# Impact Evaluation of 2011 Rhode Island Prescriptive Retrofit Lighting Installations

## FINAL REPORT

National Grid

Prepared by KEMA, Inc.

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# 1. Executive Summary

This document summarizes the work performed by DNV KEMA Energy and Sustainability (DNV KEMA) between 2012 and 2013 to quantify the actual energy and demand savings due to the installation of 18 Prescriptive Lighting projects installed through the National Grid C&I Large Retrofit Program in Rhode Island in 2011. Note that this document presents the final results for the two Prescriptive Lighting categories of interest, Systems and Controls.

## 1.1 Purpose of Study

The objective of this impact evaluation is to provide verification or re-estimation of electric energy and demand savings estimates and new savings factors for 18 Prescriptive Lighting retrofit projects through site-specific inspection, monitoring, and analysis. The final study results will be used to determine the final realization rates for Prescriptive Lighting energy efficiency projects beginning in 2014.

This report presents realization rates for gross energy savings and savings factors, including summer and winter coincidence factors. A listing of all results and savings factors with descriptions is presented in Appendix A. The evaluation sample for this study was designed in consideration of the 90% confidence level for energy (kWh) and the 80% confidence level for coincident peak summer demand (kW).

## 1.2 Scope

The scope of work of this impact evaluation covered the 2011 Prescriptive Lighting end-use, which includes retrofit lighting systems and controls. This impact evaluation includes only measures which primarily reduce electricity consumption.

## 1.3 Sample

The Prescriptive Lighting sample was designed to allow DNV KEMA to estimate realization rates for a number of savings parameters (annual kWh, connected kW, summer and winter on-peak coincidence factors, and HVAC interactive effects factor) with statistical precisions that meet National Grid requirements in two areas. The target for annual kWh was set at ±15% at 90% confidence, while the target for summer kW was set at ±15% precision at 80% confidence.

National Grid was interested in results for each of the following groups:

- Lighting Systems
- Lighting Controls

Prescriptive Lighting program data were screened to exclude Systems & Controls measures installed under the New Construction program. This is consistent with the MA approach for 2010[1], where discussion about the differences in the calculation of savings for New Constructions versus Retrofit projects led to a decision that they should be evaluated separately. This design allows for the evaluation of Retrofit projects this year, and New Construction projects in a future study cycle.

After running several scenarios based on different sample sizes and allocations, the team decided on a Prescriptive sample comprised of 18 sites as indicated in Table 1. This table also includes estimates of the precisions that were anticipated at the time of this design, assuming an error ratio of 0.4.

**Table 1: Prescriptive Lighting Sample Design**

| Measure Type | Projects | Total Savings (kWh) | Assumed Error Ratio | Confidence Level | Planned Sample Size | Anticipated Relative Precision |
|---|---|---|---|---|---|---|
| **Systems & Controls** | 241 | 17,065,351 | 0.4 | 90% | 18 | ±15.33% |

This allocation was further stratified by total savings, and sample sites were selected. After the sample selection, several adjustments were required based on unresponsive sites and refusals. In all cases, alternate sites were used. In the end, a total of 18 sites were included in the Prescriptive Lighting sample. Of these 18 sites, each of them had lighting systems, while 10 of them had lighting controls.

## 1.4 Description of Methodology

Data collection included physical inspection and inventory, interview with facility personnel, observation of site operating conditions and equipment, and long-term metering of usage. At each site, the DNV KEMA team performed a facility walk-through that focused on verifying the post-retrofit or installed conditions of each Prescriptive Lighting measure. For pre-retrofit, or baseline hours and equipment, evaluators used a combination of facility interview and tracking estimates. Instrumentation such as power/current recorders, Time-Of-Use (TOU) lighting loggers, and TOU current loggers were installed to monitor the usage of the installed lighting equipment.

An 8,760 hourly spreadsheet analysis was used to estimate hourly energy use and diversified coincident peak demand for all Prescriptive Lighting sites. A typical meteorological year (TMY3) dataset of ambient temperatures for Providence, RI was used for all savings analyses.

A full description of the methodology is provided in Section 3.2, Measurement, Verification and Analysis Methodology.

[1] Impact Evaluation of 2010 Prescriptive Lighting Installations, Prepared by: DNV KEMA Energy & Sustainability, June 21, 2013

## 1.5 Results

The results presented in the following 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 coincident summer and winter peak reductions were calculated using the following FCM definitions:

- Coincident Summer On-Peak kW Reduction is the average demand reduction that occurs over all hours between 1 PM and 5 PM on non-holiday weekdays in June, July and August.
- Coincident Winter On-Peak kW Reduction is the average demand reduction that occurs over all hours between 5 PM and 7 PM on non-holiday weekdays in December and January.

Also included in the results are savings factors for summer and winter on-peak kW HVAC interactive effect factors, kWh HVAC interactive effect factor and percent of energy savings during on-peak periods. Relative precision levels and error bounds are calculated at the 80% confidence level for demand savings factors and values. For all MWh realization rates, the standard 90% confidence level is used.

A detailed discussion of these results is presented in Section 4, Results. A summary of site level results are also presented in Appendix C.

### 1.5.1 Lighting Systems

Table 2 summarizes the results of this analysis, which was based on 18 sample sites. In the case of annual kWh savings, the realization rate for Lighting Systems was found to be 88.9% at the 90% confidence interval. Note that gross tracking savings do not generally include HVAC interactive effects. The error ratio was found to be 0.46.

**Table 2: Summary of Lighting Systems Realization Rates**

| | Lighting Systems | |
|---|---|---|
| **Parameter** | **kWh** | **% Gross** |
| Gross Savings (Tracking) | 15,452,032 | |
| Documentation Adjustment | -84,727 | -1% |
| Technology Adjustment | -295,294 | -2% |
| Quantity Adjustment | -26,793 | 0% |
| Operational Adjustment | -2,323,736 | -15% |
| Coincident Adjustment | N/A | N/A |
| HVAC Interactive Adjustment | 1,008,115 | 7% |
| Adjusted Gross Savings | 13,729,596 | 89% |
| Gross Realization Rate | 88.9% | |
| Relative Precision | ±19.5% | |
| Confidence Interval | 90% | |
| Error Ratio | 46% | |

Table 3 summarizes the savings factors resulting from this analysis. All relative precisions were calculated at the 80% confidence level. The connected kW realization rate was 99.2%, with a relative precision of ±0.4%. The on-peak summer coincidence factor was 55.0%, with a relative precision of ±16.8%. The on-peak winter coincidence factor was 48.7%, with a relative precision of ±19.7%. 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.

**Table 3: Summary of Lighting Systems Savings Factors**

| Savings Factors and Realization Rates at 80% Confidence | Systems | |
|---|---|---|
| | Value | Precision |
| **kW Factors** | | |
| Connected kW Realization Rate | 99.2% | ±0.4% |
| Summer Coincidence Factor | 55.0% | ±16.8% |
| Winter Coincidence Factor | 48.7% | ±19.7% |
| Summer kW HVAC Interactive Effect | 118.5% | ±2.7% |
| Winter kW HVAC Interactive Effect | 100.0% | ±0.0% |
| **kWh Factors** | | |
| Connected kWh Realization Rate | 97.4% | ±2.1% |
| kWh HVAC Interactive Effect | 107.9% | ±1.5% |
| Hours of Use Realization Rate | 84.6% | ±13.4% |
| % On Peak KWh | 68.24% | ±4.7% |
| **Non-Electric** | | |
| Heating HVAC Interaction Effect (MMBtu/kWh) | -0.00126 | |

### 1.5.2 Lighting Controls

Table 4 summarizes the statewide results of this analysis, which was based on 10 sample sites. The sample included only occupancy sensors. In the case of annual kWh savings, the realization rate for Lighting Controls was found to be 67.6% with HVAC interactive effects included. The relative precision for this estimate was found to be ±47.3% at the 90% level of confidence. The error ratio was found to be 0.81.

