National Grid USA

Impact Evaluation Study of 2006 Custom Lighting Installations

Executive Summary

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Introduction

This document summarizes work performed by RLW Analytics, Inc. (RLW) during 2007 to quantify the actual energy and demand savings due to the installation of the Custom lighting measures installed through National Grid's Design 2000*plus* (D2) and Energy Initiative (EI) Commercial and Industrial (C&I) Programs in 2006.

Purpose of Study

The objective of this impact evaluation is to provide verification or re-estimation of electric energy and demand savings estimates for ten (10) Custom lighting projects through site-specific inspection, monitoring, and analysis.

This impact study consists of the following four tasks:

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

Scope

The EI and D2 programs assist commercial, industrial, institutional and governmental customers in the National Grid's Massachusetts, Rhode Island and New Hampshire service territories to install a wide range of retrofit and new construction related technologies. This study concentrates on the lighting measures installed through the Custom component of EI and D2. Custom lighting represents about 12% of the total kWh savings attributed to the Custom component.

Description of Methodology

Measurement and Evaluation Plans

National Grid, with the help of RLW (through a separate contract) randomly selected ten[1] custom lighting applications for the evaluation and provided RLW with all available information on the sample projects at the beginning of the study.

RLW detailed our standard lighting evaluation methodology in the project workplan, in which we outlined on-site methods, strategies, monitoring equipment placement and calibration, analysis issues, and HVAC interaction. Besides fixture and lamp/ballast replacement, several of the Custom lighting projects included fixtures with multiple light

[1] Site #10 was a replacement site that was selected when one site was determined to have lost most of its newly installed outdoor lighting during a severe storm. The site was in the process of replacing the damaged lighting when they were first contacted. It was determined that the lighting at this site would not be operational for monitoring until after the conclusion of this impact evaluation study.

levels, occupancy controls, daylight controls, dimming controls, and combinations thereof.

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

Data Gathering, Analysis, and Reporting

Data collection included physical inspection and inventory, interview with facility personnel, observation of site operating conditions and equipment, and short-term metering of usage. RLW performed a full facility walk-through that focused on verifying the post-retrofit or existing conditions of each EEM. Lighting surveys gathered data by functional use types, e.g. open office area, conference rooms, corridors etc. and the data were recorded and entered into a lighting analysis spreadsheet. Instrumentation such as Time-Of-Use (TOU) lighting loggers, current loggers, and power recorders were installed to monitor the usage of the installed lighting.

The analysis spreadsheet was developed and refined with the input of the National Grid project manager. The column definitions and formulae are documented in detail as Appendix A of this report. Annual hourly (8,760) operating profiles for each lighting schedule with careful consideration of daily, weekly and other seasonal effects were developed. This comprehensive hourly analysis was used to estimate diversified coincident peak demand. A typical meteorological year (TMY) dataset of ambient temperatures was used in conjunction with facility temperature set points and HVAC schedules to compute estimates of interactive heating and cooling hours.

RLW worked with National Grid to develop a site report template. Engineers submitted draft site reports to the study manager upon completion of each site evaluation, which after review and comment resulted in the final reports found in Appendix B. This executive summary provides a concise overview of the evaluation methods and findings.

Description of Sample Projects

Site 1 Wastewater Treatment Plant, Providence, RI
EI Program, Appl #: 508924

This site is a wastewater treatment plant that consists of several buildings and processes. The lighting renovation, which included most of the buildings, upgraded fixtures from (12) 70 watt metal halide fixtures, (44) 150 watt metal halide fixtures and (40) 250 watt metal halide fixtures to (12) 55 watt induction light fixtures, (44) 85 watt induction light fixtures and (40) 165 watt induction light fixtures. All fixtures were intended to operate 8,760 hours per year.

Site 2 Education Center, Providence, RI
D2 Program, Appl #: 510866

This facility is a small educational building that includes classrooms and lecture rooms. The measure being evaluated for this site is the installation of daylight sensors and the appropriate controls along the building perimeter to maintain preset light levels. This measure was one of eleven that were modeled using DOE 2.2. Twenty two dimming ballasts located on the building perimeter glass walls were to have their lighting output modulated to maintain the preset light levels from seven daylight sensors.

