Going Long: Assessing the Value of 12 Month Monitoring of Lighting Systems

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ABSTRACT

Energy efficiency program savings associated with lighting reductions are still a significant component of electric energy efficiency portfolios. A key variable in the evaluation of lighting systems is the annual operating hours of the new systems. Traditionally, lighting impact evaluations have been conducted by monitoring lighting systems for a period of four to six weeks. Data from the monitoring period are then annualized using a combination of averaging methods, sinusoidal modeling, use of seasonal schedules and other seasonal effects. The question has always been, "How accurate are these annualized operating schedules?"

Electric utilities in the Northeast are looking to answer that question by conducting full year metering of lighting systems for their Large C&I and Small Business programs. As the contractor for both impact evaluations, we have designed the evaluations so that the program administrators would have annualized hours based upon extrapolated short term and actual long term metering for comparison.

In both studies, lighting loggers were deployed in the winter of 2011. Logger data were retrieved from all locations after approximately three months. An analysis of annual energy savings and demand impacts were completed following this initial three-month metering period using the aforementioned approach to annualizing the logger data. These results represent the traditional lighting impact evaluation. Normally, this would be the point where the evaluation would be complete. However, that's just the beginning of the story.

At the time of the initial logger retrieval, evaluation staff placed new lighting loggers in place of those removed to record lighting operations over the balance of the year. Now, rather than metering over one season (winter), evaluators will have a full year of data on which to base their results.

The benefits of the longer term metering are numerous. First, annual operating hours can be assessed more accurately since we now see what the effects of seasonality have on facilities' lighting systems. Also, rather than averaging schedules and adjusting for seasonality, evaluators can identify the actual operating characteristics of the lighting systems during peak hours to better estimate summer and winter peak demand savings. Last, evaluators will be able to provide program staff with an assessment of how well the short term metering results compare with the long term metering results. This information is almost as valuable to program staff as are the actual results because it may determine how future lighting evaluations are conducted. In fact, the design of this evaluation approach allows for an exploration of which methods of hour annualization of the short term data would most accurately reflect the true final annual hours.

Although the small business study is not yet complete, and will have completed full year results by fall of 2013, the large commercial and industrial study has been finalized. A comparison of the short term results and long term results for this study is included so that the value of this long term metering effort may be assessed.

Introduction

DNV KEMA is in the process of conducting concurrent impact evaluations of lighting system savings using 12 months of monitoring. The programs being evaluated are the Massachusetts Large Commercial and Industrial (LCI) Prescriptive Lighting Program, and the National Grid Upstate New York Small Business Services (SBS) Lighting Program. The sponsors of the LCI evaluation include all electric Program Administrators (PA) in Massachusetts, including Cape Light Compact, National Grid, NSTAR, Unitil and Western Massachusetts Electric. The MA Energy Efficiency Advisory Council (EEAC) provided oversight and guidance of the impact evaluation. National Grid is the sponsor of the SBS evaluation being performed under the guidance of the New York State Department of Public Service (NYS DPS).

Background

Impact evaluations of electric utility lighting efficiency programs have traditionally been conducted by using short term lighting logger data to assess annual energy and peak demand savings. Data from the monitoring period are usually annualized using a combination of averaging methods, sinusoidal modeling, use of seasonal schedules and other seasonal effects. The question has always been, "How accurate are these annualized operating schedules?" Both the MA LCI and National Grid SBS impact evaluations are looking to answer that question by conducting full year metering of lighting systems for their Large C&I and Small Business programs, respectively.

Objectives

The objective of both impact evaluations was to provide verification and re-estimation of energy and demand savings resulting from a sample of 2010 lighting program participants. Data collected as part of this evaluation will be used to provide retrospective savings adjustment factors, as well as help inform the deemed savings factors used by PAs going forward. Additionally, the comparison of the 12 month analysis to the interim, three month, analysis, will provide valuable information to program staff in the Northeast about when best to perform lighting monitoring, and for how long. It also is intended to determine which one, two or three-month metering period may best represent the entire year.

