National Grid

Lighting Controls Impact Evaluation

FINAL REPORT

2005 Energy Initiative,
Design 2000*plus* and
Small Business Services Programs

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Table of Contents

Listing of Tables

Listing of Figures

Executive Summary

I Introduction

This document summarizes work performed by RLW Analytics, Inc. (RLW) during 2006 to quantify the actual energy and demand savings due to the installation of prescriptive lighting control measures through National Grid's[1] Commercial & Industrial (C&I) programs, Design 2000*plus* (D2), Energy Initiative (EI), and the Small Business Services (SBS) Programs during the 2005 program year.

Purpose of Study

This study had two primary objectives. The first was to review the current algorithms used in the National Grid tracking database to calculate gross and net savings and recommend any necessary changes. The second objective was to determine, via on-site monitoring within a participant sample, the following factors which are applied to gross savings:

A. Summer diversity factor,
B. Winter diversity factor,
C. Connected kW realization rate,
D. Hours-of-use reduction realization rate, and
E. Percent energy savings on-peak.

Scope of Work

The following section provides an overview of the five fundamental tasks that RLW successfully completed as part of this study. In support of this study, National Grid provided an extract of tracking system data for the 2005 Design 2000*plus*, Energy Initiative, and Small Business Services programs, as well as all site-specific supporting documentation for each selected sample point.

In pursuit of the objectives presented above, National Grid designed this study to consist of the following five tasks:

1. Review Savings Algorithms
    - RLW reviewed all computations employed in the program tracking database to determine if each factor is appropriate and applied correctly.
    - The savings algorithms were revised where appropriate to reflect RLW's technical recommendations.
    - The revised computations were used to drive the site-specific data collection, subsequent analysis, and reporting.
2. Site Selection and Sample Design
    - RLW examined the distribution of applications, customers, and measures in the 2005 Design 2000*plus*, Energy Initiative, and Small Business Services programs.

[1] The results of this study are applicable to National Grid's electric distribution service territories in MA, RI, and NH.

- National Grid decided to structure the study by program size: large C&I (D2 and EI) and small C&I (SBS) programs. The sample design targeted ±10% relative precision at the 90% confidence interval for all programs combined.
- The final sample was comprised of forty (40) participants: twenty-five (25) D2/EI customers and fifteen (15) SBS customers.

3. Develop Measurement and Analysis Plan
   - RLW performed a complete review of project documentation.
   - RLW developed individual measurement and analysis plans for each sample site in order to detail, pre-define, streamline, and unify the data collection procedures.
4. Data Gathering and Analysis
   - RLW performed visits to each site in the on-site sample.
   - Site visits included physical inspection and inventory, spot power measurements, interview with facility personnel, observation of site operating conditions and equipment, and short-term metering of usage.
   - RLW computed the summer and winter diversity factors, the connected kW realization rate, the hours-of-use reduced realization rate, and the percent of energy savings on-peak.
5. Report Writing
   - The preceding tasks have culminated in the Lighting Controls Impact Evaluation report on findings. This report details the study overview and purpose, methodology and analysis, results, and conclusions.

II Review of Savings Algorithms

To support this task, National Grid provided RLW with documentation of all algorithms and factors used in the tracking database to calculate program savings. RLW reviewed these algorithms for appropriateness and correctness in estimating lighting controls savings. The purpose of this task was to 1) validate and/or revise the savings algorithms and factors and 2) establish the data collection needs for the site visits. As such, this task was critical to the ultimate success of this study.

The review focused on the algorithms and factors only as they pertain to lighting occupancy controls. The project kickoff meeting established that dimming controls were not to be included in this study. The savings algorithms and factors that result from this study apply to lighting occupancy controls exclusively.

Algorithm Review

RLW conducted a full review of the impact savings equations for all D2, EI and SBS lighting control measures as presented in Appendix B. The review consisted of a recalculation of all the savings parameters based on tracking system data. All calculations were verified to be consistent with the tracking system calculations.

Relevant Findings

The D2 and EI programs both calculate kW reduction by multiplying the connected kW by a 0.5 factor. This 0.5 is a *gross savings factor* used to convert controlled watts to

gross kW reduction. It is an empirically-based rule-of-thumb that expresses the average demand reduction attained by implementing lighting controls. While reasonable – in practice, lighting controls may reduce lighting demand by about 50% - it undermines the validity of all subsequent engineering algorithms. Likewise, kWh reduction is also calculated by multiplying the kW reduction by the hours reduced. Therefore, all subsequent kW and kWh savings calculations start out being half of the total connected kW and kWh savings. Note that the SBS savings algorithms for kW saved and kWh saved do not use this 0.5 factor, or any adjustment factor.