Site 3 Grocery Store, Cranston, RI
EI Program, Appl #: 511788

A lighting retrofit of a grocery store was done to replace older inefficient lighting fixtures with new more efficient fixtures. The majority of the fixtures included in the retrofit are located in the main retail area of the store. There were (252) 400 watt metal halide fixtures and (34) 175 watt metal halide fixtures replaced with (354) two lamp F54/T5 fixtures, (98) two lamp F32/T8 fixtures and (80) 35 watt metal halide spot lights.

Site 4 Grocery Store, Revere, MA
EI Program, Appl #: 511789

A lighting retrofit of a grocery store was done to replace older inefficient lighting fixtures with new more efficient fixtures. The majority of the fixtures included in the retrofit are located in the main retail area of the store. There were (225) 320 watt metal halide fixtures replaced with (353) two lamp F54/T5 fixtures, (92) two lamp F32/T8 fixtures and (114) 35 watt metal halide spot lights.

Site 5 Grocery Store, Bristol, RI
EI Program, Appl #: 511791

A lighting retrofit of a grocery store was done to replace older inefficient lighting fixtures with new more efficient fixtures. The majority of the fixtures included in the retrofit are located in the main retail area of the store. There were (237) 320 watt metal halide fixtures replaced with (332) two lamp F54/T5 fixtures, (100) two lamp F32/T8 fixtures and (49) 35 watt metal halide spot lights.

Site 6 Grocery Store, Middletown, RI
EI Program, Appl #: 511796

A lighting retrofit of a grocery store was done to replace older inefficient lighting fixtures with new more efficient fixtures. The majority of the fixtures included in the retrofit are located in the main retail area of the store. There were (219) 320 watt metal halide fixtures replaced with (270) two lamp F54/T5 fixtures, (87) two lamp F32/T8 fixtures and (71) 35 watt metal halide spot lights.

Site 7 High School, Norwell, MA
EI Program, Appl #: 512281

A lighting retrofit of a school was done to replace older inefficient lighting fixtures with new more efficient fixtures. Included in the retrofit are classrooms, offices, corridors, locker rooms and the gymnasium. A total of 1,324 older technology lighting fixtures were replaced with 1,299 new high efficiency fixtures. The existing fixtures included: (73) metal halide fixtures, (539) two lamp T8 fixtures, (293) three lamp T8 fixtures and (419) four lamp T8 fixtures. These fixtures were replaced by various size high efficiency T8 lamps with low power ballasts and high efficiency compact fluorescent lamps.

Site 8 Manufacturer, Haverhill, MA
EI Program, Appl #: 513662

A lighting retrofit of a paper manufacturer was done to replace older inefficient lighting fixtures with new more efficient fixtures. There were (26) 400 watt metal halide fixtures replaced with (26) 150 watt induction light fixtures. In addition to energy savings, the new induction light fixtures perform well in extreme temperatures. Since some areas of the plant reach temperatures up to 200 degrees Fahrenheit, this was the main reason this fixture type was selected.

Site 9 Office and Warehouse, Randolph, MA
EI Program, Appl #: 516545

A lighting retrofit of a manufacturing facility was done to replace older inefficient lighting fixtures with new more efficient fixtures. Included in the retrofit are warehouses, offices, corridors and restrooms. A total of 511 older technology lighting fixtures were replaced with 511 new high efficiency fixtures. The existing fixtures included; (162) 400 watt metal halides, (29) 320 watt metal halides, (4) 250 watt metal halides, (12) incandescent exit signs, (194) three lamp F40/T12, (105) two lamp F40/T12, (7) four lamp F40/T12 and (1) two lamp F96/T12 fixtures. These fixtures were replaced with (185) six lamp F32/T8 high bay, (4) three lamp F32/T8 high bay, (12) LED exit signs, (194) three lamp F32/T8 low power, (7) four lamp F32/T8 low power, (13) two lamp F28/T8 low power, (83) two lamp F17/T8 and (6) four lamp F54/T5 high output fixtures.