Scope of Work

In order to achieve the research objectives and ensure the Sponsors' satisfaction with the MA LCI and National Grid SBS impact evaluations, DNV KEMA performed the following tasks:

- Examine the populations so that the PAs can better understand the characteristics of the MA LCI and National Grid SBS lighting measures;
- Perform a tracking system analysis so that the evaluation team fully understands how each PA's tracking system calculates both gross savings and adjusted gross savings;
- Design an efficient sampling plan, which includes the fewest sample points in order to obtain the targeted precision estimates, for the selection of MA LCI and National Grid SBS lighting participants for on-site visits;
- Perform three months of comprehensive data collection at each sample site to support an independent analysis of adjusted gross energy and demand savings realization rates;
- Perform 12 months of comprehensive data collection at each sample site; and
- Produce comprehensive reporting of results, including analysis methods, findings and trends.

Project Overviews

Table 1 presents a high level overview of the two different impact evaluation timelines. As shown below, the MA LCI impact evaluation started in November, 2011, and the National Grid SBS evaluation was about a month behind. This table presents the key steps and deliverables for each evaluation. Both studies followed the same methodology.

Table 1. Evaluation Timelines

Key Step/ Deliverable	Evaluation	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13
Meter Installs	MA LCI																					
	NGRID SBS																					
Meter Swaps	MA LCI																					
	NGRID SBS																					
Interim Analysis	MA LCI																					
	NGRID SBS																					
Ongoing Metering	MA LCI																					
	NGRID SBS																					
Meter Removals	MA LCI																					
	NGRID SBS																					
12 Month Analysis	MA LCI																					
	NGRID SBS																					
12 Month Report	MA LCI																					
	NGRID SBS																					

Evaluation Methodology

MA LCI Sample Design

The 2010 MA LCI program was comprised of 1,095 participants at the account level, and approximately 92,000 MWh of prescriptive lighting savings. Note that this includes some lighting controls savings, albeit a small component of the overall lighting savings.

The primary variable of interest for the sample design was annual kWh savings. The targeted relative precision was ±10% at the statewide level. The sample design results for annual kWh were calculated at the 90% confidence level. No consideration was given to sampling by building type or sector due to the limited availability of this information, and the inability to achieve good enough precisions at this level of granularity. Since the number of sample points required to achieve a desired level of precision depends upon the expected variability of the observed realization rates, DNV KEMA looked at prior lighting evaluation studies to determine a likely error ratio. Based on studies that have been done for these PAs in the past, the error ratios for realization rates for annual energy savings have ranged from about 0.3 to 0.4. To be conservative and provide confidence that precision targets will be met, the sample design presented here was based on an error ratio of 0.4 for annual energy savings.

The sample design presented in Table 2 provides for the estimation of a MA statewide realization rate for lighting systems savings. The final sample size was 36 rather than 37 due to one site dropping out of the sample. Additionally, two of the 36 projects included lighting controls only, which left us with 34 lighting systems projects in this evaluation.

Table 2. Estimated Precision for MA LCI Sample Design

Result Level	Projects	Total Energy Savings (kWh)	Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
Statewide	1,095	92,442,396	0.4	90%	37	±11.03%

National Grid SBS Sample Design

The National Grid SBS program was comprised of 2,762 participants at the account level. The 2010 program savings associated with prescriptive lighting without controls was approximately 65,000 MWh. Similar to the MA LCI study, DNV KEMA produced several sample design options with error ratios between 0.4 and 0.5. Ultimately, the final sample design was selected using an error ratio of 0.5 because this program had not yet been evaluated by National Grid in New York. The 0.5 error ratio was a bit more conservative, and provided a better chance that the study would achieve the targeted ±10% precision at 90% confidence.

The sample design presented in Table 3 provides for the estimation of a National Grid realization rate for lighting systems savings based on a sample size of 70 sites.

Table 3. Estimated Precision for National Grid SBS Sample Design

Result Level	Projects	Total Energy Savings (kWh)	Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
National Grid NY	2,762	64,498,471	0.5	90%	70	±9.71%

On-site Recruitment

The key difference with these studies as compared to typical lighting impact evaluations was the plan to obtain 12 continuous months of logger data. In order to ensure that the evaluation teams would have the best chance to collect a full year of data, interim visits were built into the evaluation plans so that loggers could be swapped out. These interim visits were designed to serve two purposes. First, the three month interim visit was used to swap out lighting loggers with new ones so that the initial three months of data could be used in an interim analysis. The other reason was so that the evaluation team could limit the amount of lost loggers and bad data.