Recommendations

It is recommended that National Grid rename some of the variables that are used in their savings algorithms. The calculation of winter and summer diversified kW reduction is the same for all three programs in the sense that it utilizes the connected kW reduction times a winter or summer diversity factor and a non-coincident demand factor. The winter and summer diversity factors refer to the percent of connected kW reduced during the defined winter or summer peak periods. The non-coincident demand factor in this algorithm is the connected kW realization rate as founded in previous studies.

It is recommended that National Grid rename the summer diversity factor in favor of a Summer Coincident Diversity Factor (SCDF) and the winter diversity factor in favor of a Winter Coincident Diversity Factor (WCDF). The reasoning is that ISO New England is moving towards using a combined coincidence and diversity factor for system planning purposes. It is important to note that the SCDF and WCDF should represent the diversity of the savings load shape, not the installed load shape. The result of using this combined coincidence and diversity factor would be the actual reduction during the defined summer and winter peak periods.

It is also recommended that National Grid rename the non-coincident demand factor in favor of a connected kW realization rate to make it easier to understand what this factor really is. In addition, the kWh adjustment factor and the energy realization rates used in the current algorithms were created from an old billing analysis. It is recommended that National Grid use the hours realization rates and connected kW realization rates calculated in this study in favor of the current billing analysis.

III Sample Design and Selection

Population Characteristics

At project initiation, National Grid provided RLW with a full data extract of D2, EI, and SBS data for the 2005 program year. Since National Grid designed this study to pursue savings factors for lighting controls only, exclusive of any lighting retrofits or dimming controls, evaluators filtered the tracking system to include lighting occupancy controls only. Table i - 1 presents a summary of the energy savings and demand impacts extracted from the tracking system by program.

Program	Gross kWh Energy Savings		Gross kW Demand Reduction		
	Annual	On-Peak	Peak	Summer	Winter
D2	1,235,282	926,103	560	139	144
EI	3,742,306	2,997,812	1,379	341	355
D2+EI	**4,977,588**	**3,923,915**	**1,939**	**480**	**500**
SBS	701,140	521,220	415	44	33
TOTAL	**5,678,728**	**4,445,135**	**2,354**	**524**	**532**

Table i - 1: Lighting Controls Tracking Savings Summary

National Grid chose to group the programs according to target customer size: D2 and EI are large C&I programs, while SBS is a small C&I program. Evaluation experience indicates that these two program markets tend to perform differently, supporting this decision. Table i - 2 presents the final D2/EI sample design, and Table i - 3 presents the design for the SBS sample.

Each of the following tables present the stratum, the maximum project controls savings, the total number of projects in the population, the total lighting control savings associated with the population of projects, the final sample size, and the weight each sample point carried in the final extrapolation of results. For example, in Table i - 2, stratum 1 is defined as all 2005 D2/EI projects (lighting controls only) with an annual estimate of lighting savings less than or equal to 11,907 kWh. There were a total of 108 program participants in stratum 1 with total savings of 395,277 kWh. The sample size for stratum 1 was four (4) program participants. The stratum 1 weight, i.e. the number of customers in the population represented by each sample point, is 108/4=27. Sample sites were randomly selected by strata for inclusion in the sample based on the designs presented below. The expected relative precision for each design follows the table caption.

Strata	Maximum Savings[2] kWh	Population		Sample Size (n)	Weight (N/n)
		Size (N)	Control Savings		
1	11,907	108	395,277	4	27.00
2	29,211	26	512,116	4	6.50
3	46,925	15	561,782	4	3.75
4	68,418	11	647,527	4	2.75
5	204,000	7	791,641	4	1.75
6	1,000,000	5	2,069,245	5	1.00
TOTAL		172	4,977,588	25	

Table i - 2: D2/EI Program Sample Design

The D2/EI sample design in Table i - 2 was expected to achieve ±11.8% relative precision with 25 sample points. The SBS sample design in Table i - 3 was expected to achieve ±16.2% relative precision with 15 sample points. For both samples in aggregate, RLW estimates that this study would achieve ±10.5% relative precision at the 90% confidence interval.

	Maximum	Population		Sample	
	SavingsError!	**Size**	**Lighting**	**Size**	**Weight**

[2] Maximum savings are for controls only. Lighting retrofit savings are not included.