**Table 4: Summary of Lighting Controls Realization Rates**

| | Lighting Controls | |
|---|---|---|
| **Parameter** | **kWh** | **% Gross** |
| Gross Savings (Tracking) | 1,613,319 | |
| Documentation Adjustment | -7,402 | 0% |
| Technology Adjustment | 0 | 0% |
| Quantity Adjustment | -177,192 | -11% |
| Operational Adjustment | -409,820 | -25% |
| Coincident Adjustment | N/A | N/A |
| HVAC Interactive Adjustment | 72,003 | 4% |
| Adjusted Gross Savings | 1,090,908 | 68% |
| Gross Realization Rate | 67.6% | |
| Relative Precision | ±47.3% | |
| Confidence Interval | 90% | |
| Error Ratio | 81% | |

Table 5 summarizes the statewide savings factors resulting from this analysis. All relative precisions were calculated at the 80% confidence level. The connected kW realization rate was 96.4%, with a relative precision of ±3.7%. The on-peak summer coincidence factor was 12.9%, with a relative precision of ±37.3%. The on-peak winter coincidence factor was 18.4%, with a relative precision of ±16.5%. 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 reduced realization rate and percent on-peak kWh.

**Table 5: Summary of Lighting Controls Savings Factors**

| Savings Factors and Realization Rates at 80% Confidence | Controls | |
|---|---|---|
| | **Value** | **Precision** |
| **kW Factors** | | |
| Connected kW Realization Rate | 96.4% | ±3.7% |
| Summer Coincidence Factor | 12.9% | ±37.3% |
| Winter Coincidence Factor | 18.4% | ±16.5% |
| Summer kW HVAC Interactive Effect | 118.9% | ±4.3% |
| Winter kW HVAC Interactive Effect | 100.0% | ±0.0% |
| **kWh Factors** | | |
| Connected kWh Realization Rate | 88.6% | ±6.3% |
| kWh HVAC Interactive Effect | 107.1% | ±2.4% |
| Hours of Use Realization Rate | 71.3% | ±33.2% |
| % On Peak KWh | 68.97% | ±21.3% |
| **Non-Electric** | | |
| Heating HVAC Interaction Effect (MMBtu/kWh) | -0.00083 | |

## 1.6 Conclusions and Recommendations

Overall, Rhode Islands' Prescriptive Lighting programs are underperforming relative to tracking estimates in both lighting systems and lighting controls. The primary drivers for the lower evaluated gross savings estimates were the operating hours for lighting systems, and the hours of use reduced for lighting controls. Both of these are operational parameters, which, for tracking savings, are estimated by vendors and/or customers based on building specific input.

In the case of lighting systems, the energy realization rate of 89% is somewhat lower than previous lighting impact evaluations, which are typically at or above 100%. As stated above, tracking estimates of operating hours were overstated. This was especially true for schools and universities. In fact, each of the sampled schools/universities showed hours of operation that were less than 80% of tracking estimates.

Lighting controls under performed with a realization rate of 68% on energy savings. The lower realization rate is somewhat consistent with a recently completed Massachusetts small business lighting controls impact evaluation[2] as well as a Massachusetts large C&I lighting controls impact evaluation[3], which resulted in 43% and 74% realization rates, respectively. Note that the small business study was a pre/post effort, and the large C&I study was a post-only evaluation similar to this one.

Since Prescriptive New Construction projects were not considered in this study, it is recommended that National Grid consider performing an impact evaluation of this program in the near future. Until then, the results from this study may be considered for use in place of the current realization rate of 99%. Though the programs calculate the delta watts differently, the hours of use results in this study should be applicable to New Construction as well.

The following are some conclusions and recommendations specific to each measure analyzed.

### 1.6.1 Lighting Systems

- **School Lighting Hours of Use.** The primary reason for the decrease in savings was the overestimated annual operating hours, and specifically school estimates. On average, lighting hours of use were found to be approximately 85% of those predicted in the tracking savings. Lighting operation is the most difficult parameter to predict when developing lighting savings, and schools can be even more difficult given the seasonal nature of these facilities. National Grid typically bases this parameter on building specific data provided by the customer or lighting vendor rather than a deemed value. Since school lighting hours were consistently lower than their

[2] Small Business Direct Install Program: Pre/Post Lighting Occupancy Sensor Study, Prepared by: The Cadmus Group and Energy & Resource Solutions, Inc., October 23, 2012

[3] Impact Evaluation of 2010 Prescriptive Lighting Installations, Prepared by: DNV KEMA Energy & Sustainability, June 21, 2013

tracking estimates, it is strongly recommended that National Grid scrutinize these hours estimates, or apply a de-rating factor for this building type. It became apparent early on in the evaluation that school hours were significantly overstated. The simple average of tracking estimates of operating hours for schools was 3,500 hours. This equates to approximately 19.4 hours per day for 180 days a year, which is the typical number of days in a school year. The evaluation found that the actual hours of use were approximately 2,100 hours per year, or about 11.9 hours per day for 180 days a year. Evaluated school operating hours typically ranged from 1,500 to 2,500 hours per year. Tracking hours outside of this range for schools should be looked at more closely.

- **Connected Lighting Demand Savings.** This evaluation found that the connected demand savings from lighting systems was found to be very close to 100%. This means that lighting implementers are doing a good job of installing the correct quantity and type of fixture as proposed in the tracking savings. There were only two sites with negative quantity adjustments and only four with negative technology adjustments. However, these two adjustments were minor as compared to the hours of use issues described above. Evaluators found that in most cases, project documentation was detailed, and provided a sufficient level of detail to be able to verify installed lighting systems. It is recommended that lighting implementers continue to develop detailed lighting installation plans, which include location, fixture type and quantity.

### 1.6.2 Lighting Controls

- **Consider a Pre/Post Lighting Controls Study.** Lighting controls is a measure type that changes the operation of the equipment rather than the equipment itself. This type of measure is difficult to evaluate on a post-only basis as the baseline hours of use must be estimated or inferred from other data sources. As shown above, a recent small business lighting controls evaluation was completed in Massachusetts, which resulted in a very low realization rate. This was due mostly to the operational component of the savings. This study found that there were several instances where lighting controls were installed in locations that were not saving energy, or were producing negative savings. The reason for zero or negative savings is because existing lighting systems were being shut off manually when the space was unoccupied. The only way to verify this is to observe the operating characteristics of the space prior to the installation of lighting controls. It is recommended that a pre/post metering study is considered the next time a lighting controls impact evaluation is planned.

- **Consider Pre-Installation Monitoring.** Occupancy sensors represent the largest component of lighting controls program savings in RI. Savings for these measures are driven by the vendor or TA estimate of hours reduced. In most cases, this value is based on the difference between site specific estimates for baseline or pre-existing and the proposed hours of use. As found in this

study, as well as previous lighting controls studies, tracking estimates of hours reduced are generally overestimated. It tends to be more difficult to estimate hours reduced than hours of use, which is why lighting systems savings are more stable. To help implementation vendors and TAs produce more reliable estimates of hours reduced, it is recommended that National Grid considers requiring pre-installation metering to establish an estimate of baseline hours. This could be done as part of the vendors' walkthrough of a facility when trying to determine where lighting controls will be installed. A minimum of two weeks of data would be ideal for this type of effort. It is likely that this strategy would help improve lighting controls savings estimates going forward.

# 2. Introduction

This document summarizes the work performed by DNV KEMA Energy and Sustainability (DNV KEMA) between 2012 and 2013 to quantify the actual energy and demand savings due to the installation of 18 Prescriptive Lighting projects installed through the National Grid C&I Large Retrofit Program in Rhode Island in 2011. Note that this document presents the final results for the two Prescriptive Lighting categories of interest, Systems and Controls.