The evaluation teams had to be clear with customers that this was a long term metering project, and that we would be coming back three to four times during the course of the year to swap out, and ultimately remove lighting loggers. In general, most customers had no problem with this process. In both studies, customers were well aware of the program incentives that they received, and understood why long term metering was being done. In some instances, there was a bit of customer fatigue after two to three visits to their facility, but these were rare occurrences. Attrition was not a significant issue for either evaluation, as we only lost two sites between the two studies.

Data Collection & Metering

During each initial site visit, DNV KEMA verified the type and quantity of installed fixtures by confirming the make and model number of the lamps and ballasts (where possible). Metered data were collected on a representative sample of lighting fixtures using time of use lighting loggers. The selection of metering points was determined in the field, and was based on the number of different usage areas, operating schedules, and connected wattage per circuit. Multiple lighting loggers were included for spaces or usage areas that represented a large portion of the savings for redundancy purposes.

The lighting loggers used in both studies are small data loggers that have a photo sensor, which picks-up the light from the logged fixture. They record the on/off operation of the lighting being monitored. Installation of these metering devices is typically done by attaching them directly to the fixture with a magnet. In some cases, these can be mounted directly below, or adjacent to the fixture. There are no wires to connect, which make these loggers ideal, and mostly unobtrusive for most lighting applications. Calibration of the lighting loggers is done by rotating a dial on the face of the logger. Evaluators set the sensitivity of the logger so that it “picks up” only the light from the intended fixture/s.

While on-site, evaluators also collected information from facility staff that could be used to extrapolate the interim, three month, monitored data to a full year to satisfy the interim reporting requirements, and to provide a basis for comparison of the 12 month logger results. This included reported operating schedules, holidays/shutdowns, and any seasonal changes in operation. HVAC system information was also collected on-site and used to estimate HVAC interactive savings resulting from the installation of these lighting measures.

It was expected that with a logger study of this length, there were likely to be some gaps in the 8,760 hour data resulting from lost or moved loggers, bad data, dead loggers or loggers that exceeded the maximum number of records. To plan for this, DNV KEMA used new batteries in each logger that was deployed, and used redundant loggers in areas with significant savings. Additionally, most loggers were swapped again after approximately six more months following the initial three month metering period to help improve the odds of collecting good data. Evaluators based this decision to swap loggers again on a couple factors, including how many on/off transitions the loggers recorded during the first round (maximum of 8,000 transitions), and buildings/locations that may lose loggers (i.e. schools, hospitals and retail).

In the end, there were some gaps in the 12 month metering data despite our efforts to avoid these circumstances. A computer program utilized a method as a first pass to fill these gaps. In the cases where the data gap occurred in one season, the program filled these gaps with average logger data from the same hour, day of week, and season from the good data. For the MA LCI study, this occurred in 9% of the loggers, but the gaps represented only 2.5% of the total annual hours. In cases where loggers were considered bad or were missing over multiple seasons (2% of loggers, 2% of annual hours), evaluators performed more manual adjustments. In some cases, logger data from redundant loggers were used in place of the missing data. In other cases, average logger data from the same hour and day of week from the same space were used to fill in the missing data. On average, missing data accounted for approximately two weeks of the year, per site, which did not overly influence the results. The National Grid SBS study experienced similar data gaps as the MA LCI study.

Analysis

DNV KEMA utilized an 8,760 hour spreadsheet analysis for both studies, and for both the interim analysis, and the final 12 month analysis. The analysis calculates energy savings at the space or usage area level by assigning logger schedules to the appropriate locations in the facility. The 8,760 hour spreadsheet analysis provides value in that it can be used to develop 8,760 hour savings load shapes. Evaluators used Typical Meteorological Year (TMY3) weather data to estimate HVAC interactive savings for each site. The following variables and savings factors were calculated for each site:

- Summer/Winter Coincidence Factor – This is the percentage of the connected kW savings coincident with the summer/winter peak period as defined by the program administrators.
- Summer/Winter Demand HVAC Interactive Effect Factor – This is the percentage of gross connected kW savings that are due to interactive heating and cooling effects during the summer/winter peak periods.
- Connected kW Realization Rate – 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.
- Average 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.
- kWh Realization Rate – 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.
- kWh HVAC Interactive Effect Factor – This is the percentage of the gross kWh savings that are due to interactive heating and cooling effects.
- Percent Savings On-Peak Energy – This is the percentage of the gross kWh savings that occur during on-peak hours.
- Heating HVAC Interactive Effect Factor (MMBtu/kWh) – This is the non-electric heating penalty due to interactive heating effects.

