Impact Evaluation of 2010 Custom Lighting Installations

FINAL REPORT

Massachusetts Energy Efficiency Programs' Large Commercial & Industrial Evaluation

Prepared for: Massachusetts Energy Efficiency Program Administrators
Massachusetts Energy Efficiency Advisory Council

Middletown, Connecticut, May 29, 2012

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1. Executive Summary

This document summarizes the work performed by DNV KEMA Energy and Sustainability (DNV KEMA) and Energy and Resource Solutions (ERS) during 2011 and 2012 to quantify the actual energy and demand savings due to the installation of 43 Custom Lighting projects installed through the Massachusetts Energy Efficiency Program Administrator's (PAs) C&I New Construction & Major Renovation and C&I Large Retrofit programs in 2010.

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 for 45 Custom Lighting projects through site-specific inspection, monitoring, and analysis. The results of this study will be used to determine the final realization rates for Custom Lighting energy efficiency projects installed in 2011. This evaluation report presents realization rates for gross energy savings for all PAs individually. It also provides realization rates for on-peak summer and winter demand savings for all PAs except for Western Massachusetts Electric (WMECO). For WMECO, realization rates for summer and winter seasonal peak savings are provided. For National Grid, realization rates for percent on-peak energy savings are also provided. Realization rates for each of these parameters are also provided at the statewide level. 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 2010 Custom Lighting end-use, which includes all lighting systems and control strategies installed using a Custom or non-prescriptive approach. This impact evaluation includes only measures which primarily reduce electricity consumption

1.3 Sample Design

The Custom Lighting sample was designed to allow DNV KEMA to estimate realization rates for a number of savings parameters (annual kWh, percent of kWh savings on-peak, summer on-peak kW, and winter on-peak kW) with statistical precisions that meet PA requirements in two areas. The target for annual kWh was set at the traditional ±10% at 90% confidence, while the target for summer kW was set at ±10% precision at 80% confidence.

After running several scenarios based on different sample sizes and allocations, the team decided on a Custom sample comprised of 45 sites split between the PAs 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. While the PA-specific results were expected to achieve relative precisions in the range of ±13% to ±17%, the overall statewide values were anticipated to be better than ±11%.

Table 1: Custom Lighting Sample Design

Program Administrator	Accounts	Total Savings	Assumed Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
CLC	1	31,227	0.4	90%	1	±0.00%
National Grid	76	8,058,744	0.4	90%	13	±13.02%
NSTAR	424	30,374,908	0.4	90%	18	±15.66%
WMECO	73	7,998,529	0.4	90%	12	±16.84%
Total	574	46,463,408	0.4	90%	45	±10.86%

This allocation by PA was further stratified by total savings, and sample sites were selected. After the sample selection, several adjustments were required based on observations made during initial file reviews and early site visits. In some cases, alternate sites were used, but in other cases there were no additional sites to select. In the end, a total of 43 sites were included in the Custom Lighting sample. With the addition of two National Grid Advanced Lighting Design (ALD) sites into their PA specific analysis, the total increased to 45 sites.

1.4 Description of Methodology

Following the final sample selection of 2010 Custom Lighting applications and prior to beginning any site visits, DNV KEMA and ERS developed detailed measurement and evaluation plans for each of the 43 applications. The plans outlined on-site methods, strategies, monitoring equipment placement, calibration and analysis issues. The PAs provided comments and edits to clarify and improve the plans prior to them being finalized.

The site evaluation plan played an important role in establishing approved field methods and ensuring that the ultimate objectives of the study 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, summer on-peak and seasonal demand, and winter on-peak and seasonal demand savings associated with each project.

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 Custom Lighting measure. 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 Custom Lighting sites. A typical meteorological year (TMY3) dataset of ambient temperatures for Worcester, MA was used for all savings analyses.

Engineers submitted draft site reports to the PAs upon completion of each site evaluation, which after review and comment resulted in the final reports found in Appendix C: Site Reports. This executive summary provides a concise overview of the evaluation methods and findings.

1.5 Results

The results presented in the following section include realization rates (and associated precision levels) for annual MWh savings, on-peak MWh savings, and on-peak and seasonal demand (kW) savings 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.
- Seasonal Peak: Non-holiday week days when the Real-Time System Hourly Load is equal to or greater than 90% of the most recent “50/50” System Peak Load Forecast for the summer and winter seasons.[1]

[1] A description of the methodology used by DNV KEMA to determine the seasonal peak demand hours is presented in Appendix B: Seasonal Peak Period Coincidence.

Relative precision levels and error bounds are calculated at the 80% confidence level for demand values, since that is the requirement for participation in the FCM. For all MWh realization rates, the standard 90% confidence level is used.

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

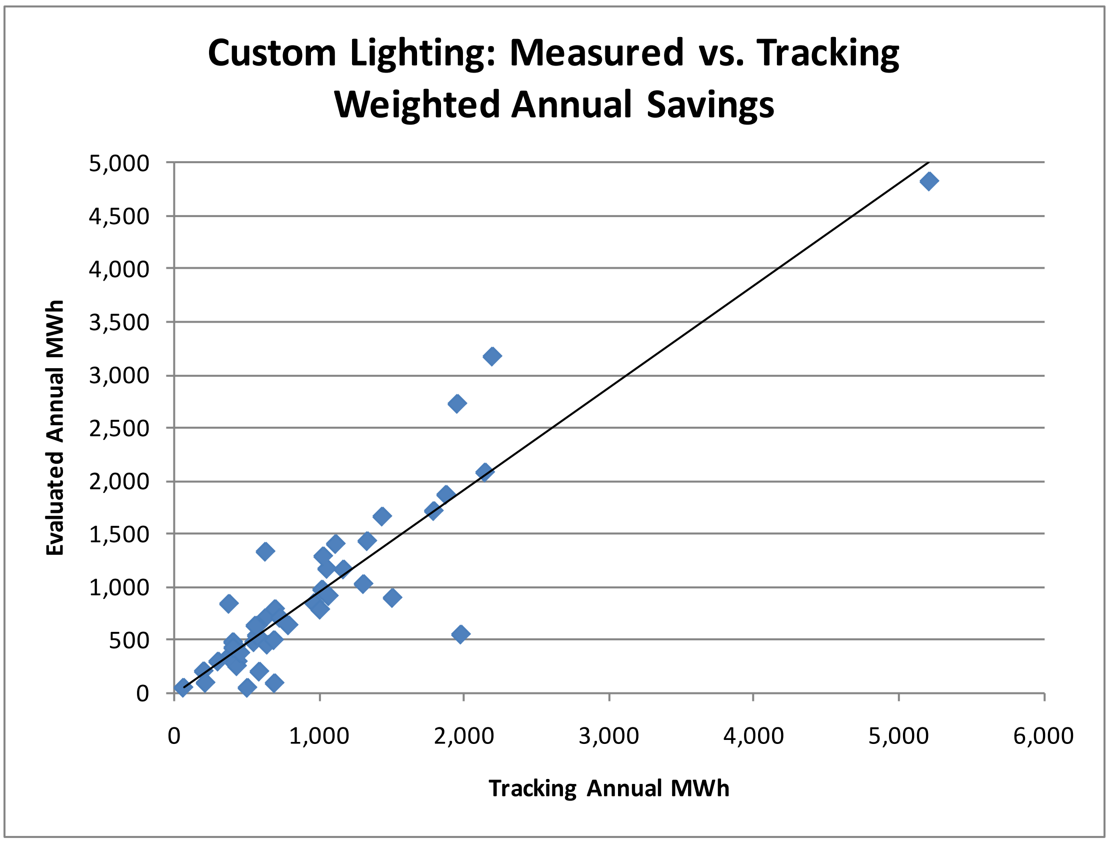

Figure 1: Scatter Plot of Evaluation Results for Annual MWh Savings

The site-level evaluation results were aggregated using stratified ratio estimation. The PA realization rates are calculated, and then applied to each PA's total tracking savings to determine their total measured savings. The statewide realization rate is the ratio of the total measured savings to the total tracking savings, each of which is calculated by summing across the PAs.

DNV KEMA aggregated the PA results to determine statewide realization rates, for use by the smaller PAs as needed. Table 2 summarizes the statewide results of this analysis. In the case of annual MWh savings, the realization rate for Custom Lighting measures was found to be 98.3%. The relative precision for this estimate was found to be ±9.3% at the 90% level of confidence. The error ratio was found to be 0.30. Table 2 also shows the results for the on-peak and seasonal summer and winter coincident demand savings, measured in KW. Since the design criteria for the demand realization rates were based on an 80% confidence level, the precisions and error bounds at this level are reported in the appropriate rows in Table 2 and Table 3. For the on-peak summer kW, the overall realization rate was 93.6%, with a relative precision of ±7.3% at an 80% confidence level. For on-peak winter kW, the realization rate was a bit lower, at 91.7%, with a relative precision of ±10.2%. For the seasonal summer kW, the overall realization rate was 92.1%, with a relative precision of ±7.6%. For on-peak winter kW, the realization rate was 87.5%, with a relative precision of ±10.2%.

The grey cells in Table 2 and Table 3 represent the energy savings presented at 80% confidence, and demand savings at 90% confidence. These cells are grey because the precision at these confidence levels were not required, but included for information purposes only.