The warehouse, where the (185) six lamp F32/T8 high bay fixtures were installed, was to have occupancy sensors installed on each fixture.

Site 10 Middle School, Northboro, MA
EI Program, Appl #: 516669

A lighting retrofit of a middle school was done to replace older inefficient lighting fixtures with new more efficient fixtures. The entire school was retrofit with new low power T8 lamps and ballasts and compact fluorescent lighting. There were (50) two lamp F48/T12 high output fixtures replaced with (50) two lamp F32/T8 high output fixtures in the Gymnasium. The music room had

(102) 250 watt halogen spot lights replaced with (102) 57 watt compact fluorescents. The classrooms, library, cafeteria, offices, hallways and restrooms had two, three and four lamp F32/T8 fixtures that were replaced with two, three and four lamp F32/T8 low power fixtures. All of the classrooms were to have occupancy sensors installed.

Results

Major Findings and Observable Trends

Figure 1 displays a scatter plot of the evaluation results. As evidenced by the figure, most projects trended at or above 100% realization. One project had a particularly low realization rate of 15%. This was also the smallest site in the sample. Five of the ten projects had realizations rates at or above 139% including the three largest sites. The non-weighted realization rate for the ten sample points is 126%.

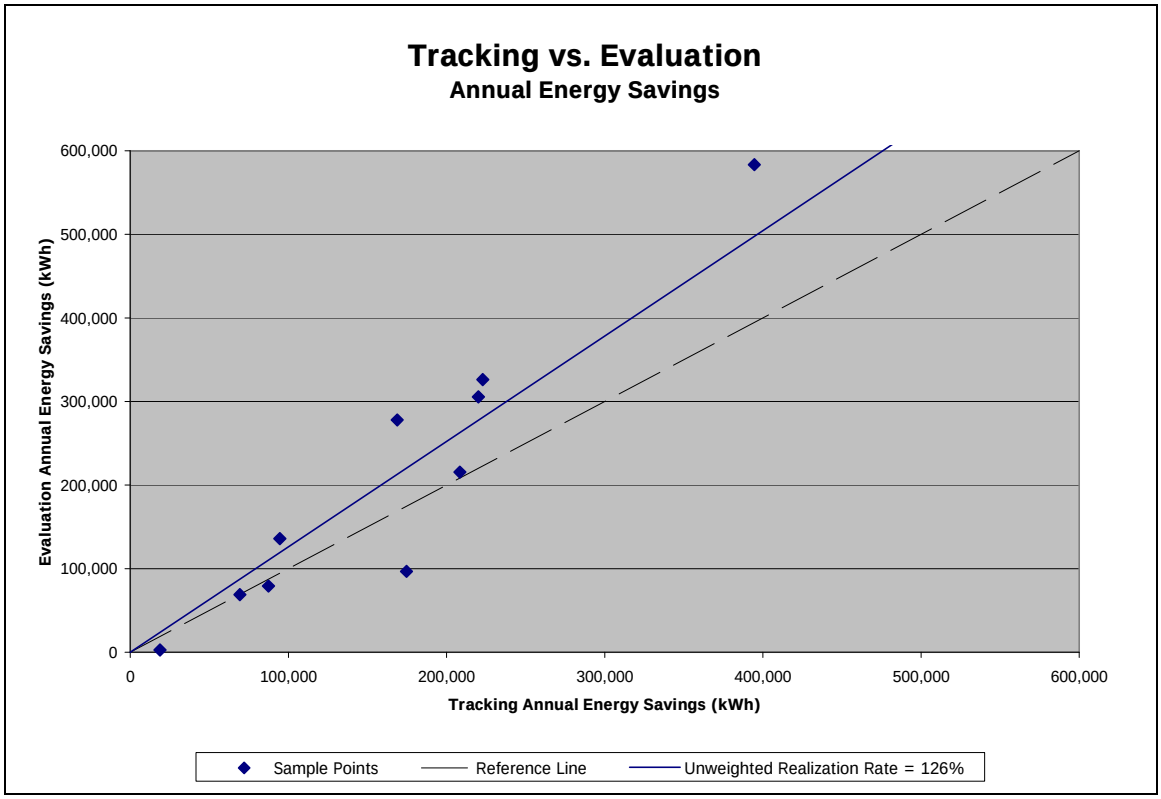

Figure 1 - Scatter Plot of Evaluation Results

Presentation of Results

Table 1 presents a tabular summary of the site level results. The site realization rates ranged from a low of 15% for Site #2 to a high of 165% for Site #4.

			Nat. Grid TRACKING EST. SVGS				RLW EVALUATION SVGS						RATIO RLW / TRACKING					
					Peak Coinc.				Current Peak Coinc.		FCM Peak Coinc.				Current Peak Coinc.		FCM Peak Coinc.	