## 2.1 Purpose of Study

The objective of this impact evaluation is to provide verification or re-estimation of electric energy and demand savings estimates and new savings factors for 18 Prescriptive Lighting retrofit projects through site-specific inspection, monitoring, and analysis. The final study results will be used to determine the final realization rates for retrofit Prescriptive Lighting energy efficiency projects beginning in 2014.

This report presents the following realization rates based on metered data collected from each sampled site:

- **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.

This report also provides the following savings factors:

- **Summer Coincidence Factor** – Diversity x Coincidence. This is the percentage of the connected kW savings coincident with the summer on-peak period.
- **Winter Coincidence Factor** – Diversity x Coincidence. This is the percentage of the connected kW savings coincident with the winter on-peak period.

- **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 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.

A listing of all realization rates and savings factors with descriptions and algorithms is presented in Appendix A. The savings factors presented in this report are developed so that they may be applied prospectively for future program savings estimates.

The evaluation sample for this study was designed in consideration of the 90% confidence level for energy (kWh) and the 80% confidence level for coincident peak summer demand (kW).

## 2.2 Scope

The scope of work of this impact evaluation covered the 2011 Prescriptive Lighting end-use, which includes retrofit lighting systems and controls. This impact evaluation includes only measures which primarily reduce electricity consumption.

# 3. Evaluation Approach

## 3.1 Sample Design

The Prescriptive Lighting sample was designed to allow DNV KEMA to estimate realization rates for a number of savings parameters (annual kWh, connected kW, summer and winter on-peak coincidence factors, and HVAC interactive effects factor) with statistical precisions that meet National Grid requirements in two areas. The target for annual kWh was set at ±15% at 90% confidence, while the target for summer kW was set at ±15% precision at 80% confidence.

National Grid was interested in results for each of the following groups:

- Lighting Systems
- Lighting Controls

- Prescriptive Lighting program data were screened to exclude Systems & Controls measures installed under the New Construction program. This is consistent with the MA approach for 20104, where discussion about the differences in the calculation of savings for New Constructions versus Retrofit projects led to a decision that they should be evaluated separately. This design allows for the evaluation of Retrofit projects this year, and New Construction projects in a future study cycle.

After running several scenarios based on different sample sizes and allocations, the team decided on a Prescriptive sample comprised of 18 sites as indicated in Table 6. This table also includes estimates of the precisions that were anticipated at the time of this design for systems and controls, assuming an error ratio of 0.4. Since the sample design could not determine which sample sites would contain lighting systems and/or controls, an assumed split was used based on population data. This assumed split allowed for the estimation of relative precision for both measure types.

**Table 6: Prescriptive Lighting Sample Design**

| Measure Type | Projects | Total Savings (kWh) | Assumed Error Ratio | Confidence Level | Planned Sample Size | Anticipated Relative Precision |
|---|---|---|---|---|---|---|
| **Systems & Controls** | 241 | 17,065,351 | 0.4 | 90% | 18 | ±15.33% |
| **--- Systems** | 235 | 15,452,032 | 0.4 | 90% | 17 | ±15.77% |
| **--- Controls** | 86 | 1,613,319 | 0.4 | 90% | 6 | ±31.54% |

This allocation was further stratified by total savings, and sample sites were selected. After the sample selection, several adjustments were required based on unresponsive sites and refusals. In all cases, alternate sites were used. In the end, a total of 18 sites were included in the Prescriptive Lighting sample. Of these 18 sites, each of them had lighting systems, while 10 of them had lighting controls.

## 3.2 Measurement, Verification and Analysis Methodology

A key task in the on-site engineering assessment is the installation of measurement equipment to aid in the development of independent estimates of savings. The type of measure influences the measurement strategy used. Time-of-use loggers, electrical current loggers, and multi-channel three-phase power loggers may all be utilized to inform the savings calculations with a direct measurement of electrical usage and/or hours of operation. For this impact evaluation, a minimum of three months of data was collected for most sites. Data collection began in June 2012 and continued through January 2013. Figure 1 presents a graphical representation of the initial logger installations. As shown below, 90% of the sites had loggers installed by August 1, which means that almost all sites had some summer metering.

[4] Impact Evaluation of 2010 Prescriptive Lighting Installations, Prepared by: DNV KEMA Energy & Sustainability, June 21, 2013

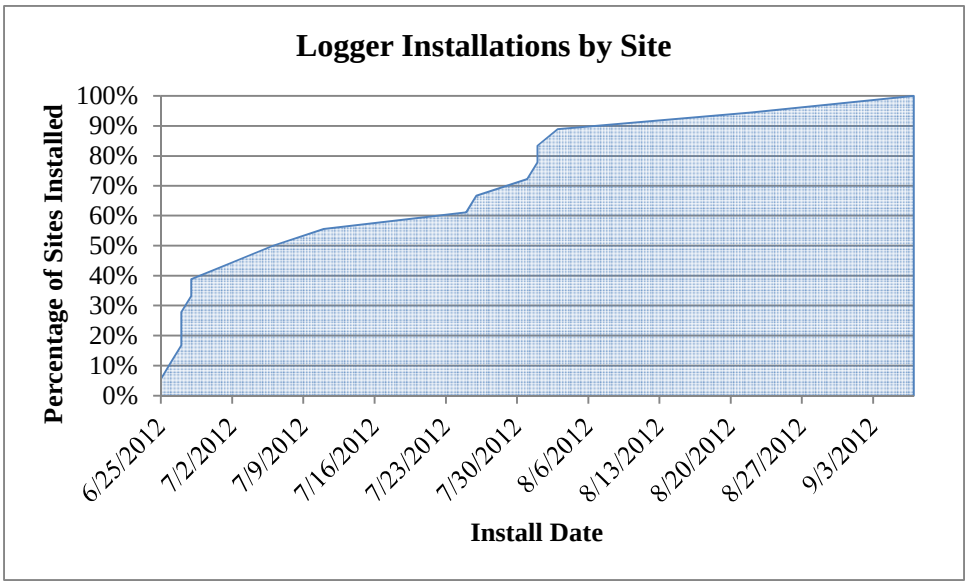


**Figure 1: Logger Installations by Date**

In the context of an energy analysis, most efficiency measures can be characterized as either time-dependent or load-dependent. Time-dependent equipment typically runs at constant load according to a time-of-day operating schedule. Mathematically, hour-of-day and day-of-week are usually the most relevant variables in the energy savings analysis of these measures. Lighting is the most prevalent time-dependent measure.

The following section outlines the methodology for time-dependent lighting measures. A more detailed description of the calculation methodology is presented in Appendix B.

### 3.2.1 Monitoring

Time-dependent measures typically call for the installation of time-of-use (TOU) loggers to measure hours of use. These small devices use specialized sensors – photocells in the case of lighting measures – to sense and record the dates and times that a device turns on and off. This TOU data will be used to support the evaluation in two key ways:

1. To develop peak coincidence factors, and
2. To develop annual hours of use.

The measure scope influences the appropriate number of loggers and systems monitored for each site. Factors that drive the number of installed loggers include the number of unique schedules at the site, and the anticipated level of variation among the schedules within a particular space type.

Clamp-on time-of-use, current, or power loggers may also be used in selective situations such as high-bay lighting, or exterior fixtures where traditional time-of-use lighting loggers may be impractical due to installation height or accessibility.

### 3.2.2 Verification

A detailed inventory was performed for each installed measure. This inventory included a verification of the quantity and technologies installed from the program, as well as customer reported operating hours for specific equipment and locations. For pre-retrofit, or baseline hours and equipment, evaluators used a combination of facility interview and tracking estimates. Methods of control were also examined and inventoried at this time. Other variables that were analyzed include the types of heating and cooling systems serving the areas of the installed measure for the calculation of interactive HVAC effects.

