling interaction increased savings by 7%.

DNVGL ID	Facility Type	Annual kWh	Annual kWh (Including HVAC)	Connected kW	Average Hours of Use	Primary Reasons for Discrepancies
DNV0307	Restaurant	17,663	69%	74%	94%	The 12-watt LEDs reported in the tracking system were found to be 11-watt LEDs on site; resulting in a 1% increase in savings. Evaluation hours of use are 6% lower than assumed in the tracking system. This site is heated and cooled by an electric heat pump system. The 13% heating losses exceeded the 6% cooling gains; resulting in a 7% decrease in savings.
DNV0401	Manufacturing	27,499	96%	100%	89%	Evaluation hours of use are 11% lower than assumed in the tracking system savings estimate. Cooling interaction increases savings by 6%.
DNV0404	Other	28,466	94%	100%	94%	Evaluation hours are 6% less than hours assumed in the tracking system.
DNV0405	Grocery	24,556	107%	100%	103%	Evaluation hours of use are 3% greater than those assumed in the tracking savings estimate. Cooling credit increased savings by 4%.
DNV0406	Restaurant	29,423	79%	100%	79%	Evaluation hours of use are 21% lower than assumed in the tracking system savings estimate.
DNV0408	Retail	40,670	39%	100%	39%	Evaluation hours of use are 61% lower than assumed in the tracking system savings estimate. Cooling interaction increases savings by 1%.
DNV0409	Office	31,755	94%	100%	94%	Evaluation hours are 6% less than hours assumed in the tracking system.
DNV0501	Warehouse	46,853	86%	96%	82%	Six 1L4' fixtures were not found and six others were burned out at the time of the site visit; causing a 4% decrease in savings. Evaluation hours of use are 18% lower than assumed in the tracking savings estimate. A cooling credit increased savings by 8%.
DNV0502	Other	59,203	76%	99%	77%	A slight quantity difference resulted in a 1% decrease in savings. Evaluation hours are 23% lower than assumed in the tracking system.
DNV0503	Office	63,812	141%	100%	135%	Evaluation hours of use are 35% higher than the hours assumed in the tracking system savings estimate. Cooling interaction increases savings by an additional 6%.
DNV0505	Retail	178,547	124%	100%	124%	Evaluation hours are 24% higher than hours assumed in the tracking system.
DNV0507	Retail	78,608	103%	106%	95%	Using the pre and post quantities, wattages, and hours of use in the tracking system results in savings that are 6% higher than those recorded in the tracking system. Evaluation hours of use are 5% lower than assumed in the tracking system savings estimate. Cooling interaction increases savings by 2%.
DNV0510	Medical (Hospital)	68,899	75%	91%	77%	Forty-three fixtures, which were reported to have been installed according to the tracking system, were not found during the on-site visit; causing a 9% decrease in savings. Evaluation hours of use are 23% lower than assumed in the tracking system savings estimate. Cooling interaction increased savings by 7%.

C. Interior vs. Exterior Results

The original scope of work for this evaluation called for the results to be presented for all fixture types combined; as they are in the main body of this report. Due to the large proportion of exterior fixtures rebated through the program, National Grid requested that the results be split by interior versus exterior fixtures. This section summarizes these results.

C.1 Interior Fixture Results

Table 25 summarizes the interior fixture results of this analysis, which was based on 21 sampled sites. The realization rate for was found to be 103.4% with a precision of ±12.8% at the 90% confidence interval. The error ratio was found to be 0.33, which is higher than the 0.31 error ratio assumed in the overall sample design presented earlier.

Table 25: Summary of Interior Fixture On-Site Savings Adjustments

Parameter	kWh	% Gross
Gross Savings (Tracking)	6,901,920	
Documentation Adjustment	9,713	0.1%
Technology Adjustment	4,012	0.1%
Quantity Adjustment	-160,789	-2.3%
Operational Adjustment	-203,016	-3.0%
HVAC Interactive Adjustment	582,672	8.9%
Adjusted Gross Savings	7,134,511	103.4%
Gross Realization Rate	103.4%	
Relative Precision	±12.8%	
Confidence Interval	90%	
Error Ratio	0.33	

Table 26 summarizes the savings factors resulting from our interior fixture analysis. All relative precisions were calculated at the 80% confidence level[7]. The connected kW realization rate was 96.1%, with a relative precision of ±2.5%. The on-peak summer coincidence factor was 54.8%, with a relative precision of ±11.4%. The on-peak winter coincidence factor was 44.9%, with a relative precision of ±10.1%. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, connected kWh realization rate, kWh HVAC interactive effect, hours of use realization rate, percent on-peak kWh, and the heating HVAC interactive effect.