RLW ID	EI / D2	CUSTOMER TYPE & LOCATION LOCATION & APPLICATION ID	kWh/yr	On-Peak %	Sum. kW	Wint. kW	kWh/yr	On-Peak %	Sum. kW	Wint. kW	Sum. kW	Wint. kW	kWh/yr	On-Peak %	Sum. kW	Wint. kW	Sum. kW	Wint. kW
1	EI	Wastewater Treatment Plant, Providence, RI Appl #: 508924	87,425	37%	9.98	9.98	79,286	48%	10.24	8.45	10.24	8.45	91%	130%	103%	85%	103%	85%
2	D2	Education Center, Providence, RI Appl #: 510866	18,780	85%	9.21	0.17	2,837	93%	0.44	0.20	0.54	0.20	15%	109%	5%	119%	6%	117%
3	EI	Grocery Store, Cranston, RI Appl #: 511788	394,564	64%	60.19	26.20	583,384	52%	91.30	71.67	91.29	71.67	148%	81%	152%	274%	152%	274%
4	EI	Grocery Store, Revere, MA Appl #: 511789	168,765	64%	25.75	11.21	278,014	51%	42.87	33.68	42.87	33.68	165%	80%	167%	301%	167%	301%
5	EI	Grocery Store, Bristol, RI Appl #: 511791	220,122	64%	33.58	14.62	305,523	51%	47.11	37.00	47.11	37.01	139%	79%	140%	253%	140%	253%
6	EI	Grocery Store, Middletown, RI Appl #: 511796	222,886	64%	34.00	14.80	326,264	51%	50.92	40.00	50.92	40.00	146%	80%	150%	270%	150%	270%
7	EI	High School, Norwell, MA Appl #: 512281	94,529	35%	10.75	21.45	136,055	70%	16.25	21.96	18.39	20.95	144%	200%	151%	102%	171%	98%
8	EI	Manufacturing, Haverhill, MA Appl #: 513662	69,276	37%	7.90	7.90	68,990	46%	7.74	7.48	7.83	7.51	100%	124%	98%	95%	99%	95%
9	EI	Office and Warehouse, Randolph, MA Appl #: 516545	208,448	35%	53.91	53.91	215,567	84%	67.79	21.50	66.16	21.25	103%	240%	126%	40%	123%	39%
10	D2	Middle School, Northboro, MA Appl #: 516669	174,667	60%	32.03	48.05	96,809	91%	12.20	18.12	14.25	16.66	55%	152%	38%	38%	44%	35%
TOTALS			1,659,462	56%	277.29	208.29	2,092,729	58%	346.87	260.07	349.60	257.37	126%	103%	125%	125%	126%	124%

Table 1 - Detailed Site Results

Summary of Discrepancies

Table 2 summarizes the primary reason for discrepancy between the tracking and evaluation estimates of annual energy savings. In most cases, hours-of-use was the most significant influence on the savings revision. There were very few differences in fixture wattage and count between the evaluated and tracking savings.