### 3.2.3 Site Analysis

The project team was responsible for data entry and analysis of all information gathered during the evaluation. On and off transition data was downloaded from each logger. The data was then analyzed using computer software, which develops time-of-use load profiles and estimates of percentage on-times during the monitoring period. These profiles were combined with facility reported holiday and shutdown times to extrapolate the three months of captured operation data out to 12 months to achieve annual hours of operation.

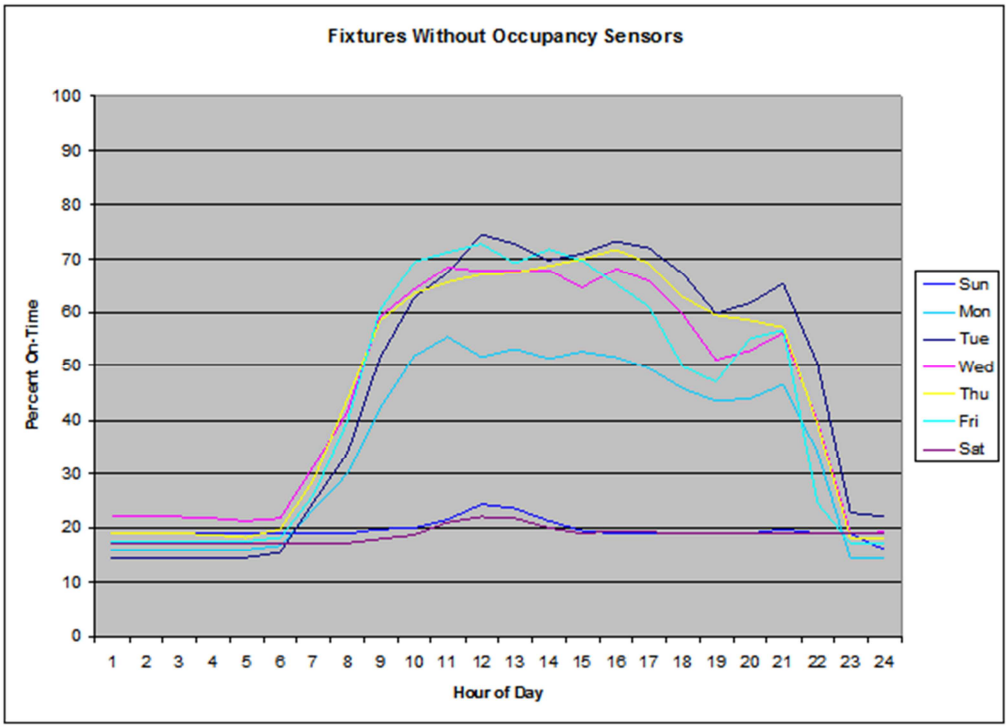


**Figure 2: Measured Hourly Lighting Profiles by Day-of-Week**

Time-of-use data from each logger, such as in Figure 2, was reviewed to identify the influence on annual trends such as seasonal effects (e.g., daylight savings), production, and occupancy swings (e.g., vacations). Detailed review of time-of-use data was expected to reveal explicable patterns that agree with other data sources, such as on-site interviews or equipment control schedules. The time-of-use profiles were combined with these other data sources to extrapolate the three month logger data to an entire year.

Annualized logger data and field verified equipment and quantities were entered into an 8,760 hour analysis spreadsheet. Rhode Island program values were used for fixture wattages. The spreadsheet calculates annual kW and kWh savings for the installed system as compared with the baseline equipment, which was mostly based on tracking estimates and verified, as best possible, through discussions with facility staff.

### 3.2.4 Lighting Controls

The key variable in estimating savings due to the installation of lighting controls is the difference in operating hours for occupancy sensors, or the difference in average lighting wattage for dimming controls. In the case of occupancy sensors, the installed condition of the system was metered. Since no pre-installation metering was conducted, the baseline operating hours needed to be estimated. The DNV KEMA team employs several different methodologies to determine these baseline hours depending on the site and usage of the space, and apply them according to information gathered on-site as illustrated below.

The most frequent method applied by evaluating engineers is to establish operating thresholds utilizing operating profiles of the monitored lights. This method is performed by determining when the lights come on in the morning and when they go off at night. This period is defined as the first hour of the day when the operating profile shows an apparent increase in lighting usage from the overnight usage, to the last hour of the day where this level of increased usage is observed. Between these hours, the baseline operation is set at a certain fixed percentage. This percentage is usually less than 100%, though not always, and is inferred from the maximum hourly operation observed during the monitoring period of the controlled fixture.

In some cases, lighting controls were installed to shut off lighting that would have otherwise been on 100% of the time during business hours. Typically, this situation occurs in warehouses or large open spaces, which are occupied continuously throughout the day. Occupancy sensors may be installed on individual fixtures, or rows of fixtures, to reduce energy usage if sections of the space are unoccupied. Typically, facility staff is confident in their estimate of baseline operating hours in these specific cases. In these cases, evaluators will discuss the baseline operating hours with facility personnel, and assess the reasonableness of these hours.

One other method used to estimate baseline operating hours is to utilize lighting logger data from a similar space type in the facility that is not being controlled. This type of proxy space is sometimes difficult to find in facilities because similar space types typically are treated the same when lighting controls are installed. However, in some circumstances, evaluators may be able to monitor some uncontrolled spaces, and apply the operating profiles, as baseline schedules, to similar space types that did receive occupancy sensors. In these cases, logger data from the uncontrolled space is compared to logger data from the controlled spaces to determine if the operating profiles match. For example, the magnitude of the operation may be different between the two profiles, but the operating profiles tend to have the same start and stop times.

For sites with both lighting systems and controls installed, the order in which fixture savings and controls savings are calculated is important. In these situations, the tracking savings for fixtures are the pre-controlled hours times the delta watts. The tracking savings for controls are the delta hours times the installed watts. The evaluation calculates savings in the same order, but the pre-controlled hours are developed according to the methods described above. The savings for both fixtures and controls are then impacted by the estimation process used to determine pre-controlled hours of use.

### 3.2.5 HVAC Interactive Effects

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 KEMA 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 7 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 7: 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 KEMA team computes electric interactive effects during the hours that lighting and HVAC are assumed to operate in unison.

DNV KEMA 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 KEMA 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. Heating factors are negative because heating interaction erodes gross lighting savings, while cooling interactive boosts it.

# 4. Results

The results presented in the following 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 coincident summer and winter peak reductions were calculated using the following FCM definitions:

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

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

The adjusted gross energy savings are presented with their associated realization rate and relative precision for each lighting measure. These tables present results as adjustments to tracking savings. Each of these adjustments, or discrepancies, is described below:

- **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 tracking system estimate of savings.

- **Quantity Adjustment**: The Quantity Adjustment reflects the change in savings due to the identification of a different quantity of lighting fixtures at the site than presented in the tracking system estimate of savings.

- **Operational Adjustment**: The Operational Adjustment reflects the change in savings due to the observation or monitoring of different lighting operating hours at the site than represented in the tracking system estimate of savings.

- **HVAC Interactive Adjustment**: The HVAC Interactive Adjustment reflects changes in savings due to interaction between the lighting and HVAC systems among the sampled sites. Generally,

these impacts cause a heating penalty and a cooling credit. This adjustment reflects impacts from electric heating and/or cooling, not other fuels.

Also included in the results are savings factors for summer and winter on-peak coincidence factors, summer and winter kW HVAC interactive effect factors, kWh HVAC interactive effect factor and percent of energy savings during on-peak periods. Relative precision levels and error bounds are calculated at the 80% confidence level for demand savings factors and values. For all kWh realization rates, the standard 90% confidence level is used.

A summary of site level results are also presented in Appendix C.

## 4.1 Lighting Systems

Figure 3 presents a scatter plot of evaluation results for Lighting Systems for annual energy savings using all 18 sample points. The dashed line in this graph represents a realization rate of 100%. The slope of the solid line in this graph is an indication of the overall realization rate, and can be seen to be less than 100%. 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.