[7] These results are reported at the 80% confidence interval to be consistent with ISO-NE requirements for peak demand results.

Table 26: Summary of Interior Fixture Savings Factors

Savings Factors and Realization Rates at 80% Confidence	Value	Precision
kW Factors		
Connected kW Realization Rate	96.1%	±2.5%
Summer Coincidence Factor	54.8%	±11.4%
Winter Coincidence Factor	44.9%	±10.1%
Summer kW HVAC Interactive Effect	113.2%	±5.1%
Winter kW HVAC Interactive Effect	98.7%	±1.7%
kWh Factors		
Connected kWh Realization Rate	97.7%	±1.5%
kWh HVAC Interactive Effect	103.2%	±9.5%
Hours of Use Realization Rate	97.3%	±14.1%
% On-Peak KWh	65.3%	[8]
Non-Electric		
Heating HVAC Interactive Effect (MMBtu/kWh)	-0.001214	

C.2 Exterior Fixture Results

Table 27 summarizes the exterior fixture results of this analysis, which was also based on 21 sampled sites. The realization rate for was found to be 104.9% with a precision of ±12.4% at the 90% confidence interval. The error ratio was found to be 0.31, which is equal to the error ratio assumed in the overall sample design presented earlier.

Table 27: Summary of Exterior Fixture On-Site Savings Adjustments

Parameter	kWh	% Gross
Gross Savings (Tracking)	5,295,894	
Documentation Adjustment	36,511	0.7%
Technology Adjustment	0	0.0%
Quantity Adjustment	0	0.0%
Operational Adjustment	222,151	4.2%
HVAC Interactive Adjustment	0	0.0%
Adjusted Gross Savings	5,554,557	104.9%
Gross Realization Rate	104.9%	
Relative Precision	±12.4%	
Confidence Interval	90%	
Error Ratio	0.31	

Table 28 summarizes the savings factors resulting from our exterior fixture analysis. All relative precisions were calculated at the 80% confidence level[9]. The connected kW realization rate was 100.0%. The on-peak summer coincidence factor was 11.2%, with a relative precision of ±63.1%. The on-peak winter coincidence factor was 91.3%, with a relative precision of ±7.3%. The table also provides savings factors for connected kWh realization rate, hours of use realization rate, and percent on-peak kWh. The on-peak summer and winter kW HVAC

[8] The precision around the % on-peak kWh result could not be calculated due to the lack of tracking values for this factor.
[9] These results are reported at the 80% confidence interval to be consistent with ISO-NE requirements for peak demand results.

interactive effect and kWh HVAC interactive effect factors are 100.0% because none of the monitored exterior fixtures were conditioned. The heating HVAC interactive effect is zero for the same reason.

Table 28: Summary of Exterior Fixture Savings Factors

Savings Factors and Realization Rates at 80% Confidence	Value	Precision
kW Factors		
Connected kW Realization Rate	100.0%	±0.0%
Summer Coincidence Factor	11.2%	±63.1%
Winter Coincidence Factor	91.3%	±7.3%
Summer kW HVAC Interactive Effect	100.0%	±0.0%
Winter kW HVAC Interactive Effect	100.0%	±0.0%
kWh Factors		
Connected kWh Realization Rate	100.0%	±0.0%
kWh HVAC Interactive Effect	100.0%	±0.0%
Hours of Use Realization Rate	97.2%	±8.7%
% On-Peak KWh	29.1%	[10]
Non-Electric		
Heating HVAC Interactive Effect (MMBtu/kWh)	0.000000	

[10] The precision around the % on-peak kWh result could not be calculated due to the lack of tracking values for this factor.

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.