			RATIO RLW / TRACKING						
					Current Peak Coinc.		FCM Peak Coinc.		
RLW ID	EI / D2	CUSTOMER TYPE & LOCATION LOCATION & APPLICATION ID	kWh/yr	On-Peak %	Sum. kW	Wint. kW	Sum. kW	Wint. kW	Primary Reason for Discrepancy
1	EI	Wastewater Treatment Plant, Providence, RI Appl #: 508924	91%	130%	103%	85%	103%	85%	Maintenance Shop had lower hours of use estimate than tracking. (3,418 on-site, 8,760 tracking)
2	D2	Education Center, Providence, RI Appl #: 510866	15%	109%	5%	119%	6%	117%	Connected load of controlled fixtures was 47% lower than tracking estimate.
3	EI	Grocery Store, Cranston, RI Appl #: 511788	148%	81%	152%	274%	152%	274%	Overall increase in operating hours (7,472 on-site weighed average, 5,572 tracking weighted average)
4	EI	Grocery Store, Revere, MA Appl #: 511789	165%	80%	167%	301%	167%	301%	Overall increase in operating hours (7,388 on-site weighed average, 5,572 tracking weighted average)
5	EI	Grocery Store, Bristol, RI Appl #: 511791	139%	79%	140%	253%	140%	253%	Overall increase in operating hours (7,345 on-site weighed average, 5,572 tracking weighted average)
6	EI	Grocery Store, Middletown, RI Appl #: 511796	146%	80%	150%	270%	150%	270%	Overall increase in operating hours (7,462 on-site weighed average, 5,572 tracking weighted average)
7	EI	High School, Norwell, MA Appl #: 512281	144%	200%	151%	102%	171%	98%	Overall increase in operating hours (3,126 on-site weighed average, 2,200 tracking weighted average)
8	EI	Manufacturing, Haverhill, MA Appl #: 513662	100%	124%	98%	95%	99%	95%	Small decrease in operating hours (8,700 on-site , 8,736 tracking)
9	EI	Office and Warehouse, Randolph, MA Appl #: 516545	103%	240%	126%	40%	123%	39%	Cooling Interaction resulted in 1% increase in savings.
10	D2	Middle School, Northboro, MA Appl #: 516669	55%	152%	38%	38%	44%	35%	Overall decrease in operating hours (1,743 on-site weighed average, 2,382 tracking weighted average). Also missing occupancy sensors.

Table 2 - Site Discrepancies

Tracking savings for Site #1 were calculated using 8,760 hours per year operation for all fixtures installed. Upon inspection of the lighting, it was determined that almost all of the new fixtures were being controlled with occupancy sensors. The installation of these occupancy sensors was done after the completion of this project without any involvement from National Grid. Therefore, the savings for all of the fixtures installed, excluding the maintenance shop, were calculated using 8,760 annual hours. This was

confirmed by the facilities manager as the correct operation of the lighting prior to the installation of the occupancy sensors. The maintenance shop was the only space that did not operate 8,760 hours per year. This space operates approximately 10 hours a day based on site interview and lighting logger data. The reduction of annual operating hours for this space resulted in the overall decrease in savings for this site.

Site #2 produced only 15% of the tracking savings. The largest reason for the discrepancy was that the connected load of controlled fixtures was approximately 47% less than the tracking estimate. The tracking savings for this site were developed in DOE-2 as part of a Design 2000 Comprehensive Design Approach (CDA) project. The daylighting measure "L-3" is one of three lighting, four envelope, and five HVAC alternatives assessed against an ASHRAE 90.1 new construction baseline. Unfortunately, the tracking savings do not reflect the relative benefit of the L-3 daylighting measure, but the absolute savings relative to a minimally compliant ASHRAE 90.1 baseline building, B-1.