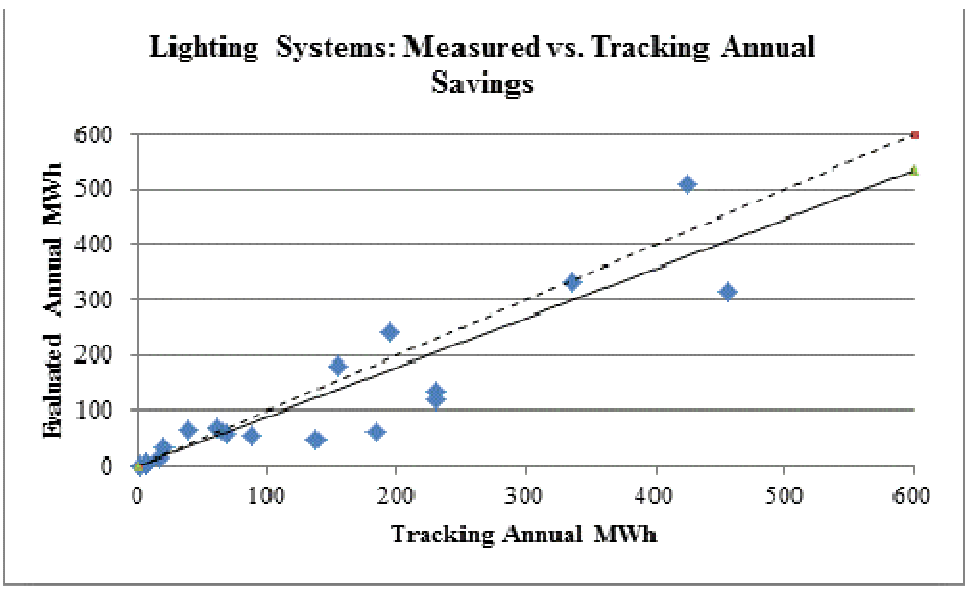


**Figure 3: Scatter Plot of Evaluation Results for Systems for Annual MWh Savings**

Table 8 summarizes the results of this analysis, which was based on 18 sample sites. In the case of annual kWh savings, the realization rate for Lighting Systems was found to be 88.9% at the 90% confidence interval. Note that gross tracking savings do not generally include HVAC interactive effects. The error ratio was found to be 0.46, which was higher than the 0.4 assumed in the sample design.

**Table 8: Summary of Lighting Systems Realization Rates**

| | Lighting Systems | |
|---|---|---|
| **Parameter** | **kWh** | **% Gross** |
| Gross Savings (Tracking) | 15,452,032 | |
| Documentation Adjustment | -84,727 | -1% |
| Technology Adjustment | -295,294 | -2% |
| Quantity Adjustment | -26,793 | 0% |
| Operational Adjustment | -2,323,736 | -15% |
| Coincident Adjustment | N/A | N/A |
| HVAC Interactive Adjustment | 1,008,115 | 7% |
| Adjusted Gross Savings | 13,729,596 | 89% |
| Gross Realization Rate | 88.9% | |
| Relative Precision | ±19.5% | |
| Confidence Interval | 90% | |
| Error Ratio | 46% | |

Table 9 summarizes the savings factors resulting from this analysis. All relative precisions were calculated at the 80% confidence level. The connected kW realization rate was 99.2%, with a relative precision of ±0.4%. The on-peak summer coincidence factor was 55.0%, with a relative precision of ±16.8%. The on-peak winter coincidence factor was 48.7%, with a relative precision of ±19.7%. 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.

**Table 9: Summary of Lighting Systems Savings Factors**

| Savings Factors and Realization Rates at 80% Confidence | Systems | |
|---|---|---|
| | **Value** | **Precision** |
| **kW Factors** | | |
| Connected kW Realization Rate | 99.2% | ±0.4% |
| Summer Coincidence Factor | 55.0% | ±16.8% |
| Winter Coincidence Factor | 48.7% | ±19.7% |
| Summer kW HVAC Interactive Effect | 118.5% | ±2.7% |
| Winter kW HVAC Interactive Effect | 100.0% | ±0.0% |
| **kWh Factors** | | |
| Connected kWh Realization Rate | 97.4% | ±2.1% |
| kWh HVAC Interactive Effect | 107.9% | ±1.5% |
| Hours of Use Realization Rate | 84.6% | ±13.4% |
| % On Peak KWh | 68.24% | ±4.7% |
| **Non-Electric** | | |
| Heating HVAC Interaction Effect (MMBtu/kWh) | -0.00126 | |

Overall, lighting systems appear to be underperforming. The decrease in the annual kWh realization rate is primarily due to lower than predicted operating hours of the lighting systems. 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 99.2% indicates that the programs are seeing the correct quantities and fixture types being installed.

The operation adjustment of 85% was the largest adjustment factor. A review of the site level results in Appendix C show that 11 of the 18 sample projects with lighting systems installed showed hours of operation that were less than 80% of the proposed estimates. Included in these 11 sites were all nine of the schools and universities included in the sample. The other two sites were a transportation facility and a healthcare facility. This is a very good indication that school/university hours are being significantly overstated in tracking estimates.

The HVAC interactive adjustment of 107.9% represents the additional savings associated with the space cooling and heating. This was the second largest adjustment factor, which provided an increase in savings.

## 4.2 Lighting Controls

Figure 4 presents a scatter plot of evaluation results for Lighting Controls for annual energy savings using all 10 sample points. The dashed line in this graph represents a realization rate of 100%. The slope of the solid line in this graph is an indication of the overall realization rate, and can be seen to be approximately 68%. These sample data spread from the trend line, which is indicative of a higher error ratio. Site level realization rates ranged from 0% to 175% in this measure category. The evaluation found that majority of the discrepancies between the tracking and evaluated savings estimates were due to the overestimation of the hours reduced.

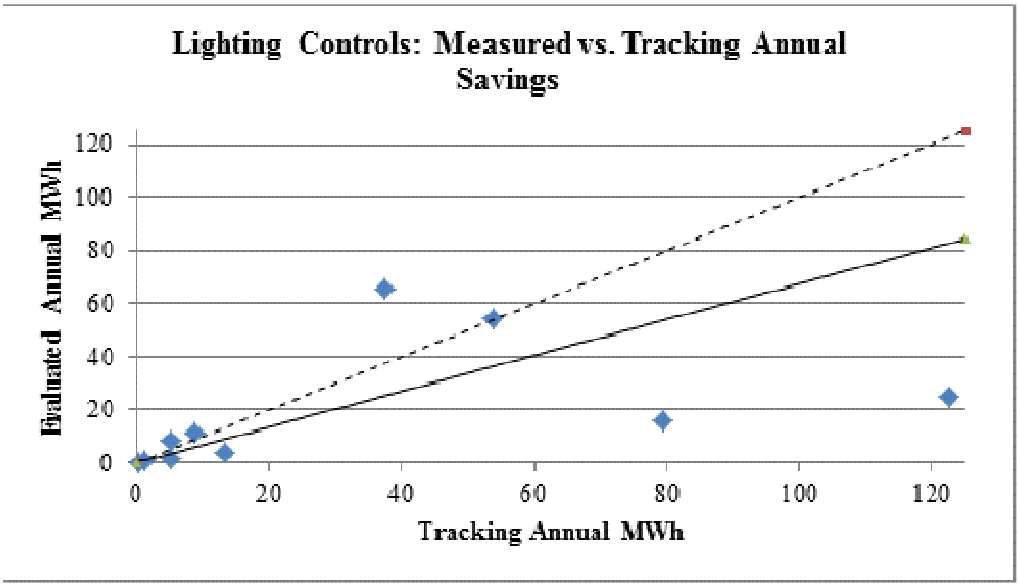


**Figure 4: Scatter Plot of Evaluation Results for Controls for Annual MWh Savings**

Table 10 summarizes the statewide results of this analysis, which was based on 10 sample sites. In the case of annual kWh savings, the realization rate for Lighting Controls was found to be 67.6% with HVAC interactive effects included. The relative precision for this estimate was found to be ±47.3% at the 90% level of confidence. The error ratio was found to be 0.81, which was much higher than the 0.4 assumed in the sample design.