Table 2: Summary of Custom Lighting Results

Statistic	Annual MWh	On-Peak Summer kW	On-Peak Winter kW	Summer Season Peak kW	Winter Season Peak kW
Total Tracking Savings	46,463	7,659	8,061	7,659	8,061
Total Measured Savings	45,696	7,166	7,392	7,056	7,056
Realization Rate	98.3%	93.6%	91.7%	92.1%	87.5%
Relative Precision at 90% Confidence	9.3%	9.3%	13.1%	9.7%	13.1%
Error Bound at 90% Confidence	4,259	669	966	685	923
Relative Precision at 80% Confidence	7.3%	7.3%	10.2%	7.6%	10.2%
Error Bound at 80% Confidence	3,319	521	752	534	719
Error Ratio	0.30	0.38	0.58	0.40	0.58

Table 3 summarizes the PA-specific results of this analysis. In the case of annual MWh savings, the realization rate for Custom Lighting measures ranged from 79.5% for CLC (based on one site) to 101.8% for NSTAR. The relative precision for these estimates was found to range from 5.9% to 13.5% at the 90% level of confidence. The error ratio was found to range from 0.16 to 0.34.

Table 3 also shows the results for the on-peak summer and winter coincident demand savings, measured in KW. Since the design criteria for the demand realization rates were based on an 80% confidence level, the precisions and error bounds at this level are reported in the appropriate rows in Table 3. These cells are grey because the precision at these confidence levels were not required, but included for information purposes only. Note that the table only shows annual MWh savings for CLC. This was because population tracking data were not available for the other savings parameters at the time of this report.

Table 3: Summary of Custom Lighting Results by Program Administrator

Statistic	Annual MWh	% On-Peak MWh	On-Peak MWh	On-Peak Summer kW	On-Peak Winter kW	Summer Season Peak kW	Winter Season Peak kW
Cape Light Compact							
Total Tracking Savings	31	-	-	-	-	-	-
Total Measured Savings	25	-	-	-	-	-	-
Realization Rate	79.5%	-	-	-	-	-	-
Relative Precision at 90% Confidence	0.0%	-	-	-	-	-	-
Error Bound at 90% Confidence	-	-	-	-	-	-	-
Relative Precision at 80% Confidence	0.0%	-	-	-	-	-	-
Error Bound at 80% Confidence	-	-	-	-	-	-	-
Error Ratio	0.00	-	-	-	-	-	-
National Grid							
Total Tracking Savings	9,109	44.3%	4,036	1,886	2,250	1,886	2,250
Total Measured Savings	8,922	47.9%	4,273	2,185	1,913	2,159	1,926
Realization Rate	97.9%	108.1%	105.9%	115.9%	85.0%	114.5%	85.6%
Relative Precision at 90% Confidence	5.9%	-	13.9%	9.5%	11.7%	10.0%	12.1%
Error Bound at 90% Confidence	529	-	595	207	225	216	232
Relative Precision at 80% Confidence	4.6%	-	10.9%	7.4%	9.2%	7.8%	9.4%
Error Bound at 80% Confidence	412	-	464	207	225	216	232
Error Ratio	0.16	-	0.33	0.25	0.33	0.26	0.34
NSTAR							
Total Tracking Savings	30,375	-	-	4,628	5,127	4,628	5,127
Total Measured Savings	30,915	-	-	3,938	4,280	3,815	3,950
Realization Rate	101.8%	-	-	85.1%	83.5%	82.4%	77.0%
Relative Precision at 90% Confidence	13.5%	-	-	14.9%	16.2%	15.3%	15.8%
Error Bound at 90% Confidence	4,182	-	-	586	694	582	622
Relative Precision at 80% Confidence	10.5%	-	-	11.6%	12.6%	11.9%	12.3%
Error Bound at 80% Confidence	3,259	-	-	457	541	454	485
Error Ratio	0.34	-	-	0.42	0.46	0.43	0.44
WMECO							
Total Tracking Savings	7,999	-	-	1,409	967	1,409	967
Total Measured Savings	7,139	-	-	1,351	1,385	1,364	1,346
Realization Rate	89.3%	-	-	95.9%	143.2%	96.8%	139.2%
Relative Precision at 90% Confidence	8.7%	-	-	19.4%	45.7%	21.7%	47.6%
Error Bound at 90% Confidence	619	-	-	262	633	296	640
Relative Precision at 80% Confidence	6.8%	-	-	15.1%	35.6%	16.9%	37.1%
Error Bound at 80% Confidence	482	-	-	204	493	231	499
Error Ratio	0.24	-	-	0.48	1.21	0.53	1.25

1.6 Conclusions and Recommendations

Overall, the Custom Lighting projects appears to be successfully providing energy and demand savings in the State of Massachusetts. Below are the DNV KEMA evaluation team findings and recommendations that apply statewide, as well as to the individual PAs. A discussion of each finding and recommendation is provided in the body of this report.

1.6.1 Statewide

- Consider a systematic approach for estimating HVAC interactive effects
- Ensure that the final savings documents are stored for future evaluations
- Look for increased savings opportunities from controls

1.6.2 Cape Light Compact

- Verify installed counts/technologies and savings assumptions

1.6.3 National Grid

- Review tracking estimates of peak demand savings more carefully
- Require more robust documentation

1.6.4 NSTAR

- Review tracking estimates of peak demand savings more carefully
- Ensure that the final savings documents are stored for future evaluations

1.6.5 Western Massachusetts Electric Company

- Review the methodology for including HVAC interactive effects in tracking savings estimates
- Consider the current energy code for lighting controls for new construction and major renovation projects
- Ensure that the final savings documents are stored for future evaluations

2. Introduction

This document summarizes the work performed by DNV KEMA Energy and Sustainability (DNV KEMA) and Energy and Resource Solutions (ERS) during 2011 and 2012 to quantify the actual energy and demand savings due to the installation of 45 Custom Lighting measures installed through the Massachusetts Energy Efficiency Program Administrator's (PAs) C&I New Construction & Major Renovation and C&I Large Retrofit programs in 2010.

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 for 45 Custom Lighting projects through site-specific inspection, monitoring, and analysis. Each of the PAs offers lighting incentives under their custom track for both their C&I New Construction and Major Renovation programs and C&I Large Retrofit programs. Gross energy and demand savings are typically developed based on detailed engineering analyses for all custom lighting projects. Annual operating hours of use are typically based on site specific information.

The results of this study will be used to determine the final realization rates for Custom Lighting energy efficiency projects installed in 2011. This evaluation report presents realization rates for gross energy savings for all PAs. It also provides realization rates for on-peak summer and winter demand savings for all PAs except for Western Massachusetts Electric (WMECO). For WMECO, realization rates for summer and winter seasonal peak savings are provided. For National Grid, realization rates for percent on-peak energy savings are also provided. Realization rates for each of these parameters are also provided at the statewide level. 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).

This impact study consists of the following four tasks:

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

2.2 Scope

The scope of work of this impact evaluation covered the 2010 Custom Lighting end-use, which includes all lighting systems and control strategies. This impact evaluation includes only measures which primarily reduce electricity consumption.

3. Description of Sampling Strategy

The primary focus of the sample design was to examine various precision scenarios for the Prescriptive and Custom Lighting programs in Massachusetts (MA). This report includes discussion of the Custom Lighting design and analysis; the Prescriptive Lighting study results will follow in a separate report. The goal of the design effort was to estimate sample sizes required to support the estimation of realization rates for a number of different parameters, including annual kWh savings, summer and winter demand reductions, and other factors that impact the calculation of net savings for various Custom lighting measures. Several dimensions and structures were considered for the design to allow for reliable estimates statewide, by PA, by deliverytrack (custom and prescriptive), and by category of lighting measure installed.

3.1 Population Analysis

The initial task was to define the population frame for the evaluation sample. The data provided by the PAs varied in terms of the level of aggregation and details provided for each transaction. For some, the records in their tracking system corresponded to single projects at single sites, while for others, there were many records per site, reflecting various technologies and locations within buildings. The projects were classified into Custom and Prescriptive, with adjustments made in order to maintain consistency across PAs. One measure that was adjusted was LED case lights; these were all removed from the Custom study, since they are in the MA TRM, and will be calculated as prescriptive by all PAs in the future.

A second adjustment was required because National Grid indicated that they will continue to offer their performance lighting, or Advanced Lighting Design (ALD), projects under their custom program, and will compute custom summer and winter kW reduction values. This is different than the other PAs, who calculate savings for ALD projects using prescriptive summer and winter coincidence factors. As a result, the National Grid sampled ALD projects will go into the computation of National Grid's PA-specific Custom Lighting results, but will be excluded from the statewide results.

After review and consolidation, the resulting population of 2010 C&I Custom Lighting projects reported by PA is summarized in Table 4.

Table 4: Population Statistics

Program Administrator	Measure Group	Projects	Total Savings	Average Savings	Minimum	Maximum	StdDev	CV
CLC	Custom	1	31,227	31,227	31,227	31,227	0	0.00
National Grid	Custom	76	8,058,744	106,036	3,174	2,418,500	287,911	2.72
National Grid	Custom (ALD Projects)	8	1,050,480	131,310	10,159	335,301	107,610	0.82
NSTAR	Custom	424	30,374,908	118,190	117	3,317,127	296,923	2.51
WMECO	Custom	73	7,998,529	109,569	514	1,166,354	184,651	1.69
Total (Excludes NGRID ALD Projects)		**574**	**46,463,408**					

3.2 Sample Design

The Custom Lighting sample was designed to allow DNV KEMA to estimate realization rates for a number of savings parameters (annual kWh, percent of kWh savings on-peak, summer on-peak kW, and winter on-peak kW) with statistical precisions that meet PA requirements in two areas. While the primary variable of interest for the sample design was annual kWh savings, the PAs also were interested in coincident peak summer kW because it is used in the ISO-NE Forward Capacity Market (FCM). The target for annual kWh was set at the traditional ±10% at 90% confidence, while the target for summer kW was set at ±10% precision at 80% confidence during the design. The summer kW target is based on the ISO-NE precision requirements, but need not be achieved in each individual study because the FCM precision may be calculated for each PA's overall portfolio of demand resources. All of the results for annual kWh savings were calculated at the 90% confidence level, while results for summer kW were calculated at the 80% confidence level.