Strata	Bookmark not defined. kWh	(N)	Savings	(n)	(N/n)
1	3,660	83	86,724	4	20.75
2	9,904	19	108,757	3	6.33
3	25,623	8	147,887	3	2.67
4	46,913	5	177,964	3	1.67
5	200,000	2	179,807	2	1.00
TOTAL		117	701,140	15	

Table i - 3: SBS Program Sample Design

The stratified ratio estimate of the realization rate is calculated by multiplying the measured savings of each project in the sample by the case weight. The sum of this calculation is divided by the sum of the weighted tracking estimate of savings. The weighted tracking estimate of savings is calculated by multiplying the tracking savings of each project in the sample by the case weight.

IV Data Collection and Site Analysis

Measurement and Analysis Plans

The site evaluation plan played an important role in establishing approved field methods and ensuring the production of useful study results. Since each site visit culminated in a series of independent savings estimates, it was critical that each site plan detail and pre-define the procedures by which this was to be accomplished.

A thorough and comprehensive documentation review was vital to development of strong measurement and analysis plans. RLW reviewed the documented analyses in order to validate and recreate the tracking system estimates of savings. Any inconsistencies were investigated and submitted to the National Grid study manager. This initial review of projects ensured a consistent and numerically sound base from which to proceed with the on-site evaluations and the subsequent analyses.

In some cases, project documentation provided more thorough descriptions than the tracking system of the baseline and installed conditions. A complete file review ensured a full understanding of the facility and efficiency measures and helped to minimize site time and intrusiveness to the customer. This documentation review culminated in the development of detailed measurement plans for each sample project. A sample Measurement, Verification and Analysis (MVA) plan is provided in Appendix D of this report.

V Results

Table i - 4 presents the results of the stratified ratio estimation (SRE) analysis conducted on the Design 2000*plus* and Energy Initiative savings parameters. The table presents the tracking system estimate of annual energy savings for the total program and the final adjusted gross estimate of savings as well as on-peak kWh savings, percent on-peak savings, connected kW, hours of use reduction, summer coincident diversified kW, summer coincident diversity factor, winter coincident diversified kW and winter coincident diversity factor. In addition, this table shows the realization rate calculated as the total on-site value divided by the total revised tracking value along with the achieved relative precision associated with each result. All relative precisions are calculated at a confidence level of 90%.

All realization rates are based on the revised tracking system value for each savings parameter. Currently, the tracking system calculates kW and kWh reduction by multiplying the connected kW times a 0.5 *gross savings factor*. It was recommended that the 0.5 factor be eliminated because lighting controls savings should be calculated based on the full connected kW of the measure. Therefore, all of the realization rates are valid only if the 0.5 *gross savings factor* is removed from the current algorithms.

Design 2000*plus* and Energy Initiative	Tracking Estimates	Revised Tracking	Evaluation Results	Realization Rate	Relative Precision	Confidence Level
Annual kWh Savings	4,977,588	9,955,176	7,551,585	75.9%	±11.4%	90%
On-Peak kWh Savings	3,820,755	7,641,509	3,899,460	51.0%	±24.4%	90%
Percent On-Peak	76.8%	76.8%	**51.6%**[3]	67.3%	±17.5%	90%
Connected kW	3,877	3,877	3,702	**95.5%**[4]	±2.7%	90%
Connected kW Realiz. Rate	102.7%	102.7%	95.5%	93.0%	N/A	N/A
Hours-of-Use Reduction	1,284	2,568	2,040	**79.4%**[5]	±12.9%	90%
Summer Coin/Div kW	480	960	1,127	117.4%	±28.8%	90%
Summer Coin/Div Factor	12.1%	24.1%	**30.4%**[6]	126.3%	±28.7%	90%
Winter Coin/Div kW	500	999	711	71.2%	±30.3%	90%
Winter Coin/Div Factor	12.6%	25.1%	**19.2%**[7]	76.5%	±30.2%	90%

Table i - 4: D2/EI Program Analysis Results

Table i - 5 presents the savings factors of interest for the Design2000*plus* and Energy Initiative programs. The SCDF replaces the summer diversity factor in the current calculation for summer diversified peak kW reduction. This value was calculated to be 30.4% with a precision of +/-28.7% at 90% confidence. This is approximately 23% higher than the value for the summer diversity factor of 24.1% currently being employed. Likewise, the WCDF was calculated to be 19.2% with a precision of +/-30.2% at 90% confidence. This is approximately 25% less than the value for the winter diversity factor of 25.1% currently being used.