**Table 10: Summary of Lighting Controls Realization Rates**

| | Lighting Controls | |
|---|---|---|
| **Parameter** | **kWh** | **% Gross** |
| Gross Savings (Tracking) | 1,613,319 | |
| Documentation Adjustment | -7,402 | 0% |
| Technology Adjustment | 0 | 0% |
| Quantity Adjustment | -177,192 | -11% |
| Operational Adjustment | -409,820 | -25% |
| Coincident Adjustment | N/A | N/A |
| HVAC Interactive Adjustment | 72,003 | 4% |
| Adjusted Gross Savings | 1,090,908 | 68% |
| Gross Realization Rate | 67.6% | |
| Relative Precision | ±47.3% | |
| Confidence Interval | 90% | |
| Error Ratio | 81% | |

Table 11 summarizes the statewide savings factors resulting from this analysis. All relative precisions were calculated at the 80% confidence level. The connected kW realization rate was 96.4%, with a relative precision of ±3.7%. The on-peak summer coincidence factor was 12.9%, with a relative precision of ±37.3%. The on-peak winter coincidence factor was 18.4%, with a relative precision of ±16.5%. 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 reduced realization rate and percent on-peak kWh.

**Table 11: Summary of Lighting Controls Savings Factors**

| Savings Factors and Realization Rates at 80% Confidence | Controls | |
|---|---|---|
| | Value | Precision |
| **kW Factors** | | |
| Connected kW Realization Rate | 96.4% | ±3.7% |
| Summer Coincidence Factor | 12.9% | ±37.3% |
| Winter Coincidence Factor | 18.4% | ±16.5% |
| Summer kW HVAC Interactive Effect | 118.9% | ±4.3% |
| Winter kW HVAC Interactive Effect | 100.0% | ±0.0% |
| **kWh Factors** | | |
| Connected kWh Realization Rate | 88.6% | ±6.3% |
| kWh HVAC Interactive Effect | 107.1% | ±2.4% |
| Hours of Use Realization Rate | 71.3% | ±33.2% |
| % On Peak KWh | 68.97% | ±21.3% |
| **Non-Electric** | | |
| Heating HVAC Interaction Effect (MMBtu/kWh) | -0.00083 | |

# 5. Conclusions and Recommendations

Overall, Rhode Islands' Prescriptive Lighting programs are underperforming relative to tracking estimates in both lighting systems and lighting controls. The primary drivers for the lower evaluated gross savings estimates were the operating hours for lighting systems, and the hours of use reduced for lighting controls. Both of these are operational parameters, which, for tracking savings, are estimated by vendors and/or customers based on building specific input.

In the case of lighting systems, the energy realization rate of 89% is somewhat lower than previous lighting impact evaluations, which are typically at or above 100%. As stated above, tracking estimates of operating hours were overstated. This was especially true for schools and universities. In fact, each of the sampled schools/universities showed hours of operation that were less than 80% of tracking estimates. Additionally, the error ratio of 0.46 was somewhat higher than the assumed error ratio (0.4). This is an indication of greater variability in the savings estimates as compared to tracking. Future impact evaluations of lighting systems should consider increasing the planning error ratio to 0.45 or even 0.5 to account for this increased variability. This will result in increased sample sizes.

Lighting controls underperformed relative to tracking estimates with a realization rate of 68% on energy savings. The lower realization rate is somewhat consistent with a recently completed Massachusetts small business lighting controls impact evaluation[5] as well as a Massachusetts large C&I lighting controls impact evaluation[6], which resulted in 43% and 74% realization rates, respectively. Note that the small business study was a pre/post effort, and the large C&I study was a post-only evaluation similar to this one. Additionally, the error ratio of 0.81 was significantly higher than the assumed error ratio (0.4). This is an indication of greater variability in the savings estimates as compared to tracking. Future impact evaluations of lighting controls should consider increasing the planning error ratio to 0.8 or 0.9 to account for this increased variability. This will result in a significant increase in sample sizes.

Since Prescriptive New Construction projects were not considered in this study, it is recommended that National Grid consider performing an impact evaluation of this program in the near future. Until then, the results from this study may be considered for use in place of the current realization rate of 99%. Though the programs calculate the delta watts differently, the hours of use results in this study should be applicable to New Construction as well.

The following are some conclusions and recommendations specific to each measure analyzed.

## 5.1 Lighting Systems

- **School Lighting Hours of Use.** The primary reason for the decrease in savings was the overestimated annual operating hours, and specifically school estimates. On average, lighting hours of use were found to be approximately 85% of those predicted in the tracking savings. Lighting operation is the most difficult parameter to predict when developing lighting savings, and schools can be even more difficult given the seasonal nature of these facilities. National Grid typically bases this parameter on building specific data provided by the customer or lighting vendor rather than a deemed value. Since school lighting hours were consistently lower than their tracking estimates, it is strongly recommended that National Grid scrutinize these hours estimates, or apply a de-rating factor for this building type. It became apparent early on in the evaluation that school hours were significantly overstated. The simple average of tracking estimates of operating hours for schools was 3,500 hours. This equates to approximately 19.4 hours per day for 180 days a year, which is the typical number of days in a school year. The evaluation found that the actual hours of use were approximately 2,100 hours per year, or about 11.9 hours per day for 180 days a year. Evaluated school operating hours typically ranged from

[5] Small Business Direct Install Program: Pre/Post Lighting Occupancy Sensor Study, Prepared by: The Cadmus Group and Energy & Resource Solutions, Inc., October 23, 2012

[6] Impact Evaluation of 2010 Prescriptive Lighting Installations, Prepared by: DNV KEMA Energy & Sustainability, June 21, 2013

1,500 to 2,500 hours per year. Tracking hours outside of this range for schools should be looked at more closely.

- **Connected Lighting Demand Savings.** This evaluation found that the connected demand savings from lighting systems was found to be very close to 100%. This means that lighting implementers are doing a good job of installing the correct quantity and type of fixture as proposed in the tracking savings. There were only two sites with negative quantity adjustments and only four with negative technology adjustments. However, these two adjustments were minor as compared to the hours of use issues described above. Evaluators found that in most cases, project documentation was detailed, and provided a sufficient level of detail to be able to verify installed lighting systems. It is recommended that lighting implementers continue to develop detailed lighting installation plans, which include location, fixture type and quantity.

## 5.2 Lighting Controls

- **Consider a Pre/Post Lighting Controls Study.** Lighting controls is a measure type that changes the operation of the equipment rather than the equipment itself. This type of measure is difficult to evaluate on a post-only basis as the baseline hours of use must be estimated or inferred from other data sources. As shown above, a recent small business lighting controls evaluation was completed in Massachusetts, which resulted in a very low realization rate. This was due mostly to the operational component of the savings. This study found that there were several instances where lighting controls were installed in locations that were not saving energy, or were producing negative savings. The reason for zero or negative savings is because existing lighting systems were being shut off manually when the space was unoccupied. The only way to verify this is to observe the operating characteristics of the space prior to the installation of lighting controls. It is recommended that a pre/post metering study is considered the next time a lighting controls impact evaluation is planned.