Following the site level analysis described above, DNV KEMA used stratified ratio estimation techniques to extrapolate the sample results to the program population. The stratified ratio estimation process begins by developing a case weight for each evaluated site that reflects the final sample and population counts in each stratum of the sample design. Sample data is then used to estimate the gross realization rates as the ratio of the measured gross savings to the tracking system savings. The confidence and precision levels associated with the resulting estimates were also calculated.

Evaluation Findings

MA LCI Interim Analysis

Figure 1 presents a scatter plot of the weighted MA LCI interim evaluation results for lighting systems for annual energy savings using all PA sample points. The slope of the solid line in this graph is an indication of the overall realization rate, and can be seen to be greater than one. These sample data are arranged closely around the trend line, which supports the estimate made during the design process that the error ratio would be relatively low.

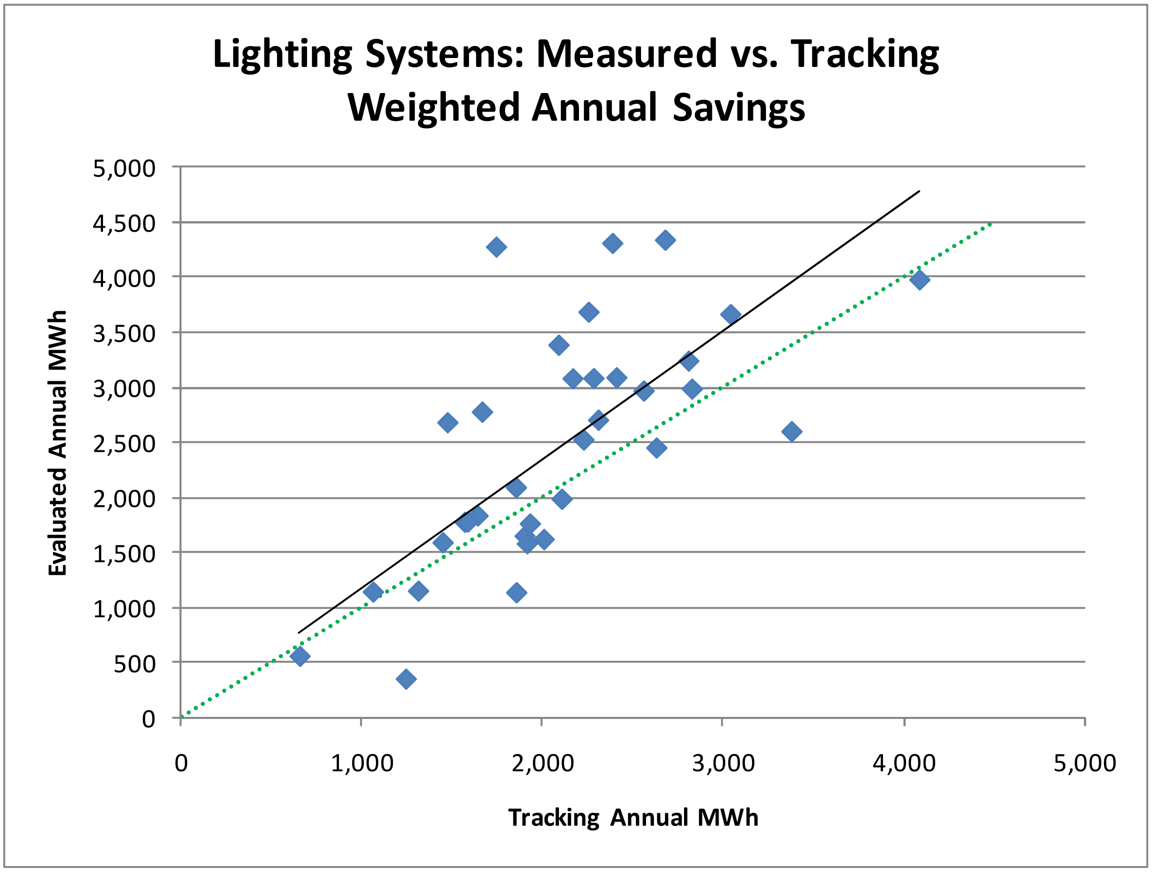

Figure 1. Scatter Plot of Weighted MA LCI Interim Evaluation Results for Annual MWh Savings

Table 4**Error! Reference source not found.** summarizes the statewide results of this analysis. In the case of annual kWh savings, the realization rate for lighting systems was found to be 118.1%. The relative precision for this estimate was found to be ±8.5% at the 90% level of confidence. The error ratio was found to be 0.31. The connected kW realization rate was 99.7% with a relative precision of ±2.6% at the 90% confidence level.

Table 4 also presents the statewide savings factors resulting from this analysis. All relative precisions were calculated at the 80% confidence level. The on-peak summer coincidence factor was 77.3%, with a relative precision of ±7.4%. The on-peak winter coincidence factor was 65.8%, with a relative precision of ±10.1%. The table also provides savings factors for on-peak summer and winter kW HVAC interactive effects, kWh HVAC interactive effect, and percent on-peak kWh.

Table 4. Summary of MA LCI Interim Lighting Savings Factors and Realization Rates

Savings Factors and Realization Rates	Factor	Precision
Annual kWh Realization Rate	118.1%	±8.54%
Connected kW Realization Rate	99.7%	±2.64%
Summer Coincidence Factor	77.3%	±7.36%
Winter Coincidence Factor	65.8%	±10.13%
Summer kW HVAC Interactive Effect	114.7%	±2.10%
Winter kW HVAC Interactive Effect	99.8%	±0.18%
Hours of Use Realization Rate	110.8%	N/A
KWh HVAC Interactive Effect	105.8%	±1.03%
% On Peak KWh	63.1%	±4.42%

Overall, lighting systems appeared to be performing better than anticipated. The significant increase in the annual kWh realization rate is primarily due to higher than predicted operation of the lighting systems. The main discrepancy factors that can be used to highlight the high realization rate are the connected kW adjustment, operation adjustment and the HVAC interactive adjustment.

The connected kW adjustment, or connected kW realization rate encompasses any documentation errors, quantity and fixture discrepancies. As found in this evaluation, the connected kW realization rate of 99.7% indicates that the programs are seeing the correct quantities and fixture types being installed.

The hours of use realization rate of 107% was the largest adjustment factor. A review of the site level results show that eight of the sample projects with lighting systems installed showed hours of operation that were more than 125% of the proposed estimates. Of these eight sites, two were manufacturing facilities. The other six sites were a dormitory, movie theater, office, school, retail store and a library. With such a range of building types, this doesn't appear to be the driver for the hours increase. In the case of the manufacturing facilities, it appears that they are operating more shifts than expected. It is likely that in most of these situations, the proposed hours were the expected business hours, while the lighting hours, especially those in common areas, tend to operate more.

MA LCI 12 Month Analysis

Table 5 presents the results of the 12 month logging study compared to the interim results. These numbers are based on the exact same sample of projects as there was no attrition throughout the entire metering period. As shown in this table, there was a decrease in some of the realization rates and savings factors in the 12 month analysis, while others stayed about the same. The annual kWh realization rate, which includes HVAC interactive effects, dropped from 118.1% to 112.3%. Also note that the summer on-peak coincidence factor dropped from 77.3% to 72.3%. Part of the reason for this drop in summer coincidence factor is due to the fact that the interim result was based on date from the non-peak period.

Table 5. Comparison of MA LCI 12 Month and 3 Month Logging Results

Lighting Systems	3 Month Analysis			12 Month Analysis		
Savings Realization Rate/Factor	**Confidence Interval**	**Realization Rate/Factor**	**Relative Precision**	**Confidence Interval**	**Realization Rate/Factor**	**Relative Precision**
Annual kWh Realization Rate	90%	118.1%	±8.54%	90%	112.3%	±7.89%
Connected kW Realization Rate	90%	99.7%	±2.64%	90%	99.7%	±2.64%
Summer On-Peak Coincidence Factor	80%	77.3%	±7.36%	90%	72.2%	±11.11%
Winter On-Peak Coincidence Factor	80%	65.8%	±10.13%	90%	65.9%	±12.15%
Summer On-Peak kW HVAC Interactive Effect Factor	80%	114.7%	±2.10%	90%	114.6%	±2.74%
Winter On-Peak kW HVAC Interactive Effect Factor	80%	99.8%	±0.18%	90%	99.8%	±0.37%
Hours of Use Realization Rate	N/A	110.8%	N/A	90%	106.5%	±7.40%
kWh Interactive Effect Factor	80%	105.8%	±1.03%	90%	105.4%	±1.27%
% On-Peak kWh	80%	63.1%	±4.42%	90%	63.9%	±5.62%

Table 6 presents a comparison of the MA LCI 12 month and three month estimates of annual hours of use and summer coincidence factor (CF) by facility type. These are simple averages shown to highlight the areas of difference between the two analyses. As shown below, the School/University facility type showed the largest differences between the two analyses. In particular, the summer CF dropped from 54% in the interim analysis to 39% in the 12 month analysis. This is not unexpected as the interim analysis was based on logger data obtained during the winter of 2011/2012. Schools are seasonal in nature, and difficult for evaluators to predict their summer usage when not explicitly monitored. The interim analysis used logger data combined with facility schedules and information on usage obtained from facility staff to adjust the metered data to represent full year operation. However, this analysis highlights the value of obtaining summer metering, especially in the development of summer coincidence factors. The impact on the overall results was a drop in the summer CF of approximately 5%, which is not a minor change.

Table 6: Comparison of MA LCI 12 Month and 3 Month Hours of Use and CF by Facility Type

Facility Type	Count of Facility Type	3 Month Hours of Use	12 Month Hours of Use	12 Month/ 3 Month	3 Month Summer CF	12 Month Summer CF	12 Month/ 3 Month
Manufacturing Facility	6	5,898	5,730	97%	88%	88%	100%
Office	5	4,079	3,759	92%	89%	81%	91%
Retail	5	5,727	5,473	96%	91%	91%	100%
School/University	4	3,114	2,839	91%	54%	39%	72%
Exercise Center	2	6,541	6,604	101%	89%	91%	102%
Library	2	2,129	1,990	93%	58%	58%	101%
Other	10	6,054	5,965	99%	81%	79%	98%
Average All Lighting Systems	**34**	**5,140**	**4,963**	**97%**	**81%**	**77%**	**96%**

National Grid SBS Interim Analysis

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 dashed line on the diagonal of the figure. In addition, the final realization rate is plotted as a solid dark line reflecting the average savings-weighted realization rate of all sample points.

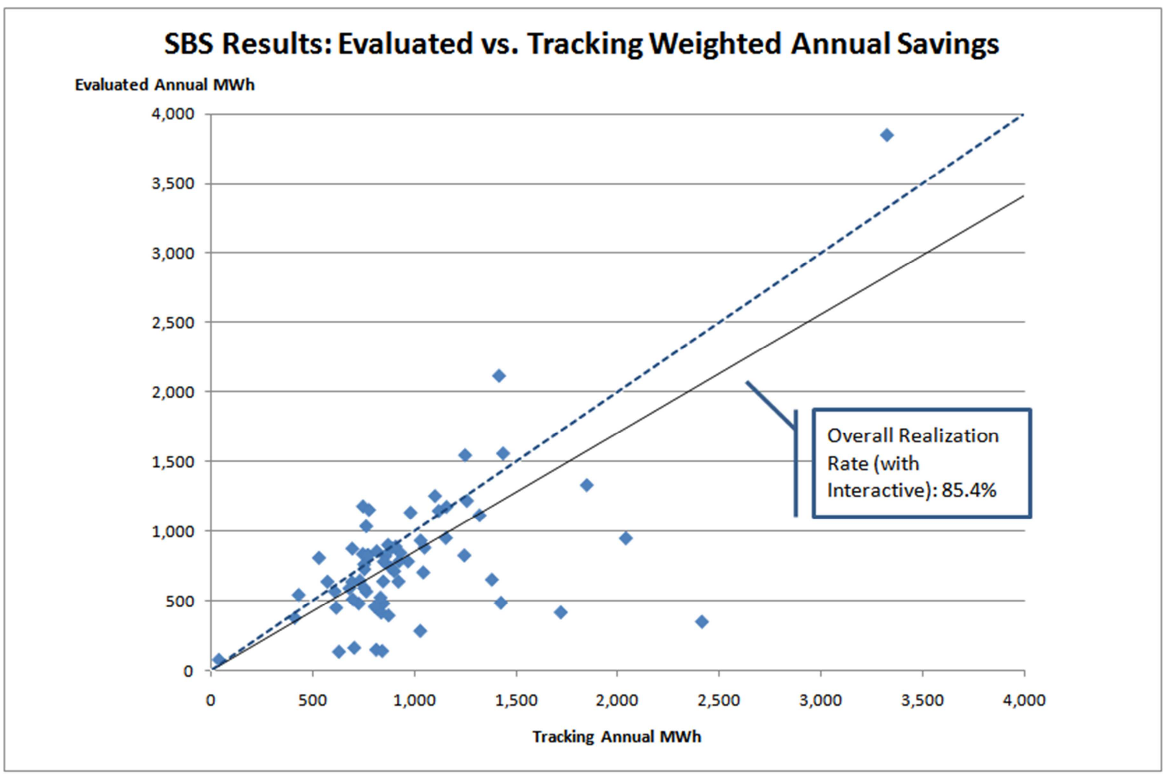

Figure 2. Scatter Plot of National Grid SBS Interim Evaluation Results for Annual MWh Savings

Table 7 summarizes the results of this analysis for the SBS Program. In the case of annual kWh savings, the realization rate for Lighting Systems was found to be 81.9% without HVAC interactive effects included. The relative precision for this estimate was found to be ±9.6% at the 90% level of confidence. The annual kWh savings including HVAC interactive effects was 85.4% with a relative precision of ±9.88% at the 90% confidence level. The error ratio was found to be 0.46. The connected kW realization rate was 97.0% with a relative precision of ±2.9% at the 90% confidence level.

Table 7. Summary of National Grid SBS Interim Lighting Systems Realization Rates

Realization Rate Results	Annual KWh with HVAC	Connected KW
Total Tracking Savings	64,265,935	18,437
Total Measured Savings	54,902,396	17,881
Realization Rate	85.4%	97.0%
Relative Precision at 90% Confidence	±9.88%	±2.92%
Error Ratio	0.46	0.15

Table 8 summarizes the program wide savings factors resulting from this analysis. All relative precisions were calculated at the 80% and 90% confidence level. The on-peak summer coincidence factor was 50.9%, with a relative precision of ±15.55% at the 90% confidence interval. The table also provides savings factors for summer kW HVAC interactive effects, kWh HVAC interactive effect, and percent on-peak kWh.

Table 8. Summary of National Grid SBS Interim Lighting Systems Savings Factors

Factor Results	Summer KWh HVAC Interactive Effect	Summer On-peak KWh Percent	Summer Coincidence Factor	Summer KW HVAC Interactive Effect
Factor	104.3%	71.7%	50.9%	109.3%
Relative Precision at 90% Confidence	±1.21%	±6.16%	±15.55%	±2.28%
Relative Precision at 80% Confidence	±0.94%	±4.80%	±12.12%	±1.78%
Error Ratio	0.06	0.28	0.77	0.11

National Grid SBS 12 Month Analysis

The National Grid SBS 12 month results are currently in progress, and a similar comparison will be conducted.

Conclusions

Although the National Grid SBS study was not completed in time for this paper, the MA LCI study produced and compared results of monitoring periods of three months and 12 months in length.

The three month metering study was more typical of a lighting impact evaluation, while the 12 month study was more comprehensive and costly. In consideration of study costs of performing 12 months of metering, the two analyses were compared. The evaluation team analyzed the MA 12 month savings results to try to determine the most representative one, two and three month metering periods for lighting systems. In general, it was found that the typical, three month study did a good job of estimating annual energy savings using shorter term monitoring. There were cases such as schools and offices in which it proved to be more difficult to estimate summer usage using only three months of winter data. Additionally, it was difficult to estimate summer coincidence factors for schools since these facilities tend to be closed, or have inconsistent usage in the summer.

The three month period that was most representative of the entire year was between September and November. However, all combinations of three month monitoring periods were within 5% of the annual savings when annualized. Therefore, it is recommended that lighting efficiency program administrators consider monitoring for a minimum of three months. Also consider including a summer or winter month in that period if possible.

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