After running several scenarios based on different sample sizes and allocations between Custom and Prescriptive measures, the team decided on a Custom sample comprised of 45 sites split between the PAs as indicated in Table 5. This table also includes estimates of the precisions that were anticipated at the time of this design, assuming an error ratio of 0.4. While the PA-specific results were expected to achieve relative precisions in the range of ±13% to ±17%, the overall statewide values were anticipated to be better than ±11%.

Table 5: Custom Lighting Sample Design

Program Administrator	Accounts	Total Savings	Assumed Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
CLC	1	31,227	0.4	90%	1	±0.00%
National Grid (excluding ALD)	76	8,058,744	0.4	90%	13	±13.02%
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Total	574	46,463,408	0.4	90%	45	±10.86%

This allocation by PA was further stratified by total savings, and sample sites were selected. After the sample selection, several adjustments were required based on observations made during initial file reviews and early site visits. These changes are described in the following section. In some cases, alternate sites were used, but in other cases there were no additional sites to select. In the end, a total of 43 sites were included in the Custom Lighting sample. When the two National Grid ALD sites were added into their PA specific analysis, the total increased to 45 sites. The realization rate results for the final sample are presented in Section 5: Results.

3.3 Final Sample

Table 6 presents the list of 45 projects selected as the final sample for Custom Lighting, including National Grid's ALD sites. Also presented in this table are the site assignments by evaluating company on the DNV KEMA Team. DNV KEMA evaluated 11 of the 45 projects and ERS evaluated 34 of the 45 projects. The final sample required the selection of three back-up sample points. NGRID site 620114 replaced 540519 due to customer refusal from the primary selection. NSTAR site BS9336 replaced BS8903 due to customer refusal from the primary selection. WMECO site WM10L501 replaced WM09R304 because project documentation could not be provided for the primary selection. In addition, two sample sites were dropped from the final design. The first dropped site was a CLC site, which was confirmed by CLC to have been a prescriptive project, not custom. There was no CLC back-up sample point in this case. The second dropped site was an NGRID site, which was unable to be evaluated because the DNV KEMA team was not given access to the site or facility staff.

Table 6: Final Sample Selection

KEMA Site Number	Program Administrator	Stratum	Site ID	Evaluator	Project Description
1	CLC	1	D021784401	ERS	Retrofit, Retail, LED Track Lights
3	National Grid	1	649363	ERS	Retrofit, Municipal, Exterior LED and Induction Lighting
4	National Grid	1	566565	ERS	Retrofit, Retail, LED Track Lights
5	National Grid	1	632603	ERS	Retrofit, Retail, LED Track Lights
6	National Grid	2	660038	ERS	Retrofit, Warehouse, LED Lighting and Controls
106	National Grid	2	620114	ERS	Retrofit, Retail, LED Track Lights
8	National Grid	2	649352	ERS	Retrofit, Municipal, Induction Lighting
9	National Grid	3	577832	ERS	Retrofit, Office, Dimmable T8 Lighting
10	National Grid	3	660095	ERS	Retrofit, Manufacturing, LED and T8 Lighting and Controls
11	National Grid	3	704757	ERS	Retrofit, Municipal, Exterior Lighting
12	National Grid	4	588063	ERS	Retrofit, Office, T8 Lighting and Controls
13	National Grid	4	559032	ERS	Retrofit, Municipal, Traffic Lighting
14	National Grid	4	577835	ERS	Retrofit, Manufacturing, Induction Lighting
74	National Grid - ALD	1	550483	DNV KEMA	New Construction, Healthcare, T8 and CFL Lighting
76	National Grid - ALD	2	528704	DNV KEMA	New Construction, School, T8, T5 and CFL Lighting
16	NSTAR	1	CS8176B	ERS	New Construction, School, High Performance T8
17	NSTAR	1	CS8176P	ERS	New Construction, School, High Performance T8
18	NSTAR	1	BS9237	ERS	Retrofit, Library, T8 and CFL Lighting
19	NSTAR	1	BS8558	DNV KEMA	Retrofit, Retail, LED Refrigerated Cases
20	NSTAR	1	BS9455M	ERS	Retrofit, School, Lighting Controls
21	NSTAR	2	CS8176H	ERS	New Construction, School, High Performance T8
22	NSTAR	2	BS9455L	ERS	Retrofit, School, Lighting Controls
23	NSTAR	2	BS8633	ERS	Retrofit, Retail, LED Track Lights
24	NSTAR	2	BS7776	ERS	Retrofit, University, LED Lighting
25	NSTAR	2	CS8176C	ERS	New Construction, School, High Performance T8
26	NSTAR	3	BS9292	ERS	Retrofit, Parking Structure, CFL Lighting
27	NSTAR	3	BS9301	ERS	Retrofit, University, High Performance T8
28	NSTAR	3	BS9446	ERS	Retrofit, Parking Structure, T8 Lighting and Controls
29	NSTAR	3	BS8106	ERS	Retrofit, Healthcare, T8 and CFL Lighting
30	NSTAR	4	BS8813	ERS	Retrofit, School, T8 and CFL Lighting
31	NSTAR	4	BS8463	ERS	Retrofit, Transportation Facility, T8 Lighting and Controls
109	NSTAR	4	BS9336	DNV KEMA	Retrofit, Laboratory, Lighting Controls
33	NSTAR	4	BS8288	DNV KEMA	Retrofit, Municipal, T8, Induction Lighting and Controls
34	WMECO	1	WM10L127	ERS	Retrofit, School, T8 Lighting
35	WMECO	1	WM10L134	ERS	Retrofit, Office, T8 Lighting
36	WMECO	1	WM10L304	DNV KEMA	New Construction, Office, MH, CFL and LED Lighting
113	WMECO	2	WM10L501	ERS	New Construction, Office, T5 Lighting

KEMA Site Number	Program Administrator	Stratum	Site ID	Evaluator	Project Description
38	WMECO	2	WM09R816	ERS	Retrofit, Warehouse, Lighting Controls
39	WMECO	2	WM10R262	DNV KEMA	Retrofit, Manufacturing, T5 Lighting
40	WMECO	3	WM10L137	DNV KEMA	Retrofit, Manufacturing, T8 and T5 Lighting
41	WMECO	3	WM10C211	ERS	New Construction, University, T8, CFL and LED Lighting
42	WMECO	3	WM10L163	DNV KEMA	Retrofit, Retail, High Performance T8
43	WMECO	4	WM09R827	DNV KEMA	Retrofit, Manufacturing, T8, T5 Lighting and Controls
44	WMECO	4	WM10L146	ERS	Retrofit, Manufacturing, T8 Lighting
45	WMECO	5	WM10L136	DNV KEMA	Retrofit, Manufacturing, T8, T5 Lighting and Controls

This evaluation of custom lighting installations saw a wide variety of lighting technologies installed across the sampled projects. The most frequent lighting installation included T8 lamps with low power electronic ballasts. New high performance, four foot, T8 lamps of 25 and 28 watts were found in abundance. There was also a significant amount of 32 watt, four foot T8 lamps paired with low power electronic ballasts. LED lighting was the technology that saw increased use as compared to previous custom lighting impact evaluations. LED spot lights were installed in several retail spaces, and also as exterior surface mounted fixtures. Street lights, both traffic and pedestrian types were also popular with LEDs in this round of evaluation. High output T5 fixtures were also found in several spaces including industrial and large commercial buildings.

Nine of the 45 evaluated projects were classified as new construction or major renovation. These are identified as “New Construction” in the table above. The remaining projects were considered retrofits.

4. Description of Methodology

4.1 Measurement and Evaluation Plans

Following the final sample selection of 2010 Custom Lighting applications and prior to beginning any site visits, DNV KEMA and ERS developed detailed measurement and evaluation plans for each of the 45 applications. The plans outlined on-site methods, strategies, monitoring equipment placement, calibration and analysis issues. The PAs provided comments and edits to clarify and improve the plans prior to them being finalized.

The site evaluation plan played an important role in establishing approved field methods and ensuring that the ultimate objectives of the study 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, summer on-peak and seasonal demand, and winter on-peak and seasonal demand savings associated with each project.

Following the establishment of a site evaluation plan, DNV KEMA and ERS field technicians contacted each customer in the sample to schedule a site visit. The objective of the site visit was to perform a comprehensive assessment of all operational characteristics of the lighting measure(s) installed at the site.

4.2 Data Gathering, Analysis, and Reporting

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 Custom Lighting measure. 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.

4.2.1 Data Collection

DNV KEMA and ERS field technicians are trained in the process of selecting monitoring points within each sampled project to maximize the accuracy and reliability of the resultant data collection. Monitoring objectives are multifaceted but generally pursue prioritizing hours of use uncertainty over dominant space types. For example, the connected lighting load of a school may be evenly distributed between hallway and classroom space, but the operating schedules of classroom lighting often are considerably less certain. In this situation, a technician might deploy two loggers in corridors and six loggers in classrooms to monitor hours of use.

DNV KEMA planned to install an average of 15 lighting loggers per site. The target served only as a guideline based on previous experience conducting similar Custom Lighting impact evaluations; final monitoring decisions were made by field staff in consideration of specific site conditions and other practical issues.