Alternative L-3 represents daylighting savings on a 1.31 W/sqft lighting system with no occupancy controls. But alternative L-1 upgraded to high-efficiency lighting and brought the lighting density down to 0.94 W/sqft, and alternative L-2 reduced lighting hours-of-use via occupancy controls. It has been shown that the *sequence* in which multiple alternatives are assessed *does* have notable effect on how the savings allocate to the individual measures. In practice, to assess savings correctly for isolated measures, evaluators preserve the sequence as originally presented and compute the incremental impacts from the first alternative to the second, from the second to the third, and so on. Since all lighting alternatives are relative to a base scenario, the interactive 'ex-post' savings impacts are inherently misrepresented.

Sites #3 through #6 were all grocery stores that are part of the same chain. The evaluated savings for each of these four sites were significantly greater than the tracking savings. The reason was the same for each store in that the National Grid representative who implemented this program at these stores used a very conservative estimate of annual hours of use to calculate energy savings. The tracking savings estimated the annual hours of use to be 5,572 hours for each store. This value was based on the store's operating hours and applied to every fixture installed. Field data and customer interview revealed that approximately 60% of the lighting remains on 8,760 hours per year. This was the primary reason for the large increases in savings.

Additionally, two of these grocery stores (Sites #3 and #4) removed some of the installed 35 watt spot lights to increase savings while maintaining adequate light levels. Since the baseline fixture count was fixed, this deliberate action resulted in increased savings. According to a National Grid representative, National Grid tried to convince some of the stores that not all of the spot lights were necessary. As these stores got used to the new lighting, they felt more comfortable removing some of the installed spot lights.

At Site #7, the large increase in savings was due to a conservative estimate of annual operating hours in the tracking system. The tracking savings estimated the annual hours of use for all of the installed fixtures to be 2,200 hours per year. The weighted average of the evaluated annual operating hours was 3,126 hours per year. This was the result of most of the common spaces operating 8,760 hours per year.

The operating hours were almost exact for Site #8, which resulted in 100% realization for this site.

There were some inconsistencies found when trying to recreate the tracking savings for Site #9 involving the occupancy sensors in the warehouse. The evaluator was unable to recreate the tracking savings as a result of these inconsistencies. However, the overall savings was approximately 3% higher than the tracking savings estimate. This was mostly due to the additional savings from the interaction with the HVAC system.

Site #10 was a middle school that saw an overestimation of annual operating hours combined with missing occupancy sensors. The weighted average of the tracking annual hours of use was 2,382 hours per year while the weighted average of the evaluated annual hours of use was 1,743 hours per year. Site #10 was also missing 49 of the 50 proposed occupancy sensors. According to the facilities manager, these occupancy sensors were removed due to the complaints received from several teachers.

Conclusions

Overall, the Custom lighting component of the Energy Initiative and Design 2000*plus* Programs appears to be successfully delivering energy savings to National Grid customers. Several conservative assumptions in the estimation of the tracking savings have resulted in a non-weighted realization rate of 126% for this sample.

Incorrect fixture counts were not an issue for this evaluation. Overall, the quantities and fixture types were installed as proposed. In the most recent evaluation of this program in 2004, missing fixtures were a major issue resulting in reduced energy savings. It appears that National Grid has made an even stronger effort to ensure that fixture quantities and fixture types are being installed as proposed. This has resulted in more accurate installations and energy savings estimates for this project year.

For savings estimates that involve measure interactions, the program implementers should make sure that all installed measures have their savings calculated taking those interactions into account. This will ensure that savings from any of the measures installed are not being double counted or underestimated. Each measure should be presented in series with the installed case of the first measure representing the base case of the second measure and so on. The evaluators can then replicate that specific order of savings calculation which will properly factor in the interactions the same way as the original estimate does.

Tracking estimates of annual hours of use tended to be more conservative in this evaluation. In particular, the four grocery stores' annual hours of use were more conservative because they were based on a typical store's business operating hours not the hours that the lights were on. In some cases, these conservative estimates of annual hours may have been intended to make sure savings were not over-estimated. The recommendation is to urge the vendors to be as specific as they can when documenting annual hours of use. A more detailed interview process with building personnel should result in more accurate estimates of annual hours of use without being too conservative or too aggressive.