- **Consider Pre-Installation Monitoring.** Occupancy sensors represent the largest component of lighting controls program savings in RI. Savings for these measures are driven by the vendor or TA estimate of hours reduced. In most cases, this value is based on the difference between site specific estimates for baseline or pre-existing and the proposed hours of use. As found in this study, as well as previous lighting controls studies, tracking estimates of hours reduced are generally overestimated. It tends to be more difficult to estimate hours reduced than hours of use, which is why lighting systems savings are more stable. To help implementation vendors and TAs produce more reliable estimates of hours reduced, it is recommended that National Grid considers requiring pre-installation metering to establish an estimate of baseline hours. This could be done as part of the vendors' walkthrough of a facility when trying to determine where lighting controls

will be installed. A minimum of two weeks of data would be ideal for this type of effort. It is likely that this strategy would help improve lighting controls savings estimates going forward.

# 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.

**Winter Coincidence Factor** – Diversity x Coincidence. This is the percentage of the connected kW savings coincident with the winter on-peak period.

**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.

**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) |

# B. Calculation Methods

This section serves as a detailed example that illustrates the calculation of all savings and adjustment factors. DNV KEMA 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 6 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 | 1/1/2012 | Y |
| Martin Luther King Day | 1/16/2012 | N |
| Presidents Day | 2/20/2012 | N |
| Good Friday | 4/6/2012 | N |
| Memorial Day | 5/28/2012 | Y |
| Independence Day | 7/4/2012 | Y |
| Labor Day | 9/3/2012 | Y |
| Columbus Day | 10/8/2012 | N |
| Veteran's Day | 11/11/2012 | N |
| Thanksgiving Day | 11/22/2012 | Y |
| Day After Thanksgiving | 11/23/2012 | N |
| Christmas Eve | 12/24/2012 | N |
| Christmas Day | 12/25/2012 | Y |

To determine the annual operating hours from monitoring lighting logger data, engineers examine the hourly percent run time across the entire monitoring period. For this study, lighting logger data was adjusted for the daylight savings time change that occurred within the monitoring period.

For the three month 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 KEMA 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 KEMA team computes electric interactive effects during the hours that lighting and HVAC are assumed to operate in unison.

DNV KEMA 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 KEMA 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.

# C. Site Level Results

## C.1 Lighting Systems

**Table 22: Lighting Systems Tracking Estimates**

| Lighting Systems | | | Tracking | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) |
| KEMA ID | Application 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 |
| 747 | 794485 | Transportation | 1,471 | N/A | N/A | 0.61 | N/A | N/A | N/A | N/A | 2,411 |
| 785 | 988993 | School/University | 7,128 | N/A | N/A | 4.95 | N/A | N/A | N/A | N/A | 1,440 |
| 910 | 720373 | School/University | 17,757 | N/A | N/A | 6.84 | N/A | N/A | N/A | N/A | 2,596 |
| 920 | 831889 | School/University | 88,521 | N/A | N/A | 28.86 | N/A | N/A | N/A | N/A | 3,067 |
| 944 | 831875 | School/University | 184,650 | N/A | N/A | 61.55 | N/A | N/A | N/A | N/A | 3,000 |
| 943 | 849870 | Warehouse | 154,749 | N/A | N/A | 51.36 | N/A | N/A | N/A | N/A | 3,013 |
| 959 | 576728 | School/University | 230,982 | N/A | N/A | 51.69 | N/A | N/A | N/A | N/A | 4,469 |
| 963 | 698353 | Warehouse | 335,521 | N/A | N/A | 41.45 | N/A | N/A | N/A | N/A | 8,095 |
| 967 | 831909 | School/University | 456,103 | N/A | N/A | 150.06 | N/A | N/A | N/A | N/A | 3,039 |
| 873 | 1321654 | Retail | 38,720 | N/A | N/A | 9.68 | N/A | N/A | N/A | N/A | 4,000 |
| 849 | 826837 | Healthcare-Clinic | 20,135 | N/A | N/A | 7.47 | N/A | N/A | N/A | N/A | 2,695 |
| 780 | 994659 | School/University | 6,230 | N/A | N/A | 1.66 | N/A | N/A | N/A | N/A | 3,744 |
| 905 | 853025 | School/University | 68,709 | N/A | N/A | 11.34 | N/A | N/A | N/A | N/A | 6,059 |
| 902 | 831599 | Retail | 61,611 | N/A | N/A | 7.99 | N/A | N/A | N/A | N/A | 7,711 |
| 935 | 866180 | Healthcare-Clinic | 137,108 | N/A | N/A | 23.98 | N/A | N/A | N/A | N/A | 5,718 |
| 945 | 802008 | Retail | 194,731 | N/A | N/A | 39.74 | N/A | N/A | N/A | N/A | 4,900 |
| 962 | 576742 | School/University | 231,290 | N/A | N/A | 55.99 | N/A | N/A | N/A | N/A | 4,131 |
| 965 | 973302 | Office | 424,826 | N/A | N/A | 110.04 | N/A | N/A | N/A | N/A | 3,861 |

## Table 23: Lighting Systems Evaluation Estimates

| Lighting Systems | | | Evaluation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (j) | (k) | (l) | (m) | (n) | (o) | (p) | (q) | (r) |
| KEMA ID | Application 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 |
| 747 | 794485 | Transportation | 702 | 100% | 98% | 0.61 | 21% | 100% | 3% | 100% | 1,150 |
| 785 | 988993 | School/University | 3,855 | 100% | 78% | 4.97 | 13% | 100% | 22% | 100% | 776 |
| 910 | 720373 | School/University | 15,057 | 111% | 91% | 6.84 | 25% | 125% | 27% | 100% | 1,984 |
| 920 | 831889 | School/University | 52,176 | 100% | 95% | 30.43 | 34% | 100% | 31% | 100% | 1,715 |
| 944 | 831875 | School/University | 59,568 | 100% | 96% | 61.28 | 17% | 100% | 15% | 100% | 972 |
| 943 | 849870 | Warehouse | 178,535 | 106% | 58% | 51.89 | 59% | 118% | 37% | 100% | 3,241 |
| 959 | 576728 | School/University | 132,238 | 100% | 72% | 51.56 | 41% | 100% | 35% | 100% | 2,565 |
| 963 | 698353 | Warehouse | 330,409 | 101% | 49% | 41.45 | 95% | 104% | 94% | 100% | 7,883 |
| 967 | 831909 | School/University | 312,549 | 113% | 87% | 149.84 | 40% | 126% | 17% | 100% | 1,850 |
| 873 | 1321654 | Retail | 63,429 | 113% | 69% | 9.68 | 100% | 126% | 100% | 100% | 5,824 |
| 849 | 826837 | Healthcare-Clinic | 33,313 | 112% | 69% | 7.52 | 81% | 126% | 70% | 100% | 3,953 |
| 780 | 994659 | School/University | 3,921 | 110% | 93% | 1.66 | 22% | 124% | 56% | 100% | 2,147 |
| 905 | 853025 | School/University | 55,725 | 102% | 38% | 11.34 | 23% | 117% | 100% | 100% | 4,805 |
| 902 | 831599 | Retail | 66,941 | 119% | 58% | 7.94 | 100% | 144% | 100% | 100% | 7,063 |
| 935 | 866180 | Healthcare-Clinic | 46,016 | 112% | 59% | 20.70 | 36% | 126% | 29% | 100% | 1,984 |
| 945 | 802008 | Retail | 240,737 | 112% | 66% | 40.07 | 100% | 126% | 100% | 100% | 5,340 |
| 962 | 576742 | School/University | 118,968 | 100% | 80% | 49.93 | 33% | 100% | 38% | 100% | 2,379 |
| 965 | 973302 | Office | 508,321 | 107% | 67% | 110.04 | 87% | 114% | 57% | 100% | 4,331 |