4.2.2 Data Analysis

The DNV KEMA team processed all logger data as hourly "percent on" time. For all TOU lighting loggers deployed during the study, DNV KEMA used advanced routines from programming software to develop a full year of hourly impacts based upon verbally-reported and monitored operating profiles. In their most basic form, these routines computed average 24 hour profiles for eight day types – one for each day of the week plus another to represent a holiday schedule – and concatenated these profiles throughout a year to compile an 8,760 profile of savings impacts. If the monitoring period did not span at least one customer-specific holiday, the routine used an "off day" profile, usually a Sunday. Overall, this approach is reasonable for lighting measures at C&I facilities possessing operating schedules that vary little throughout the year.

However, some businesses have seasonal variations which require careful consideration to annualize the observed lighting usage patterns. The final sample included several schools, and the DNV KEMA team incorporated verbal descriptions of seasonality to annualize monitored data in consideration of seasonal influences. Analysts adjusted the operating profiles by month for several records in the evaluation sample with unique seasonal schedules, including schools and exterior lighting projects.

In this manner, KEMA developed 8,760 hour profiles of hourly operation across an entire year for each logger. The analytical routines employed to create this profile considered influences by hour-of-day, day-of-week, month-of-year, and local holidays. A key benefit of computing 8,760 hourly profiles is that it facilitates recalculation of coincidence factors should the peak period definition change.

4.2.3 Lighting Controls

In several of the evaluated sample lighting projects, lighting controls were also a component of the project. 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 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 employed several different methodologies depending on the site and usage of the space, and applied them according to information gathered on-site.

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 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 a handful of instances, evaluators were 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 shape.

There were some lighting projects that included daylight, or adjustable dimming controls. In most cases, these controls were monitored by the installation of power meters or current loggers. Each meter type records the average lighting usage, either kW or amperage, in 15 minute intervals. Evaluators utilized the meter data to establish full load equivalent operating hours for the installed lighting condition by dividing the metered usage by the full load usage at each interval. Using these partial loads, an average hourly profile was established in the same manner as was done with the TOU lighting logger data. Baseline operating profiles were developed as the full load of the controlled lighting during each monitored interval where usage was recorded.

4.2.4 Savings Analysis

Gross energy savings were calculated at each hour by multiplying the connected kW reduction of the lighting measure by the percentage of each hour the lighting was on in the 8,760 hour operating profile. To do this, each space in the lighting analysis spreadsheet was assigned an operating schedule based on observations of the site, and discussions with facility personnel. In some cases where multiple lighting loggers were installed in similar space types, an average operating schedule for that space type was developed. For example, in an office building, field staff may have installed several lighting loggers in private offices. Each of the operating profiles from all of these lighting loggers would be weighted by connected wattage, if necessary, and averaged. This average operating schedule would then be applied to all private offices in the project. In the case of lighting controls, the same method would be applied, except that the estimated baseline and installed operating profiles would be assigned to each space. The difference between these two operating profiles at each hour is multiplied by the connected kW of the controlled fixtures to estimate gross energy savings for lighting controls.

Each site analysis culminated in the development of savings adjustment factors, which help to explain where the savings discrepancies occurred at each site. The documentation adjustment factor reflects any change in savings due to discrepancies in project documentation (e.g. mathematical error, transposition of digits, or other unexplained discrepancy). The technology adjustment factor reflects a change in savings due to the identification of a different lighting technology (e.g. fixture type and wattage) found at the site than represented in the tracking system estimate of savings. The quantity adjustment factor reflects any change in savings due to the identification of a different number of lighting fixtures at the site than represented in the tracking system. For each sample site, evaluators developed estimates of gross connected kW reduction based upon documentation review, reassessment of savings calculations, on-site observations, and other relevant findings. Any adjustments were separated into documentation, technology, and/or quantity adjustments according to the definitions described above. Such assessments were made within each site analysis on a line-by-line basis. Adjustments were not mutually exclusive, i.e. the findings for a particular line item (e.g. space) may warrant expression as partial adjustments to all three factors.

4.2.5 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 expressed 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 yielded 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	1.4

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

Only sites at which heating or cooling systems were in use had interactive effects calculated. Leveraging the 8,760 profile of hourly demand impacts, the DNV KEMA team computed electric interactive effects during the hours that lighting and HVAC were assumed to operate in unison.

DNV KEMA utilized Typical Meteorological Year 3 (TMY3) hourly dry-bulb temperatures for Worcester, Massachusetts as the balance point criteria in this analysis. For each hour in a typical year, DNV KEMA computed 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. 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.

4.2.6 Verification of Baseline

This impact evaluation of Custom Lighting installations included a mix of new construction or major renovation measures, as well as retrofit measures. For retrofit measures, evaluators utilized the existing equipment, as defined in the project files as the baseline lighting system. Evaluators attempted to verify the existing lighting conditions through conversations with facility staff, but unless there was any evidence to change the baseline assumptions, the existing system was retained for the evaluation. The question of whether an existing lighting system is at or near the end of its useful life is difficult to determine for lighting retrofits due to the nature of the systems being evaluated. An existing lighting system can be made up of hundreds or thousands of different parts, which are all currently available to purchase should something fail. For other types of major equipment, such as a chiller or motor, it's more straightforward to determine when current code should be applied to the baseline. However, with lighting retrofits, the determination is not as clear, which is why the existing system is considered appropriate for evaluation.

New construction or major renovation projects were also examined to verify that the correct baselines were being applied. For these situations, the MA building code current at the time of the project application was referred to by evaluating engineers. Evaluators verified that the proper baseline lighting densities (watts per square foot) were used in new construction projects. However, the evaluation also found that savings were sometimes being claimed for lighting controls, where the code at the time stated that lighting controls were required. Savings were not assigned for lighting controls in these situations.

Evaluators also verified that the PAs were classifying projects as new construction or retrofit accurately. For retrofit projects, evaluators observed the space, and visually inspected the areas to confirm the retrofit. In most cases, the existing fixture housing remained in place with only the lamps and ballasts being switched out.

4.2.7 Site Reports

Engineers submitted draft site reports to the PAs upon completion of each site evaluation, which after review and comment resulted in the final reports found in Appendix C: Site Reports.

4.3 Statistical Analysis Procedures

In order to aggregate the individual site results from the Custom Lighting sample, DNV KEMA applied the model-assisted stratified ratio estimation methodology described in References [1] and [2] in Appendix A: References. The key parameter of interest is the population realization rate, i.e., the ratio of the evaluated savings for all population projects divided by the tracking estimates of savings for all population projects. This rate is estimated for the overall Massachusetts program, as well as for individual PAs. Of course, the population realization rate is unknown, but it can be estimated by evaluating the savings in a sample of projects. The sample realization rate is the ratio between the weighted sum of the evaluated savings for the sample projects divided by the weighted sum of the tracking estimates of savings for the same projects. The total tracking savings in the population is multiplied by the sample realization rate to estimate the total evaluated savings in the population. The statistical precisions and error ratios are calculated for each level of aggregation.

The results presented in the following section include realization rates (and associated precision levels) for annual MWh savings, on-peak MWh savings, and on-peak and seasonal demand (kW) savings 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.

- Seasonal Peak: Non-holiday week days when the Real-Time System Hourly Load is equal to or greater than 90% of the most recent "50/50" System Peak Load Forecast for the summer and winter seasons.[2]

Relative precision levels and error bounds are calculated at the 80% confidence level for demand values, since that is the requirement for participation in the FCM. For all MWh realization rates, the standard 90% confidence level is used.

5. Results

In preparation for analyzing the evaluation results collected for the Custom Lighting sample points, the original 2010 population stratum boundaries were used to calculate case weights for the each sample observation. These weights reflect the number of projects that each sample point represents in their respective populations, and allow for the aggregation of results across strata and PAs. The final case weights for the study, which reflect sample substitutions, are shown in the last column in Table 8. Note that the National Grid stratum 5 site was one of the sites that was dropped, which is why there are no sampled sites in this stratum.

In the table below, the National Grid ALD sites are listed separately from the other National Grid sites because the ALD sample was drawn for the Prescriptive Lighting impact evaluation, which will have its own report. As mentioned previously, National Grid continues to offer ALD projects in their Custom track, while the other PAs are currently using the Prescriptive ALD method.

[2] A description of the methodology used by DNV KEMA to determine the seasonal peak demand hours is presented in Appendix B: Seasonal Peak Period Coincidence.

Table 8: Custom Lighting Case Weights

Program Administrator	Stratum	Total Applications	Total Annual MWh	Applications in Sample	Case Weight
CLC	1	1	31	1	1.00
National Grid	1	48	982	3	16.00
National Grid	2	15	1,190	3	5.00
National Grid	3	7	1,487	3	2.33
National Grid	4	5	1,981	3	1.67
National Grid	5	1	2,419	0	0.00
National Grid - ALD	1	5	295	1	5.00
National Grid - ALD	2	3	755	1	3.00
NSTAR	1	300	4,951	5	60.00
NSTAR	2	74	6,626	5	14.80
NSTAR	3	38	7,847	4	9.50
NSTAR	4	12	10,951	4	3.00
WMECO	1	46	1,200	3	15.33
WMECO	2	13	1,522	3	4.33
WMECO	3	8	1,595	3	2.67
WMECO	4	5	2,515	2	2.50
WMECO	5	1	1,166	1	1.00

5.1 Major Findings and Observable Trends

Figure 2 presents a scatter plot of evaluation results for annual energy savings using all PA sample points. The slope of the solid line in this graph is an indication of the overall realization rate, and can be seen to be close to one. These sample data are arranged closely around the trend line, which supports the estimate made during the design process that the error ratio would be relatively low.

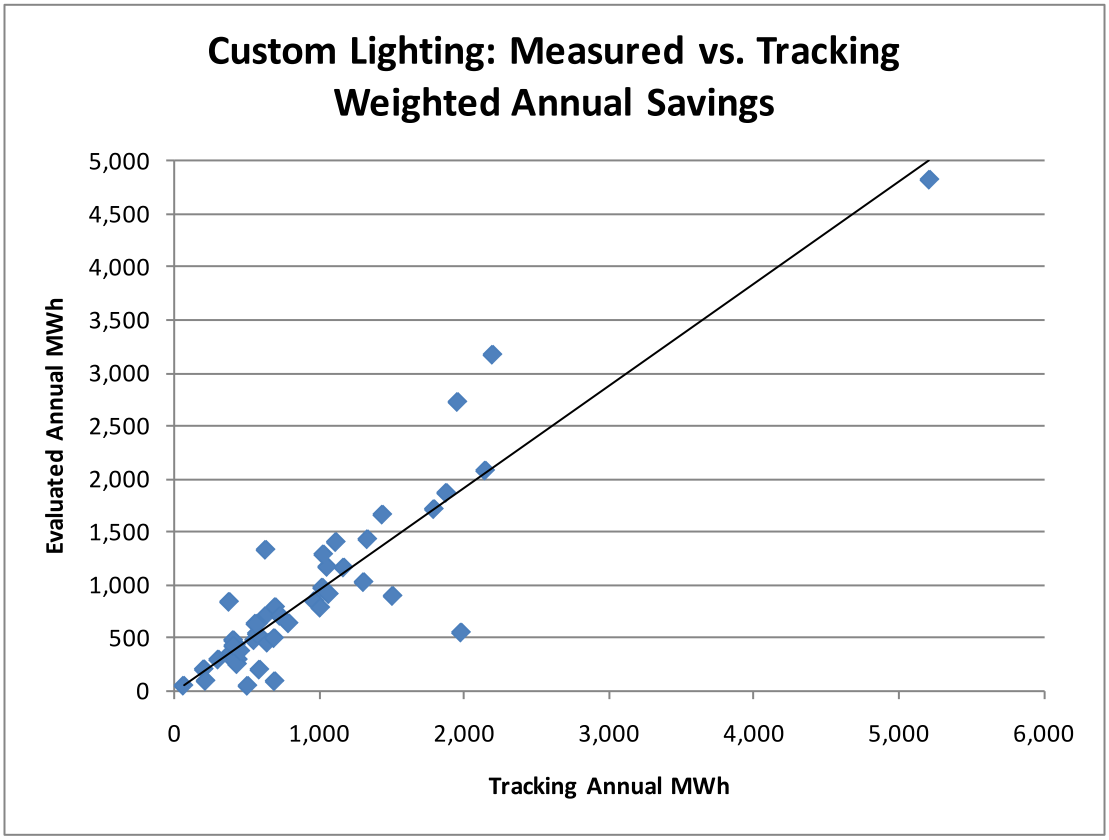

Figure 2: Scatter Plot of Evaluation Results for Annual MWh Savings

5.2 Presentation of Results

Table 9 presents a summary of the site level results for this impact evaluation. Table 10 summarizes the savings realization rates and primary reasons for discrepancies between the tracking and evaluation estimates of annual energy savings. The site energy savings realization rates ranged from a low of 10% for Site 113 to a high of 223% for Site 16. Note that some of the ratios are "N/A" for the on-peak % and peak demand reductions because the tracking estimates were zero for some of these values.

One observation to note is that winter demand savings overall are the same or even higher than summer demand savings. Though lighting savings might be expected to save more during daytime hours, which is when the summer peak occurs, rather than evening hours, the make-up of these custom lighting projects lend themselves to greater savings than in previous studies. Evaluators believe that this is due to several exterior lighting applications found in this study, and also more sophisticated controls being implemented to reduce lighting at all hours of the day.

Table 9: Detailed Site Results

Custom Lighting				Tracking				Evaluated					
KEMA Site Number	Program Administrator	Stratum	Site ID	Annual kWh	Summer kW	Winter kW	% On-peak kWh	Annual kWh	Summer On-Peak kW	Winter On-Peak kW	% On-peak kWh	Summer Seasonal kW	Winter Seasonal kW
1	CLC	1	D021784401	31,227	0.0	0.0	N/A	24,811	4.4	3.4	60%	4.3	3.4
3	NGRID	1	649363	18,856	0.0	4.3	18%	18,519	0.0	3.3	25%	0.0	3.7
4	NGRID	1	566565	27,335	4.3	4.3	65%	18,394	3.7	2.9	67%	3.7	2.9
5	NGRID	1	632603	23,390	4.7	4.7	61%	21,162	5.9	4.7	74%	5.8	4.7
6	NGRID	2	660038	115,369	8.8	8.9	67%	126,629	15.4	15.6	50%	15.4	15.6
106	NGRID	2	620114	40,457	6.3	6.3	65%	40,874	8.1	6.2	66%	8.1	6.3
8	NGRID	2	649352	138,920	0.0	31.7	18%	158,037	3.2	31.3	29%	4.8	31.3
9	NGRID	3	577832	185,158	44.0	37.7	75%	108,162	49.7	5.7	91%	46.9	3.7
10	NGRID	3	660095	235,584	27.9	28.0	52%	205,032	20.3	21.6	45%	19.7	23.1
11	NGRID	3	704757	243,423	0.0	56.6	18%	231,836	0.0	51.4	24%	0.0	51.5
12	NGRID	4	588063	578,697	41.3	41.3	46%	508,197	55.7	33.2	40%	57.5	39.9
13	NGRID	4	559032	254,748	29.0	29.0	37%	261,627	29.9	29.9	46%	29.9	29.9
14	NGRID	4	577835	376,875	56.2	56.3	47%	423,245	59.5	59.5	58%	58.6	58.9
74	NGRID - ALD	1	550483	138,185	40.8	40.8	89%	149,596	35.2	25.6	75%	34.4	23.2
76	NGRID - ALD	2	528704	335,301	53.3	76.1	100%	452,862	83.3	51.4	72%	72.4	46.4
16	NSTAR	1	CS8176B	6,281	3.6	2.3	N/A	13,998	2.5	1.7	76%	2.3	1.4
17	NSTAR	1	CS8176P	10,473	4.6	2.9	N/A	22,181	5.9	3.1	84%	5.6	2.0
18	NSTAR	1	BS9237	9,766	4.0	4.0	N/A	3,354	1.5	0.3	82%	1.4	0.2
19	NSTAR	1	BS8558	36,552	6.3	6.3	N/A	52,828	6.1	6.1	47%	6.1	6.1
20	NSTAR	1	BS9455M	3,580	0.7	0.7	N/A	1,578	0.2	0.7	84%	0.1	0.4
21	NSTAR	2	CS8176H	71,960	22.1	14.0	N/A	61,660	8.2	8.5	53%	8.1	8.6
22	NSTAR	2	BS9455L	101,646	10.1	10.1	N/A	60,475	13.8	18.9	92%	9.5	8.4
23	NSTAR	2	BS8633	69,341	7.9	7.9	N/A	86,998	11.8	9.2	48%	11.8	9.2
24	NSTAR	2	BS7776	133,522	12.0	12.0	N/A	37,217	4.2	4.3	46%	4.3	4.3
25	NSTAR	2	CS8176C	120,870	25.9	16.4	N/A	115,818	20.9	11.9	65%	19.6	11.4
26	NSTAR	3	BS9292	197,266	22.6	22.6	N/A	196,539	22.2	22.3	46%	22.0	22.1
27	NSTAR	3	BS9301	205,413	33.9	33.9	N/A	286,759	48.4	44.3	62%	49.4	44.2
28	NSTAR	3	BS9446	140,012	16.0	15.9	N/A	150,578	16.8	16.6	46%	17.0	16.5
29	NSTAR	3	BS8106	150,909	38.7	38.7	N/A	174,988	21.1	20.6	48%	21.2	20.4
30	NSTAR	4	BS8813	434,751	117.0	117.0	N/A	341,986	73.7	64.7	84%	72.5	60.6
31	NSTAR	4	BS8463	351,106	41.5	41.5	N/A	389,796	46.3	43.8	47%	46.5	43.2

Custom Lighting				Tracking				Evaluated					
KEMA Site Number	Program Administrator	Stratum	Site ID	Annual kWh	Summer kW	Winter kW	% On-peak kWh	Annual kWh	Summer On-Peak kW	Winter On-Peak kW	% On-peak kWh	Summer Seasonal kW	Winter Seasonal kW
109	NSTAR	4	BS9336	370,958	0.0	0.0	N/A	467,739	0.1	1.6	10%	0.1	11.2
33	NSTAR	4	BS8288	1,735,446	222.0	222.0	N/A	1,606,570	196.9	190.8	48%	196.5	190.5
34	WMECO	1	WM10L127	44,844	14.8	10.5	N/A	32,456	8.0	5.8	94%	7.1	4.8
35	WMECO	1	WM10L134	26,399	5.3	3.5	N/A	31,246	5.6	5.0	62%	5.5	4.8
36	WMECO	1	WM10L304	47,475	3.7	2.5	N/A	46,199	7.1	9.0	56%	7.3	8.6
113	WMECO	2	WM10L501	116,216	23.5	18.8	N/A	11,236	3.3	2.7	92%	3.0	2.2
38	WMECO	2	WM09R816	147,919	0.0	0.0	N/A	105,039	8.1	77.8	97%	16.0	78.7
39	WMECO	2	WM10R262	93,654	7.6	5.9	N/A	98,386	13.4	10.3	48%	13.4	10.5
40	WMECO	3	WM10L137	295,275	43.6	33.5	N/A	239,183	42.3	30.6	62%	42.6	28.5
41	WMECO	3	WM10C211	170,515	48.4	62.5	N/A	140,675	29.2	16.3	58%	27.6	14.9
42	WMECO	3	WM10L163	209,394	24.5	18.8	N/A	237,956	43.4	34.2	61%	43.2	34.2
43	WMECO	4	WM09R827	857,111	80.4	46.3	N/A	831,036	98.9	93.4	47%	99.0	93.5
44	WMECO	4	WM10L146	407,523	46.7	26.8	N/A	389,667	53.9	46.4	52%	51.6	44.0
45	WMECO	5	WM10L136	1,166,354	215.0	122.2	N/A	1,163,756	173.7	127.4	55%	176.1	125.1

Table 10: Primary Site Discrepancies

Custom Lighting		Realization Rates						
KEMA Site Number	Site ID	Annual kWh	Summer On-Peak kW	Winter On-Peak kW	% On-peak kWh	Summer Seasonal kW	Winter Seasonal kW	Primary Reasons for Discrepancies
1	D021784401	79%	N/A	N/A	N/A	N/A	N/A	Tracking over-estimated interactive HVAC savings.
3	649363	98%	N/A	78%	137%	N/A	86%	More installed fixtures reduced savings and higher annual operating hours increased savings, partially offsetting each other.
4	566565	67%	87%	67%	103%	87%	67%	Decrease in annual operating hours.
5	632603	90%	125%	100%	121%	123%	100%	Reduced operation led to reduced kWh savings. HVAC interactive effects led to increased summer kW savings.
6	660038	110%	174%	176%	74%	175%	176%	Positive HVAC interactive effects in refrigerated space increased savings.
106	620114	101%	129%	99%	102%	129%	100%	Offsetting positive HVAC interactive effects and negative operation adjustments.
8	649352	114%	N/A	99%	161%	N/A	99%	Increase in annual operating hours.
9	577832	58%	113%	15%	121%	107%	10%	Combination of increased operation and electric heating (negative HVAC effects).
10	660095	87%	73%	77%	86%	71%	83%	Annual kWh savings reduction primarily due to lower operation. Peak kW savings reduction primarily due to documentation error (double counting).
11	704757	95%	N/A	91%	135%	N/A	91%	Minor decrease in operating hours.
12	588063	88%	135%	80%	86%	139%	97%	Decrease in annual operating hours.
13	559032	103%	103%	103%	125%	103%	103%	Minor increase in operating hours.
14	577835	112%	106%	106%	123%	104%	105%	Minor increase in operating hours.
74	550483 - ALD	108%	86%	63%	85%	84%	57%	Positive HVAC interactive effects.
76	528704 - ALD	135%	156%	68%	72%	136%	61%	Increase in annual operating hours plus positive HVAC interactive effects.
16	CS8176B	223%	71%	77%	N/A	66%	64%	Increase in annual operating hours.
17	CS8176P	212%	129%	108%	N/A	123%	70%	Combination of a positive technology change, and increase in operating hours.
18	BS9237	34%	38%	7%	N/A	35%	5%	Combination of lower quantity, higher fixture wattage and reduced hours of operation.
19	BS8558	145%	97%	97%	N/A	97%	97%	Increase in annual operating hours and HVAC savings.
20	BS9455M	44%	27%	103%	N/A	11%	63%	Combination of lower quantity, higher fixture wattage and reduced hours of operation.
21	CS8176H	86%	37%	61%	N/A	36%	61%	Combination of lower fixture wattages, and lower annual operating hours.
22	BS9455L	59%	136%	187%	N/A	94%	83%	Decrease in annual operating hours.
23	BS8633	125%	149%	116%	N/A	149%	116%	Combination of increased operation and HVAC interactive effects.

Custom Lighting		Realization Rates						
KEMA Site Number	Site ID	Annual kWh	Summer On-Peak kW	Winter On-Peak kW	% On-peak kWh	Summer Seasonal kW	Winter Seasonal kW	Primary Reasons for Discrepancies
24	BS7776	28%	35%	35%	N/A	35%	35%	Decreased savings due to fewer fixtures installed and higher wattage lamps used.
25	CS8176C	96%	81%	73%	N/A	75%	69%	Decrease in annual operating hours.
26	BS9292	100%	98%	98%	N/A	97%	98%	Minor decrease in operating hours.
27	BS9301	140%	143%	131%	N/A	146%	130%	Increase in annual operating hours.
28	BS9446	108%	105%	105%	N/A	106%	103%	Increase in annual operating hours.
29	BS8106	116%	54%	53%	N/A	55%	53%	Combination of lower quantity, higher fixture wattage and increased hours of operation.
30	BS8813	79%	63%	55%	N/A	62%	52%	Decrease in annual operating hours.
31	BS8463	111%	111%	106%	N/A	112%	104%	Technology change resulted in increased savings.
109	BS9336	126%	N/A	N/A	N/A	N/A	N/A	Greater reduction in operating hours due to lighting controls.
33	BS8288	93%	89%	86%	N/A	89%	86%	Fewer fixtures installed, and reduced operating hours.
34	WM10L127	72%	54%	55%	N/A	48%	46%	Combination of higher quantity, higher fixture wattage and reduced hours of operation.
35	WM10L134	118%	106%	142%	N/A	104%	135%	More fixtures and higher annual operating hours.
36	WM10L304	97%	191%	361%	N/A	196%	347%	Increase in annual operating hours.
113	WM10L501	10%	14%	15%	N/A	13%	12%	No occupancy sensor savings and reduced hours of use. Higher fixture wattage.
38	WM09R816	71%	N/A	N/A	N/A	N/A	N/A	Decrease in annual operating hours.
39	WM10R262	105%	175%	176%	N/A	175%	180%	Increase in annual HVAC interactive savings.
40	WM10L137	81%	97%	91%	N/A	98%	85%	Negative savings driven by baseline fixture quantity error.
41	WM10C211	83%	60%	26%	N/A	57%	24%	No occupancy sensor savings.
42	WM10L163	114%	177%	182%	N/A	177%	182%	Combination of increased operation and HVAC interactive effects.
43	WM09R827	97%	123%	202%	N/A	123%	202%	Partially offsetting negative HVAC interactive effects and positive operation adjustments.
44	WM10L146	96%	115%	173%	N/A	110%	164%	Offsetting negative HVAC interactive effects and positive operation adjustments.
45	WM10L136	100%	81%	104%	N/A	82%	102%	Offsetting negative HVAC interactive effects and positive operation adjustments.

The site-level evaluation results were aggregated using stratified ratio estimation. The PA realization rates are calculated, and then applied to each PA's total tracking savings to determine their total measured savings. The statewide realization rate is the ratio of the total measured savings to the total tracking savings, each of which is calculated by summing across the PAs.

DNV KEMA aggregated the PA results to determine statewide realization rates, for use by the smaller PAs as needed. Table 11 summarizes the statewide results of this analysis. In the case of annual MWh savings, the realization rate for Custom Lighting measures was found to be 98.3%. The relative precision for this estimate was found to be ±9.3% at the 90% level of confidence. The error ratio was found to be 0.30. Table 11 also shows the results for the on-peak and seasonal summer and winter coincident demand savings, measured in KW. Since the design criteria for the demand realization rates were based on an 80% confidence level, the precisions and error bounds at this level are reported in the appropriate rows in Table 11 and Table 12. For the on-peak summer kW, the overall realization rate was 93.6%, with a relative precision of ±7.3% at an 80% confidence level. For on-peak winter kW, the realization rate was a bit lower, at 91.7%, with a relative precision of ±10.2%. For the seasonal summer kW, the overall realization rate was 92.1%, with a relative precision of ±7.6%. For on-peak winter kW, the realization rate was 87.5%, with a relative precision of ±10.2%.

The grey cells in Table 11 and Table 12 represent the energy savings presented at 80% confidence, and demand savings at 90% confidence. These cells are grey because the precision at these confidence levels were not required, but included for information purposes only.

Table 11: Summary of Custom Lighting Results

Statistic	Annual MWh	On-Peak Summer kW	On-Peak Winter kW	Summer Season Peak kW	Winter Season Peak kW
Total Tracking Savings	46,463	7,659	8,061	7,659	8,061
Total Measured Savings	45,696	7,166	7,392	7,056	7,056
Realization Rate	98.3%	93.6%	91.7%	92.1%	87.5%
Relative Precision at 90% Confidence	9.3%	9.3%	13.1%	9.7%	13.1%
Error Bound at 90% Confidence	4,259	669	966	685	923
Relative Precision at 80% Confidence	7.3%	7.3%	10.2%	7.6%	10.2%
Error Bound at 80% Confidence	3,319	521	752	534	719
Error Ratio	0.30	0.38	0.58	0.40	0.58

Table 12 summarizes the PA-specific results of this analysis. In the case of annual MWh savings, the realization rate for Custom Lighting measures ranged from 79.5% for CLC (based on one site) to 101.8% for NSTAR. The relative precision for these estimates was found to range from 5.9% to 13.5% at the 90% level of confidence. The error ratio was found to range from 0.16 to 0.34.

Table 12 also shows the results for the on-peak summer and winter coincident demand savings, measured in KW. Since the design criteria for the demand realization rates were based on an 80% confidence level, the precisions and error bounds at this level are reported in the appropriate rows in Table 12. These cells are grey because the precision at these confidence levels were not required, but included for information purposes only. Note that the table only shows annual MWh savings for CLC. This was because population tracking data were not available for the other savings parameters at the time of this report.

Table 12: Summary of Custom Lighting Results by Program Administrator

Statistic	Annual MWh	% On-Peak MWh	On-Peak MWh	On-Peak Summer kW	On-Peak Winter kW	Summer Season Peak kW	Winter Season Peak kW
Cape Light Compact							
Total Tracking Savings	31	-	-	-	-	-	-
Total Measured Savings	25	-	-	-	-	-	-
Realization Rate	79.5%	-	-	-	-	-	-
Relative Precision at 90% Confidence	0.0%	-	-	-	-	-	-
Error Bound at 90% Confidence	-	-	-	-	-	-	-
Relative Precision at 80% Confidence	0.0%	-	-	-	-	-	-
Error Bound at 80% Confidence	-	-	-	-	-	-	-
Error Ratio	0.00	-	-	-	-	-	-
National Grid							
Total Tracking Savings	9,109	44.3%	4,036	1,886	2,250	1,886	2,250
Total Measured Savings	8,922	47.9%	4,273	2,185	1,913	2,159	1,926
Realization Rate	97.9%	108.1%	105.9%	115.9%	85.0%	114.5%	85.6%
Relative Precision at 90% Confidence	5.9%	-	13.9%	9.5%	11.7%	10.0%	12.1%
Error Bound at 90% Confidence	529	-	595	207	225	216	232
Relative Precision at 80% Confidence	4.6%	-	10.9%	7.4%	9.2%	7.8%	9.4%
Error Bound at 80% Confidence	412	-	464	207	225	216	232
Error Ratio	0.16	-	0.33	0.25	0.33	0.26	0.34
NSTAR							
Total Tracking Savings	30,375	-	-	4,628	5,127	4,628	5,127
Total Measured Savings	30,915	-	-	3,938	4,280	3,815	3,950
Realization Rate	101.8%	-	-	85.1%	83.5%	82.4%	77.0%
Relative Precision at 90% Confidence	13.5%	-	-	14.9%	16.2%	15.3%	15.8%
Error Bound at 90% Confidence	4,182	-	-	586	694	582	622
Relative Precision at 80% Confidence	10.5%	-	-	11.6%	12.6%	11.9%	12.3%
Error Bound at 80% Confidence	3,259	-	-	457	541	454	485
Error Ratio	0.34	-	-	0.42	0.46	0.43	0.44
WMECO							
Total Tracking Savings	7,999	-	-	1,409	967	1,409	967
Total Measured Savings	7,139	-	-	1,351	1,385	1,364	1,346
Realization Rate	89.3%	-	-	95.9%	143.2%	96.8%	139.2%
Relative Precision at 90% Confidence	8.7%	-	-	19.4%	45.7%	21.7%	47.6%
Error Bound at 90% Confidence	619	-	-	262	633	296	640
Relative Precision at 80% Confidence	6.8%	-	-	15.1%	35.6%	16.9%	37.1%
Error Bound at 80% Confidence	482	-	-	204	493	231	499
Error Ratio	0.24	-	-	0.48	1.21	0.53	1.25

5.3 Implications for Future Studies

From a statistical perspective it appears that the Custom Lighting results are fairly stable, and the variation across sample sites is about as expected, with error ratios below 0.4 for energy and below 0.6 for demands. Future designs should assume these values to determine sample size requirements.

5.4 Conclusions and Recommendations

Overall, the Custom Lighting projects appear to be successfully providing energy and demand savings in the State of Massachusetts. Below are the DNV KEMA evaluation team findings and recommendations that apply statewide, as well as to the individual PAs.

5.4.1 Statewide

Consider a systematic approach for estimating HVAC interactive effects. This evaluation found that most of the PAs are applying HVAC interactive effects to the tracking estimates of savings to some extent. In the case of WMECO, HVAC estimates are applied to almost all of their lighting projects, but not all. For other PAs, HVAC estimates are only included for specific types of projects such as lighting in refrigerated spaces. The PAs should consider developing a statewide approach for including HVAC interactive effects in the savings estimates for custom lighting projects. If HVAC interactive effects are to be included in savings estimates moving forward, it is recommended that the assumptions used to calculate HVAC savings and/or penalties are based on site specific information, as this evaluation found some wide differences in savings due to HVAC interactive effects.

Ensure that the final savings documents are stored for future evaluations. There were some projects in which the post-installation inspection sheets are vague and do not provide site specific details (counts, technology). In some cases, the projects files do not show the most up to date savings calculations, counts, and technologies. On some occasions, the most recent files were obtained through follow-up requests to the PAs, and other times, the TA vendor was able to supply the most recent calculations. Since the most up to date tracking savings calculations were not always available, evaluators were unable to replicate the tracking savings exactly, and identify where the differences in savings come from. It is recommended that all PAs obtain and keep all savings calculations from the vendors performing the calculations. Particularly in cases where savings estimates are revised, the PAs should ensure that the revised savings spreadsheets are collected.

Look for increased savings opportunities from controls. There were several retrofit projects where lighting controls could have been installed but were not. It is not clear why lighting controls were not included more often than was found through this evaluation. MA PAs may consider looking deeper into lighting controls in retrofit situations, as there may be more opportunity for savings via controls.

5.4.2 Cape Light Compact

There was one CLC sample site included in the 2010 Custom Lighting Impact Evaluation, which makes it difficult to propose recommendations regarding CLC's program. However, there are some observations that could be made from reviewing this sample site.

Verify installed counts/technologies and savings assumptions. This site produced an annual energy savings estimate that was 21% less than the tracking estimate. The reason for the decrease in savings was because there was a difference between the quantities of fixtures proposed and what was installed. There was also a reduction due to an over-estimation of HVAC interactive effects calculated as part of the tracking savings. It is recommended that all savings assumptions are verified, and checked for reasonableness.

5.4.3 National Grid

Review peak demand savings estimates more carefully. This evaluation produced winter peak demand reductions that were lower than estimated in the tracking savings. Though the overall hours of use proposed in the tracking estimates were typically close, the tracking estimates for the winter peak kW reductions were calculated using somewhat aggressive winter peak coincidence factors. In seven of the twelve projects evaluated, the winter peak coincidence factor was the same as the summer peak coincident factor, despite the differing definitions of summer and winter peak. While the summer peak demand realization rate was greater than 100%, the winter peak demand realization rate was 87%. Typically, the winter peak coincidence factor is less than the summer peak coincidence factor because the winter peak period is later in the day. There are some cases where a higher winter coincidence factor is appropriate, such as exterior lighting. However, in this evaluation winter peak savings were over-estimated. It is recommended that estimated winter demand savings be reviewed closely to determine if the values are appropriate for the each project.

Require more robust documentation. There were some sites in the custom lighting sample where the post-installation inspection reports did not detail the quantities or fixture types installed. In some cases, cut sheets were not available for review by evaluators. These types of documents are not only helpful for the evaluation team to be able to identify fixtures, and quantities, but also useful as back-up documentation for savings analyses. It is recommended that if a post-installation inspection takes place, which almost always happens, that implementers provide more detailed documentation of the actual installation.

5.4.4 NSTAR

Review site specific coincidence factors used for developing summer and winter peak demand savings. NSTAR's summer and winter peak demand savings realization rates were generally lower than the other PA's. One reason is that a review of the tracking system data show that eight of the 18 projects evaluated assumed coincidence factors of 100% for both summer and winter peak demand savings. The un-weighted, average summer demand realization rate for these eight sites was 87%, while the un-weighted, average winter demand realization rate was 75%. The use of a 100% coincidence factor being applied to an entire lighting project tends to result in lower site specific realization rates on demand savings because it is unlikely that all lights in a facility are on 100% of the time during peak periods. Note that the inclusion of HVAC interactive effects in the evaluation helped offset some of the reduction, particularly for summer estimates. It is recommended that projects with 100% coincidence factors be reviewed closely to determine if this value is appropriate for the entire project.

Ensure that the final savings documents are stored for future evaluations. There were some projects in which the post-installation inspection sheets are vague and do not provide site specific details (counts, technology). In some cases, the projects files do not show the most up to date savings calculations, counts, and technologies. On some occasions, the most recent files were obtained through follow-up requests to NSTAR, and other times, the TA vendor was able to supply the most recent calculations. Since the most up to date tracking savings calculations were not always available, evaluators were unable to replicate the tracking savings exactly, and identify where the differences in savings come from. It is recommended that NSTAR obtain and keep all savings calculations from the vendors performing the calculations. Particularly in cases where savings estimates are revised, NSTAR should ensure that the revised savings spreadsheets are collected.

5.4.5 Western Massachusetts Electric Company

Review the methodology for including HVAC interactive effects in tracking savings estimates. In most projects evaluated by the DNV KEMA team, it was found that HVAC interactive effects were being included in the tracking savings. It does not appear that all projects included this additional component of savings. Though the methodology provides a reasonable estimate of HVAC interactive savings, evaluators found that in some projects where this factor was included, it should not have been, and vice versa. If WMECO continues to apply this HVAC factor going forward, it is recommended that site specific information is taken into account to determine if a project gets this treatment or not.

Consider the current energy code for lighting controls for new construction projects. There were two new construction projects in the WMECO sample, and each included lighting controls savings. However, current Massachusetts building code at the time of these applications required lighting controls to be installed.[3] In both cases, the evaluation team utilized the logged operating hours of the installed lighting systems for both the baseline and installed cases. This resulted in a reduction in savings for both sites in the sample.

Ensure that the final savings documents are stored for future evaluations. There were some projects in which the post-installation inspection sheets are vague and do not provide site specific details (counts, technology). In some cases, the projects files do not show the most up to date savings calculations, counts, and technologies. On some occasions, the most recent files were obtained by following up with account managers, but other times they were not. Since the most up to date tracking savings calculations were not always available, evaluators were unable to replicate the tracking savings exactly, and identify where the differences in savings come from. It is recommended that WMECO obtain and keep all savings calculations from the vendors performing the calculations.

[3] 2006 IECC, Section 505, Electrical Power and Lighting Systems

6. Appendix A: References

[1] *The California Evaluation Framework,* prepared for Southern California Edison Company and the California Public Utility Commission, by the TecMarket Works Framework Team, June 2005, Chapters 12-13.

[2] *Model Assisted Survey Sampling,* C. E. Sarndal, B. Swensson, and J. Wretman, Springer, 1992.

7. Appendix B: Seasonal Peak Period Coincidence

This section describes DNV KEMA's methodology to estimating seasonal peak demand in this impact evaluation of the 2010 Large C&I programs.

7.1 Peak Period Definitions

In the ISO New England Forward Capacity Market, a participant may submit energy-efficiency "other demand resources" as one of three different types: On-Peak, Seasonal Peak, and Critical Peak. For this purpose of this discussion, the Critical Peak will be omitted. The important point is that some readers may be more familiar with the On-Peak Demand Resource, but Western Massachusetts Electric participates in FCM as a Seasonal Peak Demand Resource. The distinction is simply that the demand reduction value is computed as the average demand across the corresponding "Peak Hours" period. The following definitions are taken from ISO New England's FERC Electric Tariff No. 3:

> **"Demand Resource On-Peak Hours** are hours ending 1400 through 1700, Monday through Friday on non-holidays during the months of June, July, and August and hours ending 1800 through 1900, Monday through Friday on non-holidays during the months of December and January.
>
> **"Demand Resource Seasonal Peak Hours** are those hours in which the actual, Real-Time hourly load for Monday through Friday on non-holidays, during the months of June, July, August, December, and January, as determined by the ISO, is equal to or greater than 90% of the most recent 50/50 system peal load forecast, as determined by the ISO, for the applicable summer or winter season."[4]

It is considerably more complex to assess coincidence relative to the Demand Resource Seasonal Peak Hours because they are conditional in nature and depend upon the relationship between real time system load and the most recent 50/50 system peak load forecast. The remainder of this section details DNV KEMA's analytical approach to this challenge.

7.2 Summer Seasonal kW Reduction

The calculation of the summer seasonal peak demand reduction was based on the performance hours that were used to evaluate the Demand Reduction Values (DRV). Seasonal demand

[4] ISO New England, FERC Electric Tariff No. 3, General Terms and Conditions, Section I.2 – Rules of Construction; Definitions, Effective: January 24, 2010, Original Sheet No. 15L.

performance hours for ISO-NE FCM are defined as hours when the real time ISO-NE system load meets or exceeds 90% of the predicted seasonal peak from the most recent Capacity, Electricity, Load and Transmission Report (CELT report). The peak load forecast for the summer 2010 season was 27,190 kW, and 90% of which was 24,471 kW. There were 30 hours during the summer 2010 season when the load exceeded 24,471 kW. The evaluation used Worcester, MA real weather data for the summer of 2010 to calculate the weighted Total Heat Index (THI) at each hour. The Total Heat Index is a forecast variable used by ISO-NE and it is calculated as follows;

$$THI = 0.5 \times DBT + 0.3 \times DPT + 15$$ Where,

THI = Total Heat Index

DBT = Dry Bulb Temperature (°F)

DPT = Dew Point Temperature (°F)

Table 13 provides the summer 2010 seasonal peak hours along with the system load, percent of CELT forecast peak and the Total Heat Index (THI) for Worcester, MA.

Table 13: 2010 Summer Seasonal Peak Hours and System Load

Date	Hour	System Load (kW)	Percent of Peak	THI
7/6/2010	11	24,856	91%	80.4
7/6/2010	12	25,837	95%	80.8
7/6/2010	13	26,455	97%	81.0
7/6/2010	14	26,974	99%	81.8
7/6/2010	15	27,102	100%	81.4
7/6/2010	16	27,079	100%	81.4
7/6/2010	17	26,970	99%	82.5
7/6/2010	18	26,787	99%	81.2
7/6/2010	19	26,271	97%	80.8
7/6/2010	20	25,577	94%	80.0
7/6/2010	21	25,153	93%	78.8
7/7/2010	12	25,295	93%	80.2
7/7/2010	13	25,914	95%	80.9
7/7/2010	14	26,321	97%	81.1
7/7/2010	15	26,447	97%	81.3

Date	Hour	System Load (kW)	Percent of Peak	THI
7/7/2010	16	26,498	97%	80.8
7/7/2010	17	26,387	97%	80.9
7/7/2010	18	25,969	96%	80.7
7/7/2010	19	25,187	93%	79.3
7/8/2010	15	24,636	91%	75.8
7/8/2010	16	24,760	91%	77.0
7/8/2010	17	24,768	91%	76.2
7/8/2010	18	24,492	90%	76.0
7/16/2010	17	24,512	90%	79.1
8/31/2010	14	24,880	92%	79.3
8/31/2010	15	25,340	93%	78.3
8/31/2010	16	25,594	94%	79.5
8/31/2010	17	25,691	94%	78.5
8/31/2010	18	25,380	93%	78.4
8/31/2010	19	24,645	91%	75.7

ISO-NE also uses a variable called a Weighted Heat Index (WHI) which is a three day weighted average of the THI and is calculated as follows;

$$WHI = 0.59 \times THI_{di\ hi} + 0.29 \times THI_{d(i-1)\ hi} + 0.12 \times THI_{d(i-2)\ hi}$$ Where,

WHI = Weighted Heat Index

$THI_{di\ hi}$= Total Heat Index for the current day and hour

$THI_{d(i-1)\ hi}$= Total Heat Index for previous day and same hour

$THI_{d(i-2)\ hi}$= Total Heat Index for two days prior and same hour

The peak load data and the weighted THI and WHI data for 2010 were used to create linear regressions of peak system load as a function of THI and WHI. The analysis focused on non-holiday weekdays from June through August during hours ending 11 through 21. Evaluators used the time window of hours ending 11 to 21 because of the above observed peaks in the 2010 season that occurred outside of the 1 pm to 5 pm daily peak time period.

The following THI & WHI cutoff points were the result of the regression analyses. These represent the selection points at which both the THI and WHI from a Worcester, MA TMY3 weather file must be greater than in order to trigger a summer seasonal peak hour.

THI Cutoff Point: 78.2

WHI Cutoff Point: 77.6

Table 14 provides a summary of the THI, WHI and number of summer seasonal hours for the Worcester, MA TMY3 weather file used in the analysis by month and for the summer season. These are the total number of TMY3 hours applied to the 2010 evaluation year that meet the above criteria for being selected as a summer seasonal peak hour.

Table 14: Summary of Summer Seasonal Hours for Worcester, MA TMY3 File

	Mean THI	Mean WHI	# of Hours
June	NA	NA	0
July	78.7	76.7	9
August	78.9	76.1	1
Summer	78.7	76.6	10

7.3 Winter Seasonal kW Reduction

The calculation of the winter seasonal peak demand reduction was based on the performance hours that were used to evaluate the Demand Reduction Values (DRV). Seasonal demand performance hours for ISO-NE FCM are defined as hours when the real time ISO-NE system load meets or exceeds 90% of the predicted seasonal peak from the most recent Capacity, Electricity, Load and Transmission Report (CELT report).

The peak load forecast for the winter 2010/2011 season was 22,085 kW, and 90% of which was 19,877 kW. There were a total of 18 hours during the winter 2010/2011 season when the load was 19,877 kW or greater. Table 15 provides a list of the winter seasonal peak hours along with the system load, the percentage of forecasted peak and the dry bulb temperature (DBT) for each hour for Worcester, MA.

Table 15: Winter 08/09 Seasonal Peak Hours and System Loads

Date	Hour	System Load (kW)	Percent of Peak	DBT
12/9/2010	18	20,197	91%	18.0
12/9/2010	19	20,105	91%	17.0
12/14/2010	18	20,099	91%	17.0
12/14/2010	19	20,054	91%	17.0
12/15/2010	18	20,622	93%	15.0
12/15/2010	19	20,451	93%	15.0
12/15/2010	20	20,104	91%	15.0
12/16/2010	18	19,925	90%	26.0
12/20/2010	18	20,409	92%	25.0
12/20/2010	19	20,327	92%	24.0
12/20/2010	20	19,941	90%	24.0
12/27/2010	18	20,233	92%	15.0
12/27/2010	19	19,949	90%	14.0
1/24/2011	18	20,878	95%	6.0
1/24/2011	19	21,060	95%	5.0
1/24/2011	20	20,710	94%	5.0
1/24/2011	21	19,991	91%	3.0
1/25/2011	19	19,897	90%	21.0

The 2010/2011 peak load data and the Worcester, MA temperature data were used to create linear regressions of peak system load as a function of dry bulb temperature. The results of the regression were used to identify the seasonal peak hours using the Worcester, MA TMY3 weather data. The analysis focused on low temperature periods in December and January during hours ending 18, 19, and 20. Evaluators included hour ending 20 because of the above observed peaks in the 2010/2011 season that occurred outside of the 5 pm to 7 pm daily peak time period.

The following DBT cutoff point was the result of the regression analysis. This represents the selection point at which the DBT from the Worcester, MA TMY3 weather file must be less than in order to trigger a winter seasonal peak hour.

DBT Cutoff Point: 19.4°F

Table 16 provides a summary of the Dry Bulb Temperature (DBT) and number of winter seasonal hours for the Worcester, MA TMY3 weather file use in the analysis by month and for the winter season.

Table 16: Summary of Winter Seasonal Hours for Worcester, MA TMY3 File

	Mean DBT	# of Hours
December	17.2	6
January	11.3	28
Winter	12.3	34

8. Appendix C: Site Reports