The connected kW realization rate was 95.5% with a precision of +/-2.7% at 90% confidence. This value is fairly close to the tracking value because the tracking estimate of connected kW is not cut in half using the 0.5 factor.

The hours of use reduction realization rate was calculated to be 79.4% with a precision of +/-12.9% at 90% confidence. The hours of use reduction was calculated as the kWh reduction divided by the tracking system connected kW. The tracking estimate of hours of use reduction is cut in half because the tracking kWh reduction includes the 0.5 factor. The revised tracking and on-site hours reduced was calculated without the 0.5 factor. As recommended, National Grid should eliminate the 0.5 factor and use the connected kW times the hours reduced to calculate kWh savings. If the 0.5 factor were

[3] The Percent On-peak was calculated as the On-peak kWh Savings divided by the Annual kWh Savings.
[4] The Connected kW Realization Rate was calculated as the Evaluated Connected kW divided by the Tracking Connected kW.
[5] The Hours-of-Use Reduction Realization Rate was calculated as the Evaluated Hours-of-Use Reduction divided by the Revised Tracking Hours-of-Use Reduction.
[6] The Summer Coin/Div Factor was calculated as the Summer Coin/Div kW divided by the Connected kW. The Connected kW is not corrected and does not include the Connected kW Realization Rate.
[7] The Winter Coin/Div Factor was calculated as the Winter Coin/Div kW divided by the Connected kW. The Connected kW is not corrected and does not include the Connected kW Realization Rate.

not dropped, the hours of use reduction realization rate would be 158.8%, or double the 79.4% presented below.

The percent energy savings on-peak was calculated to be 51.6% with a precision of +/- 17.5% at 90% confidence. This is 34% lower than the tracking estimate of 76.8% of savings on-peak. The reason for this value being so much lower is due to several of the sample sites where a majority of their savings occurred during the off-peak hours. For example, there were several warehouses in the sample where the baseline hours of use were close to 8,760 hours per year. The occupancy sensors installed showed these lights going off during the night and being on most of the day. Therefore, almost all of the savings occurred during the off-peak period. Nine of the 25 sites in the sample had less than 40% of the total kWh savings occur during the on-peak period.

Design 2000*plus* and Energy Initiative	**Savings Factor**	**Relative Precision**	**Confidence Level**
A. Summer Coincident Diversity Factor (SCDF)	30.4%	±28.7%	90%
B. Winter Coincident Diversity Factor (WCDF)	19.2%	±30.2%	90%
C. Connected kW Realization Rate	95.5%	±2.7%	90%
D. Hours-of-Use Reduction Realization Rate	79.4%	±12.9%	90%
E. Percent Energy Savings On-Peak	51.6%	±17.5%	90%

Table i - 5: D2/EI Savings Factors with Precision

Table i - 6 presents the results of the stratified ratio estimation (SRE) analysis conducted on the Small Business Services savings parameters. The table presents the tracking system total of annual energy savings for the total program and the final adjusted gross estimate of savings as well as on-peak kWh savings, percent on-peak savings, connected kW, hours of use reduction, summer coincident diversified kW, summer coincident diversity factor, winter coincident diversified kW and winter coincident diversity factor. In addition, this table shows the realization rate calculated as the total on-site value divided by the total tracking value along with the achieved relative precision associated with each result. All relative precisions are calculated at a confidence level of 90%.

Small Business Services	Tracking Estimates	Evaluation Results	Realization Rate	Relative Precision	Confidence Level
Annual kWh Savings	701,140	613,437	87.5%	±13.2%	90%
On-Peak kWh Savings	480,387	421,445	87.7%	±6.3%	90%
Percent On-Peak	68.5%	**68.7%**[3]	100.3%	±15.9%	90%
Connected kW	415	389	**93.6%**[4]	±6.3%	90%
Connected kW Realiz. Rate	98.2%	93.6%	95.4%	N/A	N/A
Hours-of-Use Reduction	1,688	1,577	**93.4%**[5]	±16.3%	90%
Summer Coin/Div kW	44	135	304.2%	±17.1%	90%
Summer Coin/Div Factor	10.9%	**34.8%**[6]	319.0%	±14.6%	90%
Winter Coin/Div kW	33	109	333.7%	±28.2%	90%
Winter Coin/Div Factor	8.0%	**28.0%**[7]	349.9%	±27.8%	90%

Table i - 6: SBS Program Analysis Results

Table i - 7 presents the savings factors of interest for the Small Business Services programs. The SCDF replaces the summer diversity factor in the current calculation for summer diversified peak kW reduction. This value was calculated to be 34.8% with a precision of +/-14.6% at 90% confidence. This is approximately 219% higher than the value for the summer diversity factor of 10.9% currently being employed. Likewise, the WCDF was calculated to be 28.0% with a precision of +/-27.8% at 90% confidence. This is approximately 250% higher than the value for the winter diversity factor of 8.0% currently being used. The calculated SCDF and WCDF factors are significantly higher than the tracking system factors, but are closer to the factors calculated in the D2/EI analysis. The current summer and winter factors of 10.9% and 8.0% are very low and are the result of a phone survey conducted in the early 1990's. These factors are multiplied by the non-coincident demand factor, or connected kW realization rate of 0.98, to calculate the tracking estimates for summer and winter diversified kW reduction.

The connected kW realization rate was 93.6% with a precision of +/-6.3% at 90% confidence. This value is fairly close to the tracking value because most of the sites visited in the on-site sample proved that the number of controlled fixtures was consistent with the tracking system.

The hours of use reduction realization rate was calculated to be 93.4% with a precision of +/-16.3% at 90% confidence. The hours of use reduction was calculated as the kWh reduction divided by the connected kW.

The percent energy savings on-peak was calculated to be 68.7% with a precision of +/-15.9% at 90% confidence. This is 0.3% higher than the tracking estimate of 68.5% of savings on-peak. The reason that this value is very close to the tracking value as opposed to the D2/EI sites is also because of the facility types visited in the on-site sample. Most of the SBS sites visited maintained more conventional hours of operation. For example, a small office building would only be occupied during normal business hours. The occupancy sensors could only then provide savings during these hours when the space is unoccupied. Since there was minimal off-peak use, there was little opportunity for off-peak savings.

Small Business Services	Savings Factor	Relative Precision	Confidence Level
A. Summer Coincident Diversity Factor (SCDF)	34.8%	±14.6%	90%
B. Winter Coincident Diversity Factor (WCDF)	28.0%	±27.8%	90%
C. Connected kW Realization Rate	93.6%	±6.3%	90%
D. Hours-of-Use Reduction Realization Rate	93.4%	±16.3%	90%
E. Percent Energy Savings On-Peak	68.7%	±15.9%	90%

Table i - 7: SBS Savings Factors with Precision

VI Recommendations

1. Eliminate the 0.5 gross savings factor and restructure all of the savings algorithms to include the factors provided in this evaluation. The Design 2000*plus* and Energy Initiative algorithms currently employ the 0.5 gross savings factor to calculate kW and kWh reduction. If National Grid decides not to use the savings factors provided in this evaluation, it is still recommended that the 0.5 factor be eliminated.

2. Collect more accurate information about lighting operating hours as well as hours of use reduction. There were several sites where the tracking estimate of hours of use reduction was greater than the baseline hours of use estimated in the on-site savings. This means that the tracking system estimated savings for controls based on more hours reduced than the actual operating hours of the facilities. The source of this discrepancy may be from confusion regarding the concept of reduced hours compared to operating hours. The account representative or vendor should be careful to clarify that the required parameter is hours of use reduction, not operating hours. It may be helpful to employ a worksheet that allows for the calculation of hours reduced. Table i - 8 is a simple table that may help aid this misconception.

Space Type	Current Operating Conditions of Lighting		Operating Conditions of Lighting After Controls	
	Days/Year	Hours/Day	Days/Year	Hours/Day

Table i - 8: Recommended Lighting Hours Data Collection Matrix

3. Do not install occupancy sensors in locations where the space is occupied for most of the facilities' operating hours. There were several sites in the on-site sample that had lower hours of use reductions because the spaces that had sensors installed are occupied the entire time the facility is operating. These sites operate year round with no significant seasonal changes. Spaces that are always occupied during normal facility operating hours are not good candidates for occupancy sensors because there is no opportunity for the lights to go off.

4. Verify the occupancy sensors that were installed and the type of lighting being controlled by the occupancy sensors at the time of the post-installation inspection. One site had no occupancy sensors installed. This resulted in zero savings. One other site in

the sample had a large discrepancy in connected kW because the controls were not installed on the quantity and type of fixture used in the tracking savings calculation. This resulted in the connected kW being approximately 25% of the tracking system value.

5. If the savings contributed by lighting controls grows relative to categories of savings, consider more frequent evaluation of these controls.