## Table 24: Lighting Systems Realization Rates and Primary Reasons for Discrepancies

| Lighting Systems | | | Tracking | Realization Rates | | | |
|---|---|---|---|---|---|---|---|
| | | | (a) | (t) | (w) | (ab) | |
| KEMA ID | Application ID | Facility Type | Annual kWh | Annual kWh (Including HVAC) | Connected kW | Average Hours of Use | Primary Reasons for Discrepancies |
| 747 | 794485 | Transportation | 1,471 | 48% | 100% | 48% | Operating hours approximately half of those predicted in the tracking estimates. |
| 785 | 988993 | School/University | 7,128 | 54% | 100% | 54% | Evaluation hours of operation 54% of tracking assumptions. |
| 910 | 720373 | School/University | 17,757 | 85% | 100% | 76% | Hours of use 76% of tracking assumptions. |
| 920 | 831889 | School/University | 88,521 | 59% | 105% | 56% | Annual hours of use are 56% of the proposed estimate. |
| 944 | 831875 | School/University | 184,650 | 32% | 100% | 32% | Evaluation hours of operation 32% of tracking assumptions. |
| 943 | 849870 | Warehouse | 154,749 | 115% | 101% | 108% | Evaluation hours of operation 108% of tracking assumptions. |
| 959 | 576728 | School/University | 230,982 | 57% | 100% | 57% | Evaluation hours of operation 57% of tracking assumptions. |
| 963 | 698353 | Warehouse | 335,521 | 98% | 100% | 97% | Evaluation hours of operation 97% of tracking assumptions. |
| 967 | 831909 | School/University | 456,103 | 69% | 100% | 61% | Evaluation hours of operation 61% of tracking assumptions. |
| 873 | 1321654 | Retail | 38,720 | 164% | 100% | 146% | Annual hours of use are 46% higher than proposed estimate. |
| 849 | 826837 | Healthcare-Clinic | 20,135 | 165% | 101% | 147% | Evaluation hours of operation 47% greater than tracking assumptions. |
| 780 | 994659 | School/University | 6,230 | 63% | 100% | 57% | Evaluation hours of operation 57% of tracking assumptions. |
| 905 | 853025 | School/University | 68,709 | 81% | 100% | 79% | Evaluation hours of operation 79% of tracking assumptions. |
| 902 | 831599 | Retail | 61,611 | 109% | 99% | 92% | Increase in savings due to addition of HVAC interactive effects. |
| 935 | 866180 | Healthcare-Clinic | 137,108 | 34% | 86% | 35% | Technology differences combined with reduced hours of operation. |
| 945 | 802008 | Retail | 194,731 | 124% | 101% | 109% | Addition of HVAC interactive effects, and increase in operating hours. |
| 962 | 576742 | School/University | 231,290 | 51% | 89% | 58% | Evaluation hours of operation 58% of tracking assumptions. |
| 965 | 973302 | Office | 424,826 | 120% | 100% | 112% | Evaluation hours of operation 112% of tracking assumptions. |

## C.2 Lighting Controls

**Table 25: Lighting Controls Tracking Estimates**

| Lighting Controls | | | Tracking | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) |
| KEMA ID | Application 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 Reduction in Hours of Use |
| 747 | 794485 | Transportation | 259 | N/A | N/A | 0.14 | N/A | N/A | N/A | N/A | 1,850 |
| 910 | 720373 | School/University | 53,847 | N/A | N/A | 80.47 | N/A | N/A | N/A | N/A | 669 |
| 920 | 831889 | School/University | 1,308 | N/A | N/A | 1.31 | N/A | N/A | N/A | N/A | 998 |
| 943 | 849870 | Warehouse | 13,341 | N/A | N/A | 11.98 | N/A | N/A | N/A | N/A | 1,114 |
| 959 | 576728 | School/University | 79,494 | N/A | N/A | 29.13 | N/A | N/A | N/A | N/A | 2,729 |
| 963 | 698353 | Warehouse | 37,619 | N/A | N/A | 16.29 | N/A | N/A | N/A | N/A | 2,309 |
| 967 | 831909 | School/University | 8,720 | N/A | N/A | 10.90 | N/A | N/A | N/A | N/A | 800 |
| 849 | 826837 | Healthcare-Clinic | 5,077 | N/A | N/A | 3.17 | N/A | N/A | N/A | N/A | 1,602 |
| 902 | 831599 | Retail | 5,125 | N/A | N/A | 1.44 | N/A | N/A | N/A | N/A | 3,559 |
| 962 | 576742 | School/University | 122,658 | N/A | N/A | 42.50 | N/A | N/A | N/A | N/A | 2,886 |

## Table 26: Lighting Controls Evaluation Estimates

| Lighting Controls | | | Evaluation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (j) | (k) | (l) | (m) | (n) | (o) | (p) | (q) | (r) |
| KEMA ID | Application 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 Reduction in Hours of Use |
| 747 | 794485 | Transportation | 0 | N/A | 0% | 0.00 | 0% | 100% | 0% | 100% | 0 |
| 910 | 720373 | School/University | 54,291 | 110% | 90% | 80.34 | 8% | 125% | 22% | 100% | 613 |
| 920 | 831889 | School/University | 958 | 100% | 99% | 1.31 | 22% | 100% | 41% | 100% | 733 |
| 943 | 849870 | Warehouse | 3,843 | 104% | 62% | 8.59 | 9% | 106% | 2% | 100% | 432 |
| 959 | 576728 | School/University | 15,995 | 100% | 88% | 28.98 | 13% | 100% | 9% | 100% | 552 |
| 963 | 698353 | Warehouse | 65,724 | 100% | 10% | 16.26 | 9% | 100% | 12% | 100% | 4,042 |
| 967 | 831909 | School/University | 11,504 | 113% | 99% | 11.12 | 27% | 127% | 12% | 100% | 913 |
| 849 | 826837 | Healthcare-Clinic | 8,323 | 112% | 65% | 2.39 | 60% | 127% | 32% | 100% | 3,116 |
| 902 | 831599 | Retail | 1,322 | 112% | 67% | 1.44 | 10% | 126% | 14% | 100% | 815 |
| 962 | 576742 | School/University | 25,053 | 100% | 73% | 42.50 | 8% | 101% | 14% | 100% | 587 |

**Table 27: Lighting Controls Realization Rates and Primary Reasons for Discrepancies**

| Lighting Controls | | | Tracking | Realization Rates | | | |
|---|---|---|---|---|---|---|---|
| | | | (a) | (t) | (w) | (ab) | |
| KEMA ID | Application ID | Facility Type | Annual kWh | Annual kWh (Including HVAC) | Connected kW | Average Reduction in Hours of Use | Primary Reasons for Discrepancies |
| 747 | 794485 | Transportation | 259 | 0% | 0% | 0% | Fixtures likely were controlled manually due to observations in other spaces, which negates the savings. |
| 910 | 720373 | School/University | 53,847 | 101% | 100% | 92% | Addition of HVAC interactive effects. |
| 920 | 831889 | School/University | 1,308 | 73% | 100% | 73% | Hours of use reduction was 73% of the proposed estimate. |
| 943 | 849870 | Warehouse | 13,341 | 29% | 72% | 39% | Hours of use reduction is 39% of tracking assumptions. |
| 959 | 576728 | School/University | 79,494 | 20% | 99% | 20% | The predicted reduction of operating hours was higher than the actual reduction in operating hours based on logger data. There was also a quantity adjustment from the tracking to the evaluation. |
| 963 | 698353 | Warehouse | 37,619 | 175% | 100% | 175% | Hours of use reduction approximately 75% greater than tracking assumptions. |
| 967 | 831909 | School/University | 8,720 | 132% | 102% | 114% | Increased hours of use reduction plus interactive HVAC effects. |
| 849 | 826837 | Healthcare-Clinic | 5,077 | 164% | 75% | 195% | Hours of use reduction almost double the tracking assumptions. |
| 902 | 831599 | Retail | 5,125 | 26% | 100% | 23% | Hours of use reduction 23% of tracking assumptions. |
| 962 | 576742 | School/University | 122,658 | 20% | 100% | 20% | Average hours of use reduction was 20% of tracking savings. |