Final Report

C9: Impact Evaluation of the Connecticut Small Business Energy Advantage (SBEA) Program

Connecticut Energy Efficiency Board Evaluation Committee

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EXECUTIVE SUMMARY

The Connecticut Energy Efficiency Board (CT EEB) Evaluation Committee commissioned a study to evaluate the 2011 Small Business Energy Advantage (SBEA) Program sponsored by Connecticut Light & Power (CL&P) and United Illuminating (UI). The primary objectives of this study were to 1) develop SBEA Program level electric gross energy savings estimates targeted to achieve +/-10 precision at the 90% level of confidence, 2) develop SBEA Program electric energy demand savings coincident with summer on-peak and seasonal peak periods targeted to achieve +/-10 precision at the 80% level of confidence (to allow bidding into the capacity markets), and 3) provide inputs to update the current Program Savings Document (PSD) as appropriate with findings from the study, including metering results, installation results and other parameters.

2011 Program Activity Summary

There were 1,696 customer sites that participated in the SBEA program from January 1–December 31, 2011. The two program sponsors combined for a total of 35,205,536 kWh saved in the 2011 Program Year, with lighting measures comprising the majority of electric savings (86%). Refrigeration and custom measures account for 7.6% and 3.1% of the 2011 Program Year electric savings, respectively.

Table 1: 2011 SBEA Program Activity

	Sponsor				Statewide	
Measure Type/kWh	**CL&P kWh (N=1,396)**	**% of CL&P Total**	**UI kWh (n=300)**	**% of UI Total**	**Total kWh (N=1,696)**	**% of Total**
Lighting	23,711,294	79.6%	4,422,281	81.5%	28,133,575	79.9%
Refrigeration	2,405,946	8.1%	260,141	4.8%	2,666,087	7.6%
High Performance Lighting	2,142,427	7.2%	-	-	2,142,427	6.1%
Custom	903,743	3.0%	204,581	3.8%	1,108,324	3.1%
HVAC	617,812	2.1%	306,290	5.6%	306,290	1.8%
Process/Compressed Air	-	-	231,021	4.3%	231,021	0.7%
Total (kWh)	29,781,222	100.0%	5,424,314	100.0%	35,205,536	100.0%
Total (%)	84.6%		15.4%		100.0%	

Key Study Methods

The two primary evaluation activities undertaken in this effort include an engineering study with site-level measurement and verification (M&V) at 60 participating sites and a billing analysis.

The engineering study in this evaluation was a measure level approach that was based upon gathering and analyzing site-level data from 60 statistically selected sites. This approach incorporated M&V activities, such as metering time of use or consumption of the measures installed in the businesses in the sample.

This impact evaluation conducted a billing analysis in addition to the standard engineering M&V method (as was conducted in prior SBEA impact evaluations). Billing analysis estimates the impacts of the SBEA Program through use of consumption data and using the tracking data as a statistical variable. We performed the billing to assess its ability to provide energy savings estimates for a small business program.

Results

Table 2 summarizes the overall evaluation results from the impact evaluation M&V on-site work. A total of 33,874 MWh of energy savings are estimated from 2011 SBEA Program activity based upon the on-site M&V approach. The realization rates associated with this estimate is be 96.2%, with a precision of ±7.8% at the 90% confidence interval. The summer on-peak and seasonal peak savings estimates are 6,093 and 6,187 kW, respectively. The precision on these estimates are ±8.6% at the 80% confidence level for summer on-peak and ±8.3% for seasonal. The winter on-peak savings estimate is 5,148 kW, with a precision of ±16.2% at the 80% confidence level. The winter seasonal peak savings estimate is 4,440 kW, with a precision of ±17.6% at the 80% confidence level.

Table 2: Summary of Impact Evaluation M&V Results

Result	Tracking Estimates of 2011 Electric Savings	Evaluation Gross Realization Rate	Relative Precision at 90% Confidence (80% for demand)	Evaluation Gross Electric Savings
Overall kWh (n=60)	35,205,536	96.2%	7.8%	33,873,684
Savings from Lighting (n=42)	30,276,003	99.0%	8.5%	29,972,868
Electric Non-Lighting Savings (n=18)	4,929,534	79.1%	18.7%	3,900,816
Connected Demand kW	18,809	161.5%	13.6%	30,372
Summer On-Peak kW	6,883	88,5%	8.6%	6,093
Summer Seasonal Demand kW	6,883	89.9%	8.3%	6,187
Winter On-Peak kW	4,710	109.3%	16.2%	5,148
Winter Seasonal Demand kW	4,710	94.3%	17.6%	4,440

Overall, the CT SBEA program generated statistically significant reductions in electric consumption through the billing analysis method. The billing analysis, however, could not provide further substantiation of the results from the engineering M&V approach. The billing analysis provided an overall realization rate of 34%. Few C&I evaluations use billing analysis methods; the standard method is one within the engineering M&V approach. The divergent results from the two methods has been seen in recent C&I evaluations in the Northeast that have included both methods, with the billing analysis results consistently lower than the M&V results in each jurisdiction. The impact evaluation estimates, therefore, are from the engineering M&V work. This report provides recommendations for additional considerations needed if billing analysis is desired in future C&I program evaluations.

The Connecticut PSD is the source of savings calculations and assumptions for tracking program savings. The PSD is constantly evolving to reflect new findings and studies in its calculations and parameters. While this study did not explicitly target the updating of the measures examined, we did review the calculations for the four primary measures explored in this study (lighting, door heater controls, vendor heating controls, and evaporator fan motor replacement and evaporator fan controls) to assess opportunities to recommend changes based upon our findings, as summarized in the table below.

Table 3: Measure Reviews for Program Savings Document

Measure Type Reviewed	Findings	Conclusion
Lighting	Formula appropriately calculates energy and demand savings. Key inputs include self-reported hours of use, standard pre and post watts and COP assumption for interactive.	Formula exceeds industry standards as it includes interactive. Recommend adjustment to assumed COP.
Door Heater Controls	Formula is standard and correct. Key inputs include number of units, site-specific voltage, and amperage and a power factor fixed at 1.	Formula is consistent with industry standards for calculating energy and demand savings. Power factor is valid for electric resistance loads. The annual hours are stipulated at 6,500 for coolers and 4,070 for freezers, which are reasonable based on the metering and observations of this study.
Vending Machine Controls	Formula is standard and correct. Key inputs include number of units, site-specific voltage, amperage, annual operating hours and a savings factor fixed at 45%.	Formula is consistent with industry standards for calculating energy and demand savings. The savings factor of 45% is appropriate, within expected engineering estimates and provides reasonable estimates of savings in light of the findings of this study.
Evaporator Fan Controls and Evaporator Fan Motor Replacement	Formula is standard and correct. Key inputs include number of units, fan motor kW, annual hours before and after control, and refrigeration efficiency.	Formula is consistent with industry standards for calculating savings. The annual hours are assumed to be 5,000 hours if controls are already in place or installed with replacement motors and 8,500 hours if controls are not present. We believe these to be reasonable based upon the findings from this study. Refrigeration efficiencies are stipulated at an ACOP of 2.03 for freezers and 2.69 for coolers, which are acceptable average efficiencies for refrigeration equipment of this nature.

Conclusions and Recommendations

Below we provide conclusions and recommendations based upon the findings in this study. We note that as part of its ongoing process of reviewing and improving program operations, CL&P and UI may have undertaken some of these recommendations prior to delivery of this report.

Conclusion #1: Based upon the M&V impact results, it is apparent that the 2011 SBEA Program generated significant energy and peak demand savings. The estimate of annual energy savings is 33,874 MWh and the seasonal summer peak demand savings is 6,093 kW.

Conclusion #2: Based upon the M&V impact results, we conclude that the CT PSD used to develop the tracking estimates of savings is producing very reasonable estimates of SBEA energy and summer seasonal peak demand savings. The realization rate (or ratio of PSD generated tracking savings to study savings) is 96.2% for energy and 89.9% for summer seasonal peak demand. Despite this, we do provide some specific recommendations for PSD improvement and adherence later in this section.

Conclusion #3: We do not believe the SBEA Program is a good candidate for program level billing analyses given its current state due to uncertainty around the relationship between accounts and program treated spaces. The performance of another billing analysis on the SBEA Program should be undertaken only if the program administrators are fully confident that all billing data associated with each participant's treated area has been identified and available.

Recommendation #3: To the extent the EEB desires a billing analysis as an evaluation method for the SBEA Program, we recommend that program vendors and implementers establish a system of ensuring the acquisition of all meters and accounts associated with each treated premise.

Conclusion #4: In the M&V site work, when the PSD formulas were used to calculate summer demand and annual energy savings, the results were consistent with the estimates in the tracking system (99.6% and 98.2% realization rates, respectively). When the PSD formulas were used to calculate winter and connected demand savings, the results suggest that the tracking system estimates for these parameters are grossly underestimated (136.1% and 165.6% realization rates, respectively).

There were three sites in the sample that had tracking winter demand savings estimates of zero. When the PSD formulas were applied, the total winter demand savings for these sites was 64.52 kW. Likewise, there were four instances where the tracking connected demand savings estimates were zero and the total PSD calculated value for these sites was 73.11 kW.

Recommendation #4: Although we do not believe that connected demand or winter demand are important metrics for CT filing or ISO-NE FCM purposes, we recommend that the sponsors take steps to more closely follow the PSD in calculating these values in the tracking system.

Conclusion #5: While the overall annual energy savings results were very good (96.2% realization rate), the interactive savings applied to lighting retrofits in the tracking system appear to be slightly overestimated; causing a 7.5% reduction in lighting savings. Some of this overestimation is due to applying the cooling credit to spaces that were not found to be cooled during the on-site visits. Additionally, a review of the PSD formula used to apply interactive savings to lighting retrofits found the cooling system COP (coefficient of performance) assumption to be less efficient than the COP of the units typically found on-site.

Recommendation #5: We recommend that the cooling credit calculation only be applied to lighting retrofits that occur in spaces that are mechanically cooled. We also recommend that consideration be given to assuming an interactive COP that is more consistent with the cooling systems used in small businesses today. The current COP assumption of 2.4 is a dated assumption that is cited from an ASHRAE journal article from 1993. During the on-site visits, most of the cooling systems observed in the sample were packaged systems with estimated COP's of 2.9. As such, we recommend that consideration be made for adjusting the PSD COP assumption to 2.9 to calculate interactive savings for small business lighting retrofits that occur in cooled spaces[1].

Conclusion #6: One of the larger adjustments experienced in the electric non-lighting realization rate was that of documentation adjustment. This adjustment had a negative 11.5% impact on the final savings result. The primary measures where the documentation adjustment was particularly problematic were electrically commutated motors and cooler curtains.

Recommendation #6: We recommend that a renewed effort be undertaken to calculate savings for ECMs and cooler curtains per the PSD. We think such an effort would not need to be time consuming and once established it would greatly improve the accuracy of tracked savings for these measures.

OVERVIEW

This document summarizes the results of an impact evaluation of the Small Business Energy Advantage Program (SBEA). The previous impact study of the SBEA Program was performed on 2007 measure installations and was completed in 2009[2]. The SBEA Program provides direct install of energy-efficient measures for small commercial and industrial ("C&I") customers (an average 12-month peak demand between 10 kilowatts (kW) and up to 200 kW). Most of the savings of the SBEA program are from electric measures, lighting in particular. This impact evaluation was designed for greatest cost efficiency by focusing the evaluation on electric savings.

Purpose and Objectives of the Study

The primary objectives of the SBEA study are generally focused on determining program impacts, in addition to an effort to compare study findings to the current Program Savings Document (PSD) to identify opportunities in which the PSD might be refined. More specifically, the objectives include the following:

1. Develop SBEA Program level electric gross energy savings estimates targeted to achieve +/-10 precision at the 90% level of confidence. Within the savings analysis identify primary discrepancies in savings estimates between program tracking or reported savings estimates and final gross savings estimates, including the impact of documentation errors, technology adjustment, quantity adjustment, operation adjustment and errors in interactive effects.

2. SBEA Program electric energy demand savings coincident with summer on-peak and seasonal peak periods targeted to achieve +/-10 precision at the 80% level of confidence (to allow bidding into the capacity markets). The analysis of demand savings will also identify primary discrepancies in savings estimates between tracking savings estimates and final gross savings estimates, including the impact of documentation errors, technology adjustment, quantity adjustment, operation adjustment and interactive effects.

[1] It should be noted that as part of its routine review and updating of the PSD, UI and CL&P revised the C&I Lighting formula in the 2013 PSD to reflect a COP of 3.5.

[2] http://library.cee1.org/sites/default/files/library/8832/CEE_Eval_CTSBEA2007ImpactEvaluationReport_24Aug2009.pdf

3. Provide inputs to update the current PSD as appropriate with findings from the study, including metering results, installation results and other parameters.

The two primary evaluation activities undertaken in this effort include an engineering study with site level measurement and verification (M&V) and a billing analysis. Both study methods are empirical in nature, have different strengths and weaknesses, and provide different outputs discussed further below. One of the rationales for exercising two methods was to assist the CT EEB and PURA in testing the efficacy of the two approaches. The two approaches and their associated characteristics are discussed further in the bullets below.

- The engineering study is generally regarded as a highly rigorous approach to evaluating measures of the nature installed through the SBEA Program. Using engineering methods with on-site metering is the most accepted approach for impact evaluations of C&I efficiency programs. The engineering study in this evaluation is a measure level approach that is based upon gathering and analyzing site-level data from statistically selected sites. This approach incorporates M&V activities, such as metering time of use or consumption, of the measures installed in the businesses in our sample.
- The core billing analysis employed can provide an overall sense of the impacts of the SBEA Program through use of consumption data and the tracking data as a statistical variable. It should be noted that billing analysis results are for energy savings at a high level (in this case at the treated premise level) and has limited ability to produce findings on specific measures.

The table below summarizes the manner in which the various study objectives are addressed by the evaluation methods and tasks undertaken in this impact study.

Figure 1: Mapping of Study Objectives to Methods

Objective	Desired Outcome	Methodology: Billing Analysis	Methodology: Engineering Study: On-sites with M&V
1. Provide gross overall electric impacts of measures installed through the 2010 and 2011 SBEA Program.	• SBEA Program level electric gross energy savings targeted to achieve +/-10 precision at the 90% level of confidence.	X	X
	• Disaggregated results for measures with sufficient sample size based on on-site M&V Engineering Study.		X
	• Provision of primary discrepancies in savings estimates between tracking savings estimates and final gross savings estimates, including the impact of documentation errors, technology adjustment, quantity adjustment, operation adjustment and interactive.		X
2. Provide gross peak electric demand impacts of measures installed in the 2011 SBEA Program.	• SBEA Program electric energy demand savings coincident with summer on-peak and seasonal peak periods targeted to achieve +/-10 precision at the 80% level of confidence.		X
	• Disaggregated results for measures with sufficient sample size.		X
	• Provision of primary discrepancies in savings estimates between tracking savings estimates and final gross savings estimates, including the impact of documentation errors, technology adjustment, quantity adjustment, operation adjustment and interactive.		X
3. Provide recommendations on PSD updates	• Update the current PSD with results from this study as appropriate following an assessment of the existing 2012 PSD small business measure assumptions.		X

Program Population Summary

There are 1,696 customer sites that participated in the SBEA program from January 1–December 31, 2011. The two program sponsors combined for a total of 35,205,536 kWh saved in the 2011 Program Year, with lighting measures comprising the majority of electric savings (86%). Refrigeration and custom measures account for 7.6% and 3.1% of the 2011 Program Year electric savings, respectively.

Table 4: 2011 SBEA Program Activity

Measure Type/kWh	CL&P kWh (N=1,396)	% of CL&P Total	UI kWh (n=300)	% of UI Total	Total kWh (N=1,696)	% of Total
	Sponsor				Statewide	
Lighting	23,711,294	79.6%	4,422,281	81.5%	28,133,575	79.9%
Refrigeration	2,405,946	8.1%	260,141	4.8%	2,666,087	7.6%
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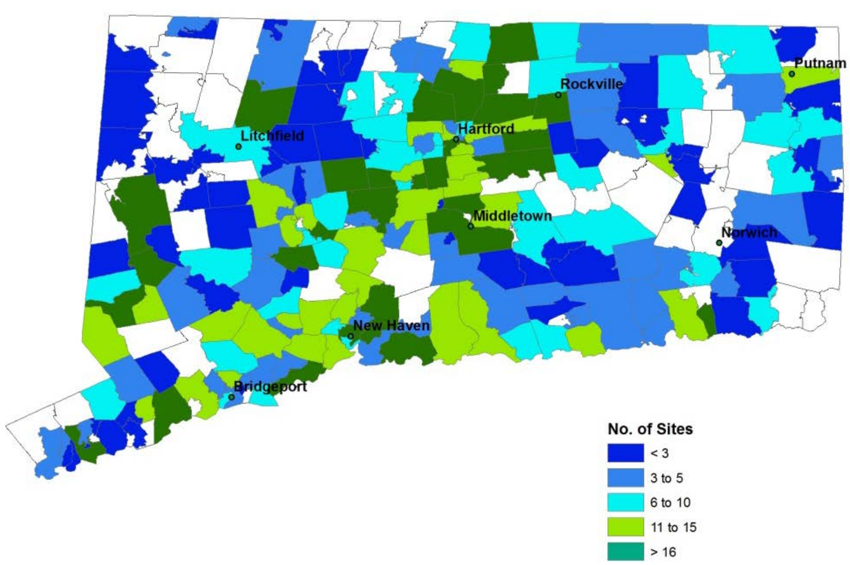
HVAC	617,812	2.1%	306,290	5.6%	306,290	1.8%
Process/Compressed Air	-	-	231,021	4.3%	231,021	0.7%
Total (kWh)	29,781,222	100.0%	5,424,314	100.0%	35,205,536	100.0%
Total (%)	84.6%		15.4%		100.0%	

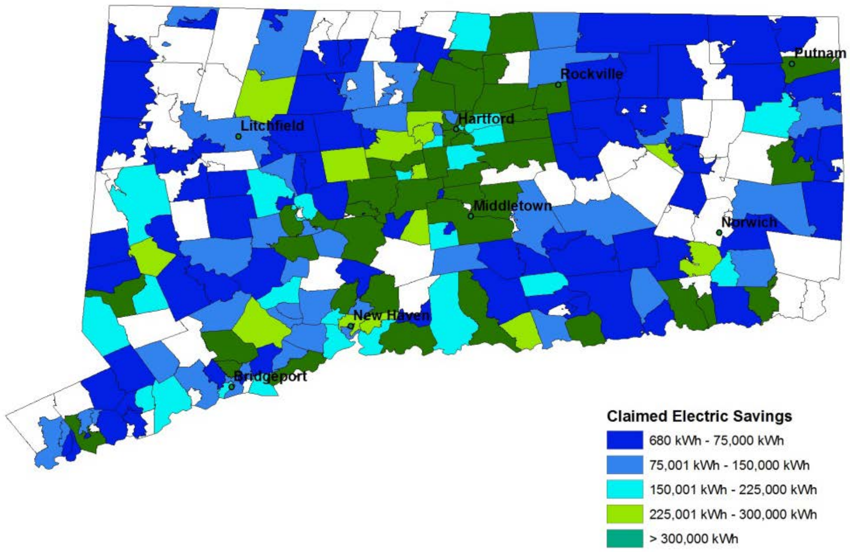
Figure 2 and Figure 3 show the spatial distribution of participants and the total claimed savings (kWh) in the 2011 CT SBEA program. Participants are spread-out across Connecticut with concentration around the major cities such as Hartford, Middletown, New Haven and Bridgeport. Many towns with SBEA activity have more than three participants in them. As expected, most of the claimed savings are clustered around these areas where program participation is high.

Figure 2: Distribution of 2011 Participants, Zip Code-Level[3]



[3] Note: 2010 Census boundary map for five zip codes (06012, 06246, 06258, 06711, and 06829) are not available. The map excludes sites/savings from these areas.

Figure 3: Distribution of Total Claimed Savings (kWh), 2011 Participants, Zip Code-Level



METHODOLOGY

This section of the report provides a detailed methodology for the two impact evaluation approaches used in this evaluation. These are 1) on-sites with metering, verification and analysis; and 2) the billing analysis.

On-sites with Metering, Verification and Analysis

There were multiple activities associated with the on-site work in this study. They included sampling, data collection, metering, savings' analysis and result expansions.[4] Each of these is discussed further below.

On-site Sampling

KEMA used Model-Based Statistical Sampling (MBSS) methodologies to inform the sample design of the on-sites with M&V. This methodology employs a stratified sample design that sorts the sample population by magnitude of estimated annual kWh savings, establishes strata cut points of roughly equal savings and randomly selects sites from within each stratum, typically of the same approximate quantity. This sample design emphasizes the portion of participants with larger impacts, thereby providing an optimal framework for conducting the analysis and for the subsequent stratified ratio estimation. We designed the sample to target ±10% relative precision at the 90% confidence interval for energy savings and ±10% relative precision at the 80% confidence interval for demand savings at the program level. In this study, we consider a sampling unit to be a lighting or non-lighting project at an account (even if they are located at the same site).

To perform the sample design for this study, we examined error ratios experienced from similar studies and assumed an error ratio of 0.35 for lighting energy savings, 0.7 for non-lighting

[4] Results expansion refers to the process used to take results from the sample and translate these into an accurate overall program result.

energy and 0.50 and 0.95 for peak demand lighting and non-lighting, respectively. Table 5 below presents the allocation and expected precisions by measure type for a total sample size of 60 sites. A sample of 42 Lighting and 18 Non-Lighting sites was expected to provide a ±8.6% precision overall for energy and ±9.5% for summer peak demand. Overall lighting was designed to achieve ±9.0% and non-lighting at better than ±30%.

Table 5: Anticipated Precision from M&V Onsite Approach

Measure Type	Total Savings	Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
Energy Savings (kWh)					
Lighting	30,276,003	0.35	90%	42	±9.0%
Non-lighting	4,929,534	0.70	90%	18	±27.6%
Total	35,205,536	0.40	90%	60	±8.6%
Summer Peak Demand Savings (kW)					
Lighting	6,328	0.50	80%	42	±10.0%
Non-lighting	554	0.95	80%	18	±29.2%
Total	6,883	0.54	80%	60	±9.5%

Table 6 provides our final stratified sample design. The first four columns in the table provides the measure type of interest (lighting versus non-lighting), stratum number, the energy savings cut point used to allocate sites to the strata and the number of projects[5] in each stratum. The final three columns show the savings in each stratum, the sample that was randomly selected and visited from the strata, and the final case weights used in the expansion analysis. The final achieved precisions are provided in the results section and are dependent on the final true error ratio experienced in this study.

[5] In this design, we defined a project as lighting or non-lighting savings collapsed by Site ID for CL&P and Project Number for UI.

Table 6: 2011 Proposed M&V On-site Sample Design

Measure Type	Stratum	Max Savings	Projects	Total Savings (kWh)	Sample	Case weights
Lighting	1	9,626	928	4,205,118	9	103.1
Lighting	2	21,435	361	5,181,736	9	40.1
Lighting	3	42,975	198	6,000,879	8	24.8
Lighting	4	77,501	120	6,835,923	8	15.0
Lighting	5	300,296	66	8,052,346	8	8.3
Non Lighting	1	10,246	250	866,384	5	50.0
Non Lighting	2	24,370	69	1,121,635	5	13.8
Non Lighting	3	50,282	39	1,300,893	4	9.8
Non Lighting	4	179,319	17	1,640,622	4	4.3
Total			2,048	35,205,536	60	

Recruitment for this sample was performed by experienced DNV KEMA phone recruiters. Table 7 presents the final disposition of the recruitment calls made for the 60 on-site visits based on the disposition codes provided in The American Association for Public Opinion Research's (AAPOR) *Standard* Definitions.[6] Based on the algorithms provided in this document we calculate a 68.2% response rate and a 4.5% refusal rate. Based upon our experience, we believe these rates are very reasonable for a study of this nature.

Table 7: Final M&V On-site Recruitment Disposition

Disposition Code	Disposition Description	Total
1.1	Completion	60
2.11	Refusal	4
2.21	Respondent Never Available	24
Total Customers Called		88

The response rate can be an indicator of potential bias associated with sample-specific estimates of population parameters. We cite it as a possible indicator since an assessment of the extent of bias due to non-response really rests upon any differences there might be between those customers that allowed the visit and those that we were unsuccessfully able to schedule. Since

[6] http://www.aapor.org/AM/Template.cfm?Section=Standard_Definitions2&Template=/CM/ContentDisplay.cfm&ContentID=3156

the recruitment was targeted to small businesses during a period of generally depressed economic conditions, we might expect the greatest risk of bias to this study being a sample of non-contacts due to business closings. In looking at the non-contacts in our sample through this prism, we note that most appear to be instances where the business was present (*e.g.,* dispositions where we left messages that were not responded to (voicemail, other), no one picked up the phone, or we spoke with someone who passed us on to another individual). As such, we are inclined to believe the response and refusal rates experienced in this study have not resulted in any particular bias in our final impact evaluation results.

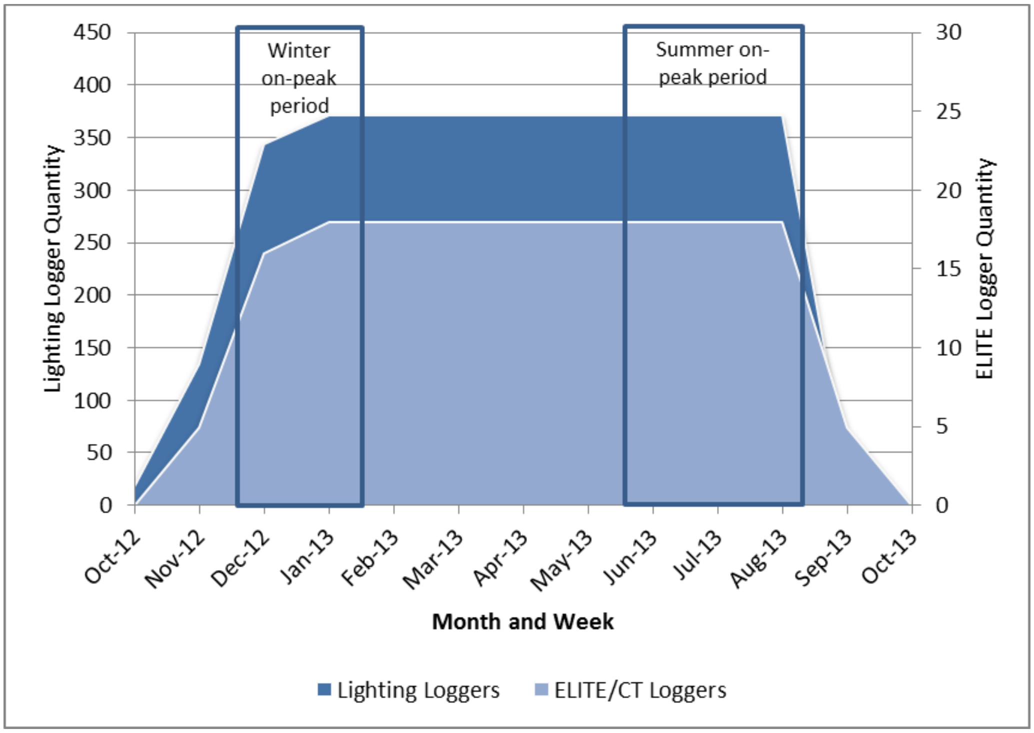
On-site Data Collection

Data collection performed at all lighting and non-lighting on-sites included physical inspection and inventory, interview with facility personnel, observation of site operating conditions and equipment, and the installation of metering for roughly 7-8 months to capture both summer and winter measure operation. At each site, the on-site team performed a facility walk-through focused on verifying the post-retrofit or installed conditions of each program-installed measure. Lighting sites also included collection of information on HVAC equipment and fuel types to assess interaction. The method employed for the lighting M&V visits adheres to IPMVP Option A and is described further below. This option (Retrofit Isolation: Key Parameter Measurement Savings) uses a combination of stipulated factors (wattage) as well as measurements of key factors (*i.e*., quantity and hours of use) to calculate savings in an engineering model.

IPMVP Option A was also used to verify non-lighting saving. The variables reviewed were similar to the lighting analysis and included the quantity of units, baseline unit kW, installed unit kW, and annual operating hours. Operating hours were further reviewed to identify potential seasonal operating variances through discussions with facility personnel. Most of the non-lighting measures were part of existing refrigeration systems. The M&V analysis also verified the type and temperatures of the refrigerated units, the efficiencies of refrigeration compressors, and physical dimensions of installed night curtains.

Figure 4 below provides a graphical presentation of the lighting logger and power meter installation deployed at the on-site visits. The Y axis shows the number of sites with loggers installed while the X axis shows the months of installation. We began installations in early October of 2012 with nearly all loggers installed by mid-January of 2013. The majority of loggers were removed between August and September of 2013.

Figure 4: M&V On-site Logger Installation and Removal Timeline



Peak Period Definitions and Methods

A key goal of the SBEA impact study is to estimate both on-peak and seasonal peak coincident demand savings. In the ISO New England Forward Capacity Market (FCM), a participant may submit energy-efficiency "other demand resources" as one of three different types: On-Peak, Seasonal Peak, and Critical Peak. The first two peak definitions (On-Peak and Seasonal Peak) are of importance to this study as United Illuminating and Connecticut Light and Power participate in FCM as a Seasonal Peak Demand Resource but are interested in understanding how performance varies with that of the on-peak resource definition. The following definitions of these peaks 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 peak load forecast, as determined by the ISO, for the applicable summer or winter season."[7]

The On-Peak defined resource is defined as the same set of hours during the same weekday conditions year after year. It is considerably more complex to assess coincidence relative to the

[7] 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.

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. Appendix B provides the specific method employed to identify the hours that qualify as seasonal peak hours. There are 53 such hours during the summer and 4 in the winter.

Savings Calculation Methodologies

We present lighting and non-lighting savings methodologies in turn in this section of the report.

Lighting

Once all on-site data was gathered and logger time of use data downloaded, all data was analyzed to produce energy, demand and peak demand savings estimates for each site. Lighting measures are a time dependent measure type that runs at a constant load. Mathematically, hour-of-day and day-of-week are usually the most relevant variables in the energy savings analysis of these measures. Therefore, to support the savings work, an 8,760 hourly spreadsheet analysis was developed for each logger series[8], which were used to estimate hourly energy use and diversified coincident peak demand for all lighting sites.

A spreadsheet engineering model was used to develop all savings estimates and factors of interest for each sampled site. A typical meteorological year (TMY3) dataset of ambient temperatures for the location closest to each site was used for all interactive savings analyses (see below). The savings analysis was performed on a line by line basis, in which pre (baseline) and post (retrofit) conditions were recorded for each location treated. The on-site pre-retrofit condition is established through review of project documents, discussion with facility personnel, and observational inference. Standard wattages consistent with those in use by the utilities were used to calculate watts saved along with quantities observed in the on-sites.

Heating and cooling interaction was calculated for each line item where applicable based on the HVAC system type and fuel serving the space. When lighting equipment converts electrical energy to light, a significant amount of that energy is dissipated in the form of heat. Energy efficient lighting measures convert more electrical energy to light and less to heat. Since installing energy efficient lighting adds less heat to a given space, a complete estimation of energy savings considers the associated impacts on the heating and cooling systems or "interactive effects." We used Coefficients of Performance (the ratio of work performed by the system to the work input of the system) associated with each system type with the 8,760 profile of hourly demand impacts to compute electric interactive affects during the hours that lighting and HVAC are assumed to operate in unison.

Typical Meteorological Year 3 (TMY3) hourly dry-bulb temperatures for the weather station closest to each facility were used as the balance point criteria in this analysis. For each hour in a typical year, DNV KEMA computed HVAC interaction. In this analysis, we assumed that 80% of lighting energy 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.

[8] By logger series, we mean the series of loggers used to log a fixture over the course of the logged period.

Non-lighting Electric Measures

Savings for all non-lighting electric measures were calculated using an 8,760 hour analysis spreadsheet. This spreadsheet calculates baseline energy usage, installed energy usage, kWh energy savings, summer on-peak kW, winter on-peak kW, summer seasonal peak kW, winter seasonal peak kW, and on-peak energy kWh as unique values for every hour of the year.

The baseline data for the calculations are obtained from tracking documentation and confirmed or modified from nameplate data obtained during the site visits. Installed performance is obtained from monitoring equipment installed during the site visits, instantaneous power measurements taken during the site visits, data taken from digital controls at the sites, and from discussions with facility personnel.

There were two primary types of monitoring equipment deployed in this study for non-lighting measures, both of which meet the ISO-NE requirements for the measurement of demand resources:

Elite power loggers monitor voltage, amperage, power factor, and kW over the monitoring period. The monitoring frequency was every 15 minutes over the monitoring period. Elite power loggers were installed on variable load and constant load measures.

Watts-Up loggers were used to monitor the operation of small plug loads. The unit was plugged into the Watts-Up meter, which was plugged into the wall socket. The meter provided the average hourly power consumption and the on/off schedule of the unit.

There were seven measure types assessed as part of non-lighting savings work. The approach taken to meter each are discussed briefly below.

Compressed Air There were two sites in the sample with compressed air measures. Elite loggers were used to monitor power of the air compressors. One air dryer was also monitored. Average monitored power was converted to percent load from performance curves. Performance curves for baseline equipment provide the corresponding power used in the savings analysis.

Novelty Timers The novelty timers installed in the sample were for refrigerated vending machines and one refrigerated water cooler. The novelty timers acted as time clocks shutting vending machine lighting and compressors off during unoccupied hours. There were 12 sites in the sample with compressed air measures. Watts-Up loggers, TOU loggers, Elite power loggers were used in various configurations to capture the impact of the controls, depending upon access to equipment. TOU meters were used if dedicated circuits could be identified in electrical panels. Elite power loggers were used if other measures were being monitored and circuits were available. Watts-Up loggers were used for remaining applications.

Variable Speed Drives There were two sites in the sample with compressed air measures. Elite power loggers were used for VSD measures. These loggers provided the operating schedule and reported the variable performance of the equipment.

Energy Efficient Motors There was one site in the sample that had an energy efficient motor compressed air measure. Elite power loggers and TOU loggers were used. This provided the operating schedules for the equipment. Baseline and confirmed nameplate efficiencies were used in the calculations.

Anti-Condensate Heater Controls There were 10 sites in the sample with Anti-Condensate Heater Controls measures. Elite power loggers and TOU loggers were used. This provided the operating schedules for the equipment. Baseline and confirmed nameplate efficiencies were used in the calculations.

Electrically Commutated Fan Motors and Fan Motor Controls There were 15 sites in the sample with electrically commutated fans and 14 with electrically commutated fan motor controls. Elite power loggers and TOU loggers were used. This provided the operating schedules for the equipment. Baseline and confirmed nameplate efficiencies were used in the calculations. Nameplate refrigeration compressor data and efficiencies were used to calculate interactive refrigeration savings.

Refrigeration Night Curtains There were three sites in the sample with refrigeration night curtain measures. The linear footage of installed curtains and refrigerated case types were verified along with store occupancy hours.

The data gathered from metering equipment was converted into hourly values for use in the 8,760 calculation spreadsheet. Two tables were commonly used in each analysis. Due to the extended monitoring period, corresponding real time hourly data was used in the calculations for each hour of the monitoring period. A second lookup table containing average hourly data was created for the remaining annual hours outside the monitoring period. This table provides a unique hourly usage for each of the week's 168 hours.

Regression analysis was also used in estimating compressed air performance. Power use is a function of the load on the air compressor. This can be expressed through a power to load formula. The monitored power was converted to a percent load using manufacturers' performance curves. Curves for baseline equipment provided the baseline power at the corresponding hourly loads through a regression analysis formula.

Savings/performance was calculated for each hour of the year. Monitored data also provided the on/off schedules of equipment identifying which hours of the year contained savings. The seasonal and on-peak demand hours provided by the utilities were then applied to the hourly calculations to generate the demand and on-peak energy savings.

Both the lighting and non-lighting measure level analyses were performed in a manner that allowed the determination of impacts at each of the primary reasons for discrepancies that might cause the gross savings to differ from the tracking savings. Performing the analysis in this manner also allows us to report impacts at each level of adjustment. Each of these adjustments, or discrepancies, is described below:

- Documentation Adjustment (kWh, kW): The Documentation Adjustment reflects any change in savings due to discrepancies in project documentation. Evaluators recalculated the tracking estimates of savings using all quantities, fixture types/wattages, and hours documented in the project file. All tracking system discrepancies and documentation errors are reflected in this adjustment.
- Technology Adjustment (kWh, kW): The Technology Adjustment reflects the change in savings due to the identification of a different lighting technology (fixture type and wattage) or equipment efficiency (*e.g.*, for motors) at the site than represented in the tracking system estimate of savings.

- Quantity Adjustment (kWh, kW): The Quantity Adjustment reflects the change in savings due to the identification of a different quantity of program installed efficient measures at the site than presented in the tracking system estimate of savings.
- Operational Adjustment (kWh): The Operational Adjustment reflects the change in savings due to the observation or monitoring of different operating hours for the measures at the site than represented in the tracking system estimate of savings.
- Coincidence Adjustment (kW): The Coincidence Adjustment reflects the change in demand savings due to measure performance during specific periods of on-peak and/or seasonal peak operation than represented in the tracking system estimate of savings.
- HVAC Interactive Adjustment (kWh, kW): The HVAC Interactive Adjustment reflects changes in savings due to interaction, which for this study was between the lighting and HVAC systems among the sampled lighting sites. Generally, these impacts cause a heating penalty and a cooling credit. This adjustment reflects impacts from electric heating and/or cooling.

Expansion Analysis

Once the field work is completed, the gross site results and the program engineering estimates are compared through a ratio term, which represents observed performance in the field relative to engineering based expectations from the project file (and tracking system). This realization rate, the ratio of measured (the M&V site visit results with any necessary re-engineering of savings) to estimated (tracking system/project file estimate) savings is the common reference for the impact evaluation. The realization rates are the most important output from impact evaluations for several reasons. These are:

1. An estimated of the evaluated savings can be obtained from either the year under evaluation or any more current year where the program's methodology for estimating savings has not changed substantially by multiplying the program's claimed/tracking system estimate of savings times the realization rate from the evaluation.
2. The realization rate provides information as to how well the program is estimating savings and when viewed by energy versus demand, measure or disaggregated by types of adjustment can point to areas where the program might want to investigate the method and assumptions used in estimating a project's savings and program savings claims.
3. Targeting the realization rate removes the large differences in savings estimates by size of facility or measure such that sampling can be accomplished efficiently and impact evaluations cost far less than if the target were the savings estimate itself.

Overall program realization rates with their associated precisions are provided below, along with lighting and non-lighting levels of disaggregation. A detailed discussion of the expansion analysis methods and formulas are provided in Appendix B.

Billing Analysis

A billing analysis was performed on all electric program measures installed in 2011. There were three stages of work associated with performing the SBEA billing analysis. These included the gathering and assessment of participant and their associated consumption data, the examination of billing data and selection of analysis candidates, and the performance of PRISM and Fixed Effects modeling. These are each discussed below.

Data Sources and Disposition

This section describes the datasets used in the billing analysis. This process began collecting participant information from the utilities, including the types of measures installed, installation months, claimed savings from CL&P and UI program tracking database and historical monthly consumption from utility billing data. Weather data used in this evaluation were gathered from NOAA[9] and NREL[10]. Table 8 summarizes the different datasets used in this evaluation effort.

Table 8: Data used in Billing Analysis

Data		CL&P	UI
Tracking data	No. of customers	1,427	297
	Installation period	Jan 2011 – Dec 2011	Jan 2011 – Dec 2011
	Total kWh savings	29,781,222	5,295,644
Billing data	Available months	May 2009 – Mar 2013	Jun 2009 – Feb 2013
Weather data	Weather stations	Bradley (USAF=725080) Bridgeport (USAF=725040)	Bradley (USAF=725080) Bridgeport (USAF=725040)

Prior to analysis, we examined the billing and tracking data for completeness and potential data issues such as duplicates, extreme values, missing observations and other possible inconsistencies. These data preparation steps and their outcomes include the following:

- Examined missing consumption values
  - For most UI sites, we found missing consumption data from Oct 2009 to Feb 2010
- Investigated multiple meter reads
  - For most CL&P sites, we found two non-overlapping meter reads in June and December. These reads are followed by short reads in July and January. For these cases, we summed up consumption values from the second read in June and short read in July to represent consumption in July and summed up usage values from the second read in December and short read in January to represent consumption in January.
- Identified the number of billing periods available within one year prior and after measure installation.
- Identified sites with estimated reads and negative consumption values.
- Identified sites that changed or added account during the analysis period.
- Examined extreme consumption values (less than 2,000 kWh/year and greater than 800,000 kWh/year).
- Identified sites with short (less than 20 days) and/or long (greater than 40 days) reads in a billing interval.

[9] National Oceanic and Atmospheric Administration

[10] National Renewable Energy Laboratory (NREL), U.S. Department of Energy

DNV KEMA limited the billing analysis to sites with a full year of consumption data during the pre- and post-installation period to ensure that winter, summer and shoulder month are well represented. Table 9 summarizes the program population, number of sites excluded from the analysis and the final sample used in estimating program savings. The final sample used in the analysis represents 71% of the initial program population.

Table 9: Initial and Final sample Used in Billing Analysis

Data	CL&P	UI	Total
Initial no. of sites/participants	1,427	297	1,724
Sites with billing data	1,376	295	1,671
Without 12 months of billing data during pre- and post-installation period	292	50	342
Sites with full year of consumption data during pre- and post-installation	1,084	245	1,329
Sites that changed accounts, with extreme usage values, with negative usage, with short/long reads in a billing interval	86	24	110
Final sample used in billing analysis	998	221	1,219

PRISM Model

The first analysis performed was that of site-level modeling to examine cooling and heating set points for program participants. This analysis results in a weather-adjusted consumption estimate that reflects a typical weather year for each site.

Below shows the model specification used:

Below shows the model specification used:

$$E_{im} = \mu_i + \beta_H H_{im}(\tau_H) + \beta_C C_{im}(\tau_C) + \varepsilon_{im}$$

where:

E_{im}	is the average electric (or gas) consumption per day for participant *i* during billing period *m*
μ_i	is the base load usage (intercept) for participant *i*,
$H_{im}(\tau_H)$	Heating degree-days (HDD) at the heating base temperature τ_H,
$C_{im}(\tau_C)$	Cooling degree-days (CDD) at the cooling base temperature τ_C,
β_H	Heating coefficient, determined by the regression,
β_C	Cooling coefficient, determined by the regression
τ_H	Heating base temperatures, determined by choice of the optimal regression,

τ_C Cooling base temperatures, determined by choice of the optimal regression, and

ε_{im} Regression residual.

We estimated consumption across a range of heating degree day bases instead of fixing to a single degree day base temperatures. Cooling degree-day bases covered 64°F to 84°F while heating degree day bases covered 50°F to 70°F. Electric consumption was estimated using a 'heating and cooling model', 'cooling only model', 'heating only model' and 'baseload only model'. For each model estimated, we used an F-test to determine which model specification is superior, and we chose the best heating degree base for each site based on the individual R-squared.

The distributions of cooling and heating base temperatures from the best model were examined. If the optimal heating degree day base temperature is on the border, we force the degree day bases to the mean (70°F for cooling and 60°F for heating) and re-estimated the models. Normalized Annual Consumption (NAC) were computed using the following equation.

$$\boldsymbol{NAC_i = (365 \times \hat{\mu}_i) + \hat{\beta}_H H_0 + \hat{\beta}_C C_0}$$

Where:

NAC_i	Normalized annual consumption for customer i,
H_0	Annual TMY HDD calculated at the optimal heating base temperature $\hat{\tau}_H$ for participant i,
C_0	Annual TMY CDD calculated at the optimal cooling base temperature $\hat{\tau}_C$ for participant i,
$\hat{\mu}_i, \hat{\beta}_H, \hat{\beta}_C$	Baseload and heating parameter estimates from the site-level models.

The average normalized annual consumption from PRISM is used to express the estimated weather-adjusted savings in percentage terms. The mean/median of the optimal base temperatures for heating and cooling are used as the set points for calculating degree days in the fixed effects model.

The distributions of the individual optimal cooling and heating temperatures calculated for each site are presented in Appendix E.

Fixed Effects Model

A billing analysis using a Fixed Effects model was also performed to estimate program savings. The Fixed Effects approach addresses non-program related change without the exclusion of a separate comparison group. It allows each customer to be their own control (what they would otherwise have done is their prior usage relationship) and provides for a more efficient regression model. For each IOU, all monthly consumption data (both pre and post-installation) of eligible participants are included in a single model with the following specification:

$$E_{im} = \mu_i + \beta_1 Post_{im} + \beta_2 CDD70_{im} + \beta_3 HDD60_{im} + \beta_4 PostCDD70_{im} + \beta_5 PostHDD60_{im} + \theta_m + \varepsilon_{im}$$

where:

E_{im}	is the average electric consumption per day for participant *i* during billing period *m*
μ_i	is the fixed effect (or specific intercept) for participant *i*
$Post_{im}$	is the post indicator (1 for post-installation and 0 for pre-installation period)
$CDD70_{im}$	is the average daily cooling degree days (CDD) at 70^{0}F for participant *i* during billing period *m*
$HDD60_{im}$	is the average daily heating degree days (HDD) at 60^{0}F for participant *i* during billing period *m*
$PostCDD70_{im}$	is the interaction term between post indicator and CDD70
$PostHDD60_{im}$	is the interaction term between post indicator and HDD60
θ_m	are monthly dummy variables for each billing month
β_1	is the change in energy consumption during post-installation period
β_2	is the effect of cooling on energy consumption during pre-installation period
β_3	is the effect of heating on energy consumption during pre-installation period
β_4	is the change in the effect of cooling on energy consumption during post-installation period
β_5	is the change in the effect of heating on energy consumption during post-installation period

Weather-normalized savings are calculated as:

$$Ave\ Normalized\ Daily\ Savings = \hat{\beta}_1 + \left(\hat{\beta}_4 \times \overline{CDD70}_{norm}\right) + \left(\hat{\beta}_5 \times \overline{HDD60}_{norm}\right)$$

where:

$\widehat{\beta_1}, \widehat{\beta_4}, \widehat{\beta_5}$	are coefficients determined by the fixed effects model
$\overline{CDD70}_{norm}$	is the average daily CDD calculated using temperature data from TMY3
$\overline{HDD60}_{norm}$	is the average daily HDD calculated using temperature data from TMY3

RESULTS

This section is broken up into two primary sections. They include a section on the results of the metering and verification with expansion followed by the billing analysis results.

On-sites with Metering, Verification and Analysis

This element of the study included both lighting and non-lighting electric measure types. We present the results separately for lighting, non-lighting, as well as overall (program level). There are five specific results of interest from this study activity, which are listed below. Where appropriate, we provide precisions around each result at the 90% confidence interval.

- kWh Savings and Realization Rate – This savings value represents the energy savings achieved by the program. The accompanying realization rate is the ratio of the evaluated gross energy savings divided by the tracking gross energy savings. This realization rate is broken out by various adjustments, including documentation, technology, quantity, hours of use and interactive. This result is provided overall as well as separately for lighting and non-lighting electric measures.
- Summer On-peak Savings and Realization Rate – This savings value is the percentage of the connected kW savings coincident with the summer on-peak period, which is defined as hours from 1 p.m. to 5 p.m. Monday through Friday on non-holidays during the months of June, July, and August. The accompanying realization rate is the ratio of the evaluated summer on-peak demand savings divided by the tracking estimate of summer demand savings.
- Summer Seasonal Peak Savings and Realization Rate – This realization rate is the percentage of connected kW savings coincident with the summer seasonal peak period, which is defined as hours in which the actual, Real-Time hourly load Monday through Friday on non-holidays, during the months of June, July, and August meets or exceeds 90% of the predicted seasonal peak from the most recent ISO-NE Capacity, Electricity, Load and Transmission Report (CELT report). The accompanying realization rate is the ratio of the evaluated summer seasonal peak demand savings divided by the tracking estimate of summer demand savings.
- Winter On-peak Savings and Realization Rate – This realization rate is the percentage of the connected kW savings coincident with the winter on-peak period, which is defined as hours from 5 p.m. to 7 p.m. Monday through Friday on non-holidays during the months of December and January. The accompanying realization rate is the ratio of the evaluated winter on-peak demand savings divided by the tracking estimate of winter demand savings.

Figure 5 presents a scatter plot of evaluation results versus tracking savings for annual energy savings (kWh). A one-to-one reference line is plotted as a dashed line on the diagonal of the figure. We plot lighting and non-lighting electric results individually along with realization rates for each reflected as light blue and dark blue lines, respectively. The lighting annual kWh realization rate is 99.0% while the electric non-lighting is 79.1%. Although not shown, the overall program level realization rate is 92.9%. The primary driver of the overall realization rate are the lighting savings, which repersent nearly 80% of the overall statewide program savings.

Figure 5: Scatter Plot of M&V On-site Evaluation Results for Annual kWh Savings

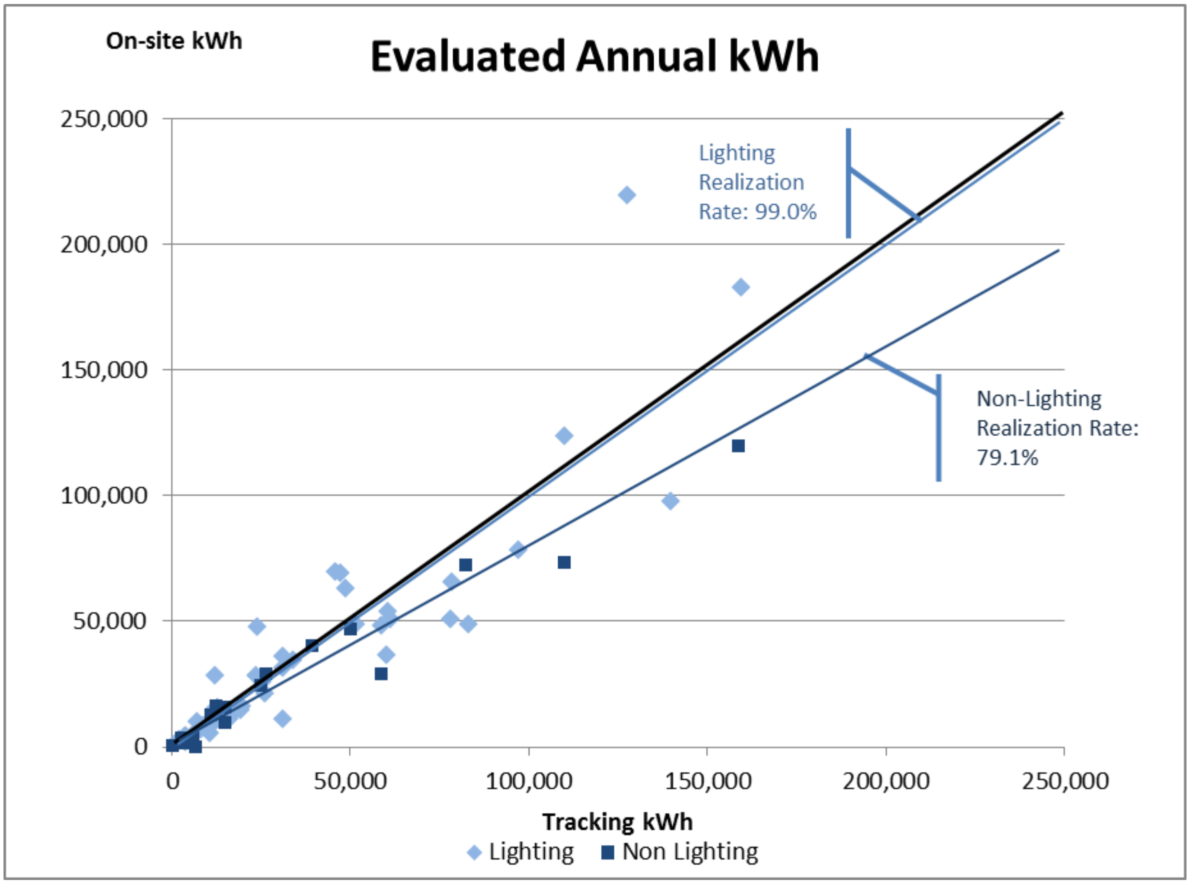


Table 10 summarizes the overall SBEA Program evaluation energy savings results. This table presents these results by nature of discrepancy in two ways. The first is by providing the incremental ratio, which shows the percent difference between each level of adjustment. The second is cumulative ratio, which shows the percent difference cumulatively at each level of adjustment and the tracking estimate. Showing the results in this manner allows one to see the relative change from one adjustment to another as well as the overall accumulated change relative to the tracking estimate.

The annual energy savings gross realization rate for the 2011 SBEA Program was found to be 96.2%, including HVAC interactive effects. The relative sampling precisions for the final impact estimate with interactive is ±7.8% at the 90% confidence interval, which is slightly better than the ±8.6% targeted in our sample design. The positive operational adjustment and negative HVAC interaction largely netted one another out while the combined documentation and quantity adjustments put some modest pressure on the final realization rate. Documentation adjustments reflect the difference between the tracking system estimate of savings and that calculated from the PSD. One interesting thing about these results is that because the CT utilities include interactive in their tracking system savings estimated (consistent with the PSD), the evaluated interactive decreases as we found it to be overestimated in the tracking system. A total of 33,874 MWh of energy savings are estimated from 2011 SBEA Program activity based upon the on-site M&V approach.

Table 10: Evaluated Annual Electricity Savings from M&V

		Incremental Ratio		Cumulative Ratio	
Overall (n=60)	kWh	Adjust-ment Factor	Relative Precision at 90% Confidence	Adjust-ment Factor	Relative Precision at 90% Confidence
Tracking	35,205,536	N/A	N/A	N/A	N/A
Documentation Adjustment	34,564,545	98.2%	1.4%	98.2%	1.4%
Technology Adjustment	34,598,578	100.1%	0.2%	98.3%	1.3%
Quantity Adjustment	34,030,225	98.4%	1.6%	96.7%	2.1%
Operational Adjustment	36,326,162	106.7%	7.3%	103.2%	7.5%
HVAC Interactive Adjustment	33,873,684	93.2%	2.0%	96.2%	7.8%
Gross Realization Rate	33,873,684	96.2%	7.8%	96.2%	7.8%

Table 11 is structured the same Table 10 and presents the evaluated energy results for the electric non-lighting measures installed in the SBEA Program. The realization rate for this subset of program measures is 79.1% with an associated sampling precision of ±18.7% at the 90% confidence interval. The largest discrepancies between the non-lighting evaluated savings and the tracking savings were observed in the documentation adjustment and quantity adjustment. The estimation of hours of use among these measures was largely accurate and resulted in a 4% adjustment.

Table 11: Evaluated Non-lighting Annual Electricity Savings from M&V

		Incremental Ratio		Cumulative Ratio	
Non-Lighting (n=18)	kWh	Adjustment Factor	Relative Precision at 90% Confidence	Adjustment Factor	Relative Precision at 90% Confidence
Tracking	4,929,534	N/A	N/A	N/A	N/A
Documentation Adjustment	4,363,045	88.5%	9.5%	88.5%	9.5%
Technology Adjustment	4,372,870	100.2%	0.3%	88.7%	9.5%
Quantity Adjustment	4,077,801	93.3%	10.6%	82.7%	14.2%
Operational Adjustment	3,900,816	95.7%	12.1%	79.1%	18.7%
HVAC Interactive Adjustment	3,900,816	100.0%	0.0%	79.1%	18.7%
Gross Realization Rate	3,900,816	79.1%	18.7%	79.1%	18.7%

Table 12 presents the evaluated energy results for the lighting measures installed in the SBEA Program. Recall, lighting measures represent nearly 86% of all program savings, and as such these results are the primary driver of overall program results. The realization rate for the lighting measures in the SBEA Program is 99.0% with an associated precision of ±8.5% at the 90% confidence interval. The tracking savings calculation under-estimated the operating hours of the installed lighting, but overestimated the interactive savings from them.

Table 12: Evaluated Lighting Annual Electricity Savings from M&V

Lighting (n=42)	kWh	Incremental Ratio		Cumulative Ratio	
		Adjust-ment Factor	Relative Precision at 90% Confidence	Adjust-ment Factor	Relative Precision at 90% Confidence
Tracking	30,276,003	N/A	N/A	N/A	N/A
Documentation Adjustment	30,201,500	99.8%	0.4%	99.8%	0.4%
Technology Adjustment	30,225,709	100.1%	0.3%	99.8%	0.5%
Quantity Adjustment	29,952,424	99.1%	1.1%	98.9%	1.1%
Operational Adjustment	32,425,346	108.3%	8.1%	107.1%	8.2%
HVAC Interactive Adjustment	29,972,868	92.4%	2.2%	99.0%	8.5%
Gross Realization Rate	29,972,868	99.0%	8.5%	99.0%	8.5%

Table 13 provides the overall results around summer on-peak and seasonal demand impacts. The value changes in these tables always reference the previous adjustment estimate. As one might expect, the on peak and seasonal peak results are very similar since the first series of adjustments are the same for each. The summer on-peak savings estimate is 6,093 kW, with a precision of ±11.0% at the 90% confidence level. The summer seasonal peak savings estimate is 6,187 kW, with an associated sampling precision of ±10.7% at the 90% confidence level. The precisions for the on-peak and seasonal peak estimates at the 80% confidence interval are ±8.6% and ±8.3%, respectively.

Table 13: Evaluated Summer On-peak and Seasonal Demand Savings from M&V

	Summer On Peak			Summer Seasonal		
Non Lighting (n=18)	**kW**	**Adjustment Factor**	**Relative Precision at 90% Confidence**	**kW**	**Adjustment Factor**	**Relative Precision at 90% Confidence**
Tracking	6,883	N/A	N/A	6,883	N/A	N/A
Documentation Adjustment	6,856	99.6%	4.7%	6,856	99.6%	4.7%
Technology Adjustment	6,868	100.2%	0.7%	6,868	100.2%	0.7%
Quantity Adjustment	6,801	99.0%	2.1%	6,801	99.0%	2.1%
Operational Adjustment	6,270	92.2%	9.7%	6,365	93.6%	9.3%
HVAC Interactive Adjustment	6,093	97.2%	1.5%	6,187	97.2%	1.5%
Gross Realization Rate	6,093	88.5%	11.0%	6,187	89.9%	10.7%

Table 14 provides the non-lighting summer on-peak and seasonal demand impacts. The summer on-peak savings estimate is 547 kW, with a precision of ±23.7% at the 90% confidence level. The summer seasonal peak savings estimate is 574 kW, or roughly 5% higher than the on-peak estimate, with an associated precision of ±25.9% at the 90% confidence level. The precisions for the on-peak and seasonal peak estimates at the 80% confidence interval are ±18.5% and ±20.2%, respectively.

Table 14: Evaluated Non-Lighting Summer On-peak and Seasonal Demand Savings from M&V

	Summer On Peak			Summer Seasonal		
Non Lighting (n=18)	kW	Adjust-ment Factor	Relative Precision at 90% Confidence	kW	Adjust-ment Factor	Relative Precision at 90% Confidence
Tracking	554	N/A	N/A	554	N/A	N/A
Documentation Adjustment	554	100.0%	0.0%	554	100.0%	0.0%
Technology Adjustment	554	100.0%	0.0%	554	100.0%	0.0%
Quantity Adjustment	512	92.4%	14.1%	512	92.4%	14.1%
Operational Adjustment	547	106.8%	18.9%	574	112.0%	21.6%
HVAC Interactive Adjustment	547	100.0%	0.0%	574	100.0%	0.0%
Gross Realization Rate	547	98.6%	23.7%	574	103.5%	25.9%

Table 15 provides the lighting summer on-peak and seasonal demand impacts. The summer on-peak savings estimate is 5,547 kW, with a precision of ±11.9% at the 90% confidence level. The summer seasonal peak savings estimate is 5,613 kW, with an associated precision of ±11.5% at the 90% confidence level. The precisions for the on-peak and seasonal peak estimates at the 80% confidence interval are ±9.2% and ±8.9%, respectively.

The average summer coincidence factor calculated for the 2011 SBEA Program population (using the assumptions provided in the PSD) is 65.1%. Using the data gathered on-site, the average summer on-peak evaluation result is 57.4% and the average summer seasonal peak evaluation result is 58.1%.

Table 15: Evaluated Lighting Summer On-peak and Seasonal Demand Savings from M&V

	Summer On Peak			Summer Seasonal		
Lighting (n=42)	**kW**	**Adjust-ment Factor**	**Relative Precision at 90% Confidence**	**kW**	**Adjust-ment Factor**	**Relative Precision at 90% Confidence**
Tracking	6,328	N/A	N/A	6,328	N/A	N/A
Documentation Adjustment	6,302	99.6%	5.1%	6,302	99.6%	5.1%
Technology Adjustment	6,313	100.2%	0.8%	6,313	100.2%	0.8%
Quantity Adjustment	6,288	99.6%	2.0%	6,288	99.6%	2.0%
Operational Adjustment	5,723	91.0%	10.4%	5,791	92.1%	9.9%
HVAC Interactive Adjustment	5,547	96.9%	1.7%	5,613	96.9%	1.7%
Gross Realization Rate	5,547	87.6%	11.9%	5,613	88.7%	11.5%

Although not requested in the RFP, Table 16 shows the overall winter on-peak and seasonal demand impacts. The largest adjustment to the tracking is the documentation adjustment, which is more than 36% higher than the tracking system value. This large documentation adjustment was due to three sites in the sample that had tracking winter demand savings estimates of zero, one of which was very large. The evaluated winter on-peak savings estimate is 5,148 kW, with a precision of ±20.8% at the 90% confidence level. The winter seasonal peak savings estimate is 4,440 kW, with an associated precision of ±22.5% at the 90% confidence level. The precisions for the on-peak and seasonal peak estimates at the 80% confidence interval are ±16.2% and ±17.6%, respectively.

The average winter coincidence factor calculated for the 2011 SBEA Program population (using the assumptions provided in the PSD) is 62.2%. Using the data gathered on-site, the average winter on-peak evaluation result is 49.4% and the average winter seasonal peak evaluation result is 42.3%.

Table 16: Evaluated Winter On-peak and Seasonal Demand Savings from M&V

Overall (n=60)	Winter On Peak kW	Winter On Peak Adjust-ment Factor	Winter On Peak Relative Precision at 90% Confidence	Winter Seasonal kW	Winter Seasonal Adjust-ment Factor	Winter Seasonal Relative Precision at 90% Confidence
Tracking	4,710	N/A	N/A	4,710	N/A	N/A
Documentation Adjustment	6,409	136.1%	17.1%	6,409	136.1%	17.1%
Technology Adjustment	6,421	100.2%	0.8%	6,421	100.2%	0.8%
Quantity Adjustment	6,362	99.1%	2.2%	6,362	99.1%	2.2%
Operational Adjustment	5,180	81.4%	11.3%	4,478	70.4%	14.4%
HVAC Interactive Adjustment	5,148	99.4%	1.1%	4,440	99.2%	1.4%
Gross Realization Rate	5,148	109.3%	20.8%	4,440	94.3%	22.5%

Although also not requested in the RFP, Table 17 presents the overall connected demand results. The documentation adjustment for connected demand is even higher than it is for winter demand, with a nearly 66% increase over the tracking system value. Despite the energy tracking savings estimates being largely correct, forty seven of the 60 sampled sites had connected demand tracking values that were incorrect; most of them lower in the tracking system than when calculated per the PSD. We do not believe that connected or winter demand values are important metrics in CT or for ISO-NE purposes, so it might be that these fields do not get the same level of attention given energy and summer demand impacts. The final overall connected demand result is 30,372 kW with ±17.4% at the 90% confidence level and ±13.6% at the 80% confidence level.

Table 17: Evaluated Connected Demand Savings from M&V

Overall (n=60)	kW	Incremental Ratio Adjust-ment Factor	Incremental Ratio Relative Precision at 90% Confidence	Cumulative Ratio Adjust-ment Factor	Cumulative Ratio Relative Precision at 90% Confidence
Tracking	18,809	N/A	N/A	N/A	N/A
Documentation Adjustment	31,149	165.6%	15.7%	165.6%	15.7%
Technology Adjustment	31,160	100.0%	0.1%	165.7%	17.0%
Quantity Adjustment	30,372	97.5%	4.4%	161.5%	17.6%
Gross Realization Rate	30,372	161.5%	17.4%	161.5%	17.4%

PROGRAM SAVINGS DOCUMENT REVIEW

The Connecticut Program Savings Document (PSD) is designed to be the source of savings calculations and assumptions for tracking program savings. The PSD is a document that is constantly evolving to reflect new findings and studies in its calculations and parameters. While this study did not explicitly target the updating of the measures examined, we did review the current PSD for the four primary measures explored in this study to assess opportunities to recommend calculation or assumption changes based upon our findings. The four measures examined in this manner are lighting, door heater controls (aka anti-condensate heaters), vendor heating controls, and evaporator fan motor replacement and evaporator fan controls. We discuss each below.

Lighting

The formula to calculate lighting energy savings in the PSD includes the calculation of savings from the installation of reduced wattage lamps, including interactive[11]. The PSD also has a formula for the calculation of savings due to lighting controls. The CT PSD is somewhat unique from similar documents used in other jurisdictions as it includes the calculation interactive in its lighting calculations, where most others do not.

The calculation method for determining lighting savings adheres to industry standards. The lighting savings calculated for the SBEA Program utilizes standard pre and post watts based upon the actual equipment removed and installed and the hours of operation as gathered from the site contact. Based on our results, these self-reported hours of use are in fact, relatively accurate.

Due to the calculation of interactive, the PSD includes assumptions regarding the fraction of annual kWh energy savings that must be removed by the cooling system and COP of the HVAC unit serving the treated space. This assumed fraction is 0.675 for buildings that are over 2,000 square feet or 0.48 for those under. In our experience in calculating interactive savings, we believe these assumptions are reasonable. The assumed COP of the HVAC system serving the treated space is 2.4 in the PSD interactive calculation. This assumption is based on an ASHRAE Journal article from November 1993. The majority of cooling systems in this evaluation were packaged systems, which can be assumed to have a COP of approximately 2.9. Later in this report, we recommend an adjustment to this PSD assumption.

Peak lighting factors are provided in the PSD by facility type. Table 18 shows these values along with the average of those from this study for each facility type in the sample. Reviewing the results in this way suggests that the PSD lighting coincident factor assumptions appear to be very reasonable and do not present the need for reconsideration based on this study.

[11] http://www.neep.org/Assets/uploads/files/emv/emv-library/2011_CT_PSD.pdf, page 80.

Table 18: Evaluated and PSD Coincident Factor Comparison from M&V On-sites

Facility Type	Count of Facility Type[12]	CT PSD Summer CF	On Peak Coincident Factor		Seasonal Peak Coincident Factor	
			Evaluation CF	Relative Precision at 90% CI	Evaluation CF	Relative Precision at 90% CI
Medical (Hospital)	3	74.0%	72.3%	16.2%	73.0%	16.6%
Office	11	70.0%	75.0%	15.6%	77.3%	14.5%
Other	8	48.0%	52.6%	29.1%	52.2%	27.6%
Restaurant	2	78.0%	67.9%	56.0%	67.9%	56.0%
Retail	14	80.0%	68.8%	28.1%	67.2%	27.6%
Overall	42	70.0%	66.5%	12.8%	66.8%	12.3%

Door Heater Controls

The savings from door heater controls result from a reduction in the operating hours of the door heaters. The off hours are stipulated values in the PSD and are overall averages derived from vendor experience. They are applicable to all store types and sizes.

The variables required to calculate energy savings in the PSD are:

- Number of units
- Voltage of the unit
- Amperage of the unit
- Power Factor
- Annual hours in reduction of door heater usage

The number of units, voltage, and amperage are site specific values that are used in a standard correct formula. The power factor is fixed at 1. This is a valid value for electric resistance loads and within acceptable engineering estimates for this measure. Per the PSD, the annual hours are stipulated at 6,500 for coolers and 4,070 for freezers. These are the hours that the heaters are off after the controls are installed. These heaters are controlled according to humidity levels within the facility. Facility humidity levels are also controlled by the HVAC systems. The annual off hours in the PSD are reasonable based on the metering and observations made in this study.

Vending Machine Controls

Savings from this measure are due to reduced hours of operation of the vending machine. In the calculation, off hours are multiplied by 45% to account for compressor cycling. This

[12] There were four sites who were the only representatives of their facility type. Precisions cannot be calculated for these facility types.

stipulated adjustment factor and the power factor values are based on vendor experience. There are no demand savings for this measure.

The savings calculation in the PSD for vending machine controls is straightforward and includes the following variables:

- kW controlled (*e.g.*, Number of units, Voltage of units, Amperage of units, Power Factor from nameplate data)
- Annual hours before control
- Annual hours after control
- Percent Savings (45%)

The number of units, voltage, and amperage are site specific values. Annual operating hours before control are not stipulated and are site specific. However, the PSD notes that baseline operation is "usually" 8,760 hours. Baseline operation less than 8,760 hours would imply some form of existing time controls are in place, which is not likely. Existing vending units should have no existing controls and the baseline operation should be stipulated at 8,760 hours. The annual hours after control is a site specific value that conforms to the facilities unoccupied periods. The use of the facility unoccupied periods to estimate the controlled usage of the vending unit is providing reasonable estimates of control savings based upon the findings of this study. The compressor cycle factor provides an estimate of how often the vending machine compressor turns on and off to maintain temperature. The 45% compressor cycle factor is appropriate and within expected engineering estimates.

Evaporator Fan Controls and Evaporator Fan Motor Replacement

These two measures are interactive with each other. Most of the sites that installed evaporator fan measures implemented both fan motor replacements and fan motor controls. Fan motor replacements and fan motor controls share equations and input variables. They are reviewed together in this discussion for these reasons.

<u>Evaporator Fan Controls</u>

The savings for evaporator fan controls are derived from a reduction in the number of hours of operation that the evaporator fans are running. If fan motors are also replaced with ECM motors in conjunction with this measure then savings are based on the reduced fan motor wattage. Interactive refrigeration savings are also achieved due to reduced fan run-hours. The off hours, power reduction factors and power factor are stipulated values.

<u>Evaporator Fan Motor Replacement</u>

The savings estimates for evaporator fan motor replacement are based on the wattage reduction from replacing existing evaporator fan motors with electronically commutated motors. Interactive refrigeration savings are also achieved due to reduced heating loads resulting from fan power reduction. The run hours, power reduction factors, and refrigeration efficiencies are stipulated values.

If evaporator fan controls are installed along with new evaporator fan motor**s**, then savings are calculated based on the assumption that the evaporator fan motor is replaced before the controls are added. This is an appropriate calculation sequence for this interactive measure.

The variables required to calculate energy savings in the PSD are:

- Number of units
- kW of the evaporator fan motor (voltage, amperage, and power factor of the motors)
- Annual hours that the controls turn fans off [evaporator fan controls]
- Annual hours that the motors operate [evaporator fan motor replacement]
- Refrigeration efficiency in ACOP (Average Coefficient of Performance[13])

The number of units and the motor kW are site specific values. The motor kW is the measured power of the evaporator fans at each site.

If evaporator fan motor controls are already in place or installed with new replacement motors, then the annual evaporator fan operation is fixed at 5,000 hours. This 5,000 hour annual operation accounts for interaction with the evaporator fan controls. This stipulated 5,000 annual operating hour is valid and conforms to average site evaluation findings.

Annual evaporator fan operation is stipulated at 8,500 hours when motor controls are not present. The 8,500 annual operating hours account for fans being shut off during defrost cycles. This high level of continuous operation is expected in uncontrolled systems and was confirmed by evaporator fan monitoring performed at the sites.

For evaporator fan control measures, the annual reduction in fan operation is stipulated at 3,000 hours. These controls shut the evaporator fans off when cooler/freezer temperatures are maintained and additional air circulation is not required. The stipulated 3,000 hour reduction in evaporator fan operating hours is appropriate and conforms to the average operation monitored at the sites.

The evaporator fan motors are located in the refrigerated spaces. The new efficient fan motors consume less energy, which results in less waste heat generated by the motors. Similarly, the reduction in motor run time realized with the installation of the motor controls also results in less waste heat. This waste heat reduction represents additional interactive savings. This is heat that does not have to be removed through the refrigeration compressors. Refrigeration efficiencies are stipulated at an ACOP of 2.03 for freezers and 2.69 for coolers. These are acceptable average efficiencies for refrigeration equipment. The PSD also allows for the use of site specific refrigeration efficiencies when available. This further enhances the accuracy of these two measures.

Billing Analysis

This section presents the results of the 2011 program year billing analysis portion of the evaluation. We discuss 2011 participation by month followed by a discussion of the annual consumption and weather data used in this evaluation effort. We conclude this section with the savings estimates and realization rates.

Figure 6 below illustrates the participation rates for CL&P and UI by month in 2011[14]. Overall, program participation rate can be regarded as stable and averages around 8% per month in 2011. Relatively stable participation over an extended period of time is an essential pre-condition for a valid fixed-effects billing analysis.

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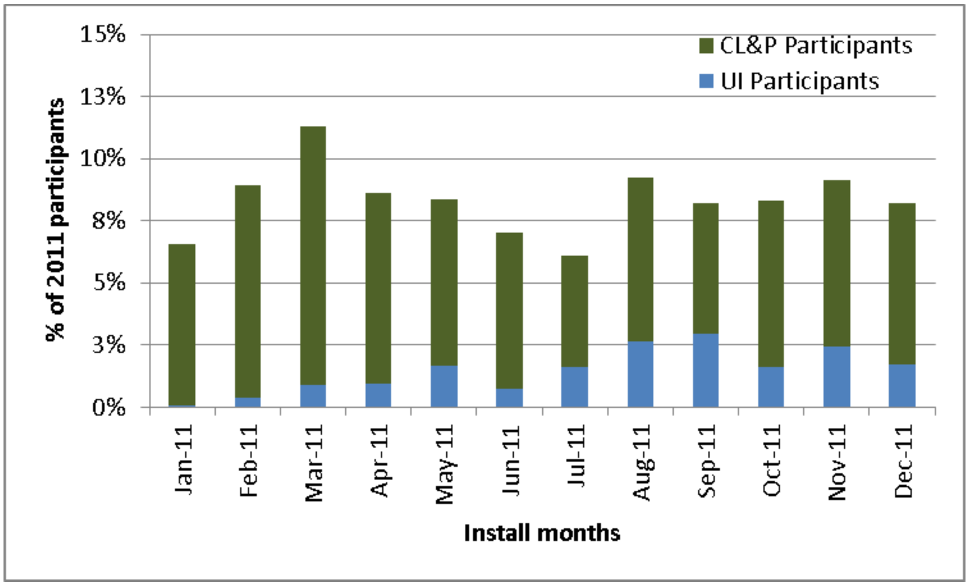
[13] ACOP is the Average Coefficient of Performance and reflects the efficiency of the refrigeration compressors.

[14] KEMA determined the date of participation based on the first installation date observed for each participant.

Figure 6: 2011 Program Participation by Month (N=1,724)



The time of participation is important in assigning the black-out, pre-installation and post-installation periods for a pre/post billing analysis. Black-out periods include the billing period covering the date of measure installation and the billing period before the measure was installed. An approximately 60-day blackout period is assigned to sites that installed a single measure while sites that installed multiple measures are assigned a longer, all-inclusive blackout period.

Table 19 shows the distribution of annual electric consumption for CL&P and UI sites with a full year of billing data during the pre- and post-installation period. Overall, the distribution shows a decrease in consumption levels after the program was implemented. In addition, we observed that CL&P sites generally use more electricity than UI sites. This may suggest that CL&P sites are relatively bigger in terms of size than UI participants.

Table 19: Distribution of Annual Electric Consumption

	CL&P		UI		All	
Quantile	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
100% Max	1,390,143	1,296,960	895,854	799,500	1,390,143	1,296,960
99%	886,544	798,600	470,609	426,480	838,560	781,680
95%	447,920	406,023	321,040	294,800	423,682	377,088
90%	292,160	259,584	247,398	239,464	279,040	248,080
75% Q3	117,320	101,049	70,353	58,649	108,056	94,363
50% Median	42,513	36,418	24,381	22,346	40,202	33,819
25% Q1	18,233	15,405	10,279	9,557	16,816	14,172
10%	9,171	7,741	4,865	3,738	7,777	6,770
5%	6,128	4,957	2,906	2,802	5,026	3,946
1%	2,446	1,955	1,501	1,122	2,137	1,648
0% Min	603	29	1,029	145	603	29

Table 20 compares the average actual and weather-normalized consumption for participants with full year consumption data during pre- and post-installation periods. The actual consumption is based on the average electric consumption as reported in the utility billing data while the weather-normalized consumption is obtained from PRISM estimates. The weather-normalized consumption reflects consumption under typical weather year, which allows us to compare consumption while holding weather variations constant between the pre and post-installation periods. Based on the weather normalized consumption, participants use less electricity by around 10% after installing the program measure. However, this reduction in consumption cannot be solely attributed to the program as it could also capture trends that are non-program related.

Table 20: Actual and Weather-normalized Annual Electric Consumption

Consumption	CL&P (n=1,084)	UI (n=245)	ALL (n=1,329)
Actual Consumption			
Pre	108,439	75,275	102,325
Post	96,285	68,375	91,140
% Difference (Pre-Post)	11%	9%	11%
Weather-normalized Consumption			
Pre	98,601	67,136	92,800
Post	88,324	60,959	83,279
% Difference (Pre-Post)	10%	9%	10%
% Difference Between Actual and Normalized Consumption			
Pre	9%	11%	9%
Post	8%	11%	9%

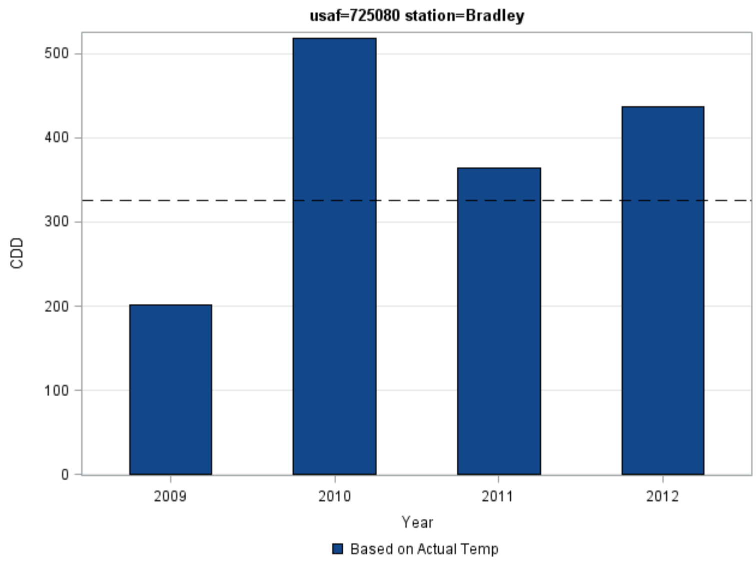
Table 20 also shows that the overall average actual consumption is 9% higher than the expected consumption under a typical weather year. This suggests that weather condition during the analysis period is different from a typical weather year and 9% of the consumption is attributed to participant's response to the change in weather condition. These findings highlight the importance of estimating a weather-normalized savings to minimize over- or under-representation of savings due to extreme weather conditions.

Actual and TMY Weather

DNV KEMA used weather data from Bradley and Bridgeport weather stations to calculate cooling and heating degree days. We assigned shoreline towns to Bridgeport and inland towns to the Bradley station. Around 77% of the participants were assigned to Bradley station while the remaining 23% were assigned to Bridgeport station.

Figure 7 and Figure 8 present the cooling and heating degree days for the Bradley and Bridgeport weather stations, respectively. The graphs compare the actual and weather-normalized cooling and heating degree days across different time periods used in the analysis. The horizontal broken line represents the annual degree days using a normal weather year while the bars represents the actual degree days observed for each year.

Figure 7: Annual Cooling and Heating Degree Days, Bradley Station, 2009-2012



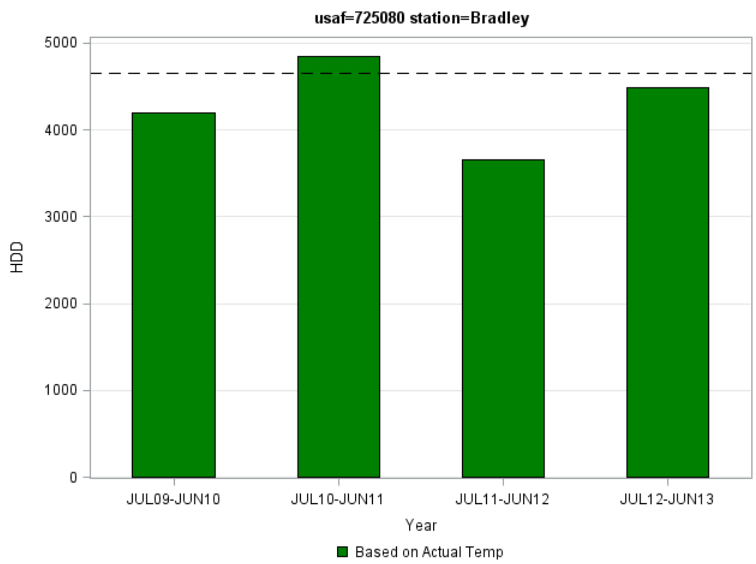
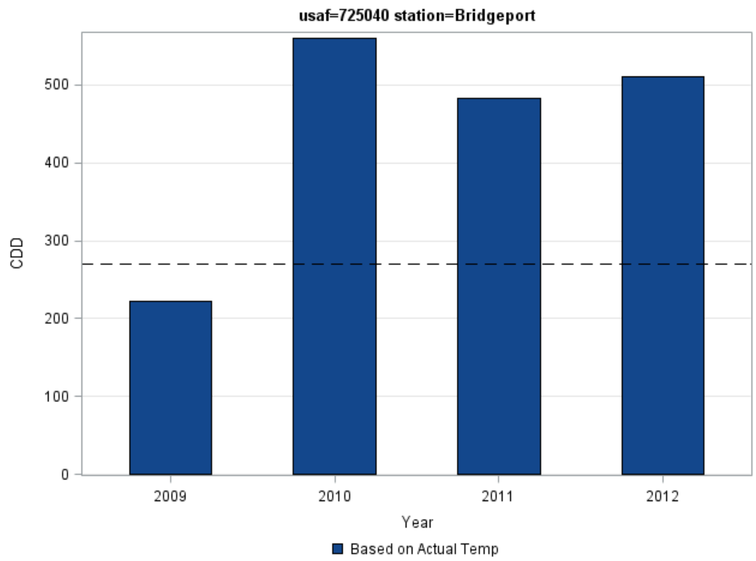
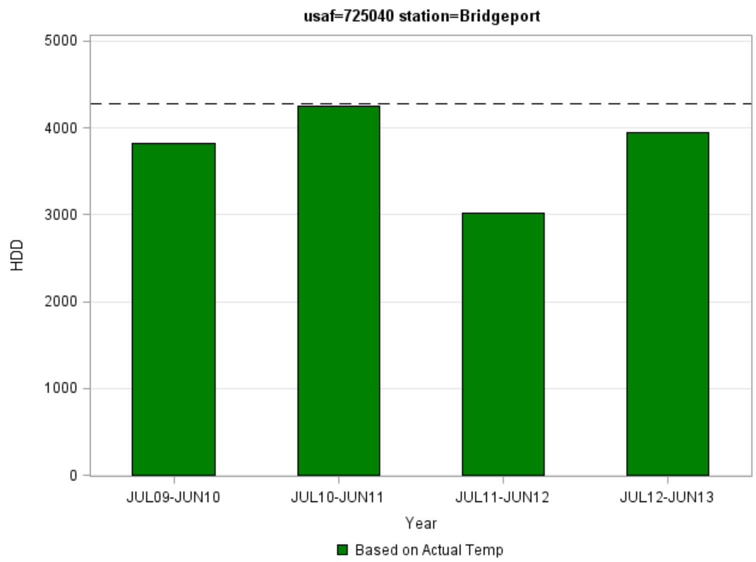


Figure 8: Annual Cooling and Heating Degree Days, Bridgeport Station, 2009-2012





In general, both stations show that annual cooling degree days were above normal in years 2010, 2011 and 2012. This would have caused participants to use more cooling load than under "normal" conditions. This pattern is the most likely explanation for the reduction from actual consumption to weather-normalized consumption in Table 20. Participants' greater cooling load due to warmer summers would have been adjusted downward to reflect "normal" conditions. To the extent that electric heat was a factor and pumps or motors for fossil fuel heating systems, the mild 2011-2012 winter would have had the opposite effect - decreasing actual consumption relative to normalized consumption. While we control for the presence of electric heat it is the cooling that we would expect to most affect electric consumption.

Program Savings

Table 21 summarizes the average annual savings estimates by utility while Table 22 presents the realization rates. Overall, the CT SBEA program generated statistically significant reductions in electric consumption through this billing analysis method. The average electric savings per site from the fixed-effects model is shown in the fifth column and represents our final billing analysis estimate of average savings per participant. This savings is just over 6,000 kWh per year or about 8% of consumption under typical weather year. CL&P participants generated 7.2% savings while UI generated 9.3% savings. However, results show that savings generated by UI participants are not statistically significant. According to this savings analysis method, the overall CT SBEA program is estimated to have an overall realization rate of 34%.

Table 21: Program Savings Estimates by Utility from Billing Analysis

	Average Normalized Annual Use (Site-level)			Average Normalized Annualized Savings Accounting for Trend (Fixed-Effects, Accounting for Trend)				
Utility	**Pre**	**Post**	**% Difference**	**Savings Estimate**	**Standard Error**	**90% Lower Confidence Limit**	**90% Upper Confidence Limit**	**% Savings**
CLP (n=998)	85,973	76,260	11.3%	6,196	1,434*	3,845	8,547	7.2%
UI (n=221)	68,632	62,526	8.9%	6,377	4,534[ns]	(1,058)	13,813	9.3%
Overall (N=1,219)	82,829	73,770	10.9%	6,229	1,996*	2,956	9,502	7.6%

* Statistically significant at 10% level
[ns] Not statistically significant

Table 22: Program Realization Rates by Utility from Billing Analysis

Utility	No. of sites	Savings Estimate (kWh per site)	Total kWh Savings from Billing Analysis	Total kWh Savings Claimed[1]	Realization Rate (%)
CLP	998	6,196	6,183,451	18,107,592	34%
UI	221	6,377	1,409,423	4,248,504	33%
Overall	1,219	6,229	7,592,874	22,356,096	34%

[1] Savings based on tracking data

The program savings reported in this evaluation effort were based on the final sample of participants reported in Table 23. The final sample constitutes 71% of the participants and comprises 64% of the participants' total electric savings portfolio. To verify the reliability of program savings estimates, DNV KEMA examined program savings across four different participant groups. All four groups cover sites with a full year of consumption data in the pre-and post-installation period but with additional data restrictions. The four groups are described below:

1. All sites with full year of consumption data during pre and post (no other restrictions imposed).
2. Excluded sites with changing number of accounts and sites with negative usage.
3. Excluded sites with changing number of accounts, negative usage and sites with extremely high/low annual consumption.
4. Excluded sites with changing number of accounts, negative usage, extremely high/low annual consumption and sites with short/long reads in a billing interval (final sample used in the analysis).

Program savings estimates from all four groups are presented in Table 23. Results show that savings estimates are robust and stable among the different groups. Average program savings estimates range from 7% to 8% while realization rates are consistently in the low 30% across four groups.

Table 23: Program Savings Using Different Sample Groups from Billing Analysis

Group	% of Total Sites	Savings Estimate (%)	Realization Rate (%)
1	77%	7%	31%
2	76%	7%	33%
3	73%	7%	32%
4	71%	8%	34%

In addition, we produced results consistent with results provided above but based only on the on-site sample subset. Depending on the size of the on-site sample, these kinds of results can be a useful comparison with the on-site results. In this case, the results are non-significant and bear little resemblance to the overall billing analysis population.

On-site M&V Results vs Billing Analysis Examination

The M&V versus billing analysis methods of assessing gross savings for the 2011 program year are divergent. Specifically, the M&V based assessment of program impacts has a realization rate of 96% while the savings from the billing analysis for the same program year is roughly 34%. These are statistically different from one another, and as such require further consideration on how to handle them. The decision to undertake both approaches in this study was to test the efficacy of them. There has been a recent pattern of divergence between M&V and billing analysis results among small business programs in the Northeast in the past 6 months, so this issue is not unique to the SBEA program. In this study, we believe the impact M&V results are the more reliable savings estimates upon which to base program performance for reasons discussed further below.

The impact M&V approach employed in this study is consistent with IPMVP Option A. Historically in the Northeast, this approach has been regarded as the standard approach to assessing savings in the small business market sector[15]. The use of engineering and M&V approaches for impact evaluations of C&I programs are considered standard nationally and the most sophisticated impact evaluations of C&I programs include an engineering and site visit approach. The reason why programs such as SBEA are typically evaluated using Option A is because the structure of these programs typically include an audit function that captures pre equipment types and quantities and a post inspection element that ensures measures are installed as intended. This leaves measure operation as the most uncertain element in savings estimates; that is best captured on-site with proper metering equipment.

It is important to note that a threshold criterion for a meaningful billing analysis is the use of all consumption data associated with the program treated areas. Many commercial sites have multiple meters or accounts, and the program application process does not always facilitate full identification of all site accounts. This is a well-known challenge to small commercial billing analysis, and it is difficult to assess the extent to which insufficient billing data might be impacting these results. We believe this to be the single most likely explanation for the lower savings estimates from the billing analysis as compared to the M&V approach.

CONCLUSIONS AND RECOMMENDATIONS

Table 24 summarizes the overall evaluation results from the impact M&V work. The annual energy savings estimate is 33,874 MWh with an accompanying gross realization rate of 96.2%, including HVAC interactive effects. The relative sampling precisions for this final energy impact estimate with interactive is ±7.8% at the 90% confidence interval. The summer on-peak and seasonal peak savings estimates are 6,093 and 6,187 kW, respectively. The precision on these estimates are ±8.6% at the 80% confidence level for summer on-peak and ±8.3% for seasonal. The winter on-peak savings estimate is 5,148 kW, with a precision of ±16.2% at the 80% confidence level. The winter seasonal peak savings estimate is 4,440 kW, with a precision of ±17.6% at the 80% confidence level.

[15] We do note that National Grid in the 2000's employed billing analyses successfully, however, most other jurisdictions in the region have employed site based M&V approaches, including CT small business study of the 2007 program year.

Table 24: Summary of Impact Evaluation Results from M&V On-sites

Result	Tracking Estimates of 2011 Electric Savings	Evaluation Gross Realization Rate	Relative Precision at 90% Confidence (80% for demand)	Evaluation Gross Electric Savings
Overall kWh (n=60)	35,205,536	96.2%	7.8%	33,873,684
Savings from Lighting (n=42)	30,276,003	99.0%	8.5%	29,972,868
Electric Non-Lighting Savings (n=18)	4,929,534	79.1%	18.7%	3,900,816
Connected Demand kW	18,809	161.5%	13.6%	30,372
Summer On-Peak kW	6,883	88,5%	8.6%	6,093
Summer Seasonal Demand kW	6,883	89.9%	8.3%	6,187
Winter On-Peak kW	4,710	109.3%	16.2%	5,148
Winter Seasonal Demand kW	4,710	94.3%	17.6%	4,440

Conclusion #1: Based upon the M&V impact results, it is apparent that the 2011 SBEA Program generated significant energy and peak demand savings. The estimate of annual energy savings is 33,874 MWh and the seasonal summer peak demand savings is 6,093 kW.

Conclusion #2: Based upon the M&V impact results, we conclude that the CT PSD used to develop the tracking estimates of savings is producing very reasonable estimates of SBEA energy and summer seasonal peak demand savings. The realization rate (or ratio of PSD generated tracking savings to study savings) is 96.2% for energy and 89.9% for summer seasonal peak demand. Despite this, we do provide some specific recommendations for PSD improvement and adherence later in this section.

Conclusion #3: We do not believe the SBEA Program is a good candidate for program level billing analyses given its current state due to uncertainty around the relationship between accounts and program treated spaces. The performance of another billing analysis on the SBEA Program should be undertaken only if the program administrators are fully confident that all billing data associated with each participant's treated area has been identified and is available.

Recommendation #3: To the extent the EEB desires a billing analysis as an evaluation method for the SBEA Program, we recommend that program vendors and implementers establish a system of ensuring the identification of all meters and accounts associated with each treated premise and this information is stored in an easily usable format in the program tracking data.

Conclusion #4: In the M&V site work, when the PSD formulas were used to calculate summer demand and annual energy savings, the results were consistent with the estimates in the tracking system (99.6% and 98.2% realization rates, respectively). When the PSD formulas were used to calculate winter and connected demand savings, the results suggest that the tracking system estimates for these parameters are grossly underestimated (136.1% and 165.6% realization rates, respectively).

There were three sites in the sample that had tracking winter demand savings estimates of zero. When the PSD formulas were applied, the total winter demand savings for these sites was 64.52 kW. Likewise, there were four instances where the tracking connected demand savings estimates were zero and the total PSD calculated value for these sites was 73.11 kW.

Recommendation #4: Although we do not believe that connected demand or winter demand are important metrics for CT filing or ISO-NE FCM purposes, we recommend that the sponsors take steps to more closely follow the PSD in calculating these values in the tracking system.

Conclusion #5: While the overall annual energy savings results were very good (96.2% realization rate), the interactive savings applied to lighting retrofits in the tracking system appear to be slightly overestimated; causing a 7.5% reduction in lighting savings. Some of this overestimation is due to applying the cooling credit to spaces that were not found to be cooled during the on-site visits. Additionally, a review of the PSD formula used to apply interactive savings to lighting retrofits found the cooling system COP (coefficient of performance) assumption to be less efficient than the COP of the units typically found on-site.

Recommendation #5: We recommend that the cooling credit calculation only be applied to lighting retrofits that occur in spaces that are mechanically cooled. We also recommend that consideration be given to assuming an interactive COP that is more consistent with the cooling systems used in small businesses today. The current COP assumption of 2.4 is a dated assumption that is cited from an ASHRAE journal article from 1993. During the on-site visits, most of the cooling systems observed in the sample were packaged systems with estimated COP's of 2.9. As such, we recommend that consideration be made for adjusting the PSD COP assumption to 2.9 to calculate interactive savings for small business lighting retrofits that occur in cooled spaces[16].

Conclusion #6: One of the larger adjustments experienced in the electric non-lighting realization rate was that of documentation adjustment. This adjustment had a negative 11.5% impact on the final savings result. The documentation adjustment was particularly problematic for electrically commutated motors and cooler curtains.

Recommendation #6: We recommend that a renewed effort be undertaken to calculate savings for ECMs and cooler curtains per the PSD. We think such an effort would not need to be time consuming and once established it would greatly improve the accuracy of tracked savings for these measures.

[16] It should be noted that as part of its routine review and updating of the PSD, UI and CL&P revised the C&I Lighting formula in the 2013 PSD to reflect a COP of 3.5.

APPENDIX A: SEASONAL PEAK CALCULATION APPROACH

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 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 2013 season was 27,840 kW, and 90% of which was 25,056 kW. There were 43 hours during the summer 2013 season when the load exceeded 25,056 kW. The evaluation used a blend of both Hartford and Bridgeport real weather data for the summer of 2013 to calculate the weighted average Total Heat Index (THI) of 79.3 for Connecticut during these hours. 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)

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

Table 25 provides the summer 2013 seasonal peak hours along with the system load, percent of CELT forecast peak, the THI and the WHI based on Connecticut weather

Table 25: 2013 Summer Seasonal Peak Hours and System Load

Date	Hour	System Load (kW)	Percent of Peak	THI	WHI	Date	Hour	System Load (kW)	Percent of Peak	THI	WHI
6/24/2013	16	25,071	90%	78.9	77.7	7/18/2013	12	25,842	93%	78.4	77.6
6/24/2013	17	25,129	90%	77.9	76.9	7/18/2013	13	26,339	95%	79.4	78.8
7/15/2013	13	25,344	91%	77.9	76.4	7/18/2013	14	26,747	96%	79.4	78.8
7/15/2013	14	25,779	93%	77.6	76.5	7/18/2013	15	26,867	97%	79.6	79.0
7/15/2013	15	25,972	93%	78.8	77.4	7/18/2013	16	26,840	96%	80.6	79.9
7/15/2013	16	26,066	94%	78.1	76.8	7/18/2013	17	26,680	96%	79.8	79.3
7/15/2013	17	26,089	94%	78.5	77.3	7/18/2013	18	26,306	94%	80.7	80.0
7/15/2013	18	25,917	93%	77.7	77.0	7/18/2013	19	25,617	92%	80.5	79.8
7/15/2013	19	25,418	91%	79.1	77.7	7/19/2013	11	25,436	91%	79.3	78.6
7/16/2013	13	25,328	91%	77.7	77.7	7/19/2013	12	26,457	95%	79.8	79.0
7/16/2013	14	25,900	93%	77.7	77.6	7/19/2013	13	27,015	97%	80.2	79.7
7/16/2013	15	26,088	94%	77.9	78.1	7/19/2013	14	27,347	98%	81.0	80.2
7/16/2013	16	26,160	94%	78.4	78.1	7/19/2013	15	27,353	98%	81.4	80.5
7/16/2013	17	26,226	94%	78.4	78.3	7/19/2013	16	27,350	98%	81.7	81.1
7/16/2013	18	26,040	94%	78.2	78.0	7/19/2013	17	27,360	98%	82.0	81.0
7/16/2013	19	25,422	91%	78.0	78.2	7/19/2013	18	27,066	97%	81.3	80.9
7/17/2013	13	25,487	92%	78.0	77.9	7/19/2013	19	26,305	94%	81.2	80.8
7/17/2013	14	26,064	94%	78.2	78.0	7/19/2013	20	25,483	92%	80.5	79.9
7/17/2013	15	26,351	95%	78.4	78.3	7/19/2013	21	25,154	90%	80.3	79.1
7/17/2013	16	26,522	95%	79.1	78.8						
7/17/2013	17	26,622	96%	78.7	78.6						
7/17/2013	18	26,494	95%	79.4	78.8						
7/17/2013	19	25,890	93%	79.2	78.8						
7/17/2013	20	25,089	90%	79.3	78.6						

The peak load data and the weighted THI and WHI data for 2013 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 July 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 2013 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 blended Connecticut TMY3 weather file must be greater than in order to trigger a summer seasonal peak hour.

THI Cutoff Point: 79.8

WHI Cutoff Point: 79.1

Table 26 provides a summary of the THI, WHI and number of summer seasonal hours for the blended Connecticut 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 evaluation year that meet the above criteria for being selected as a summer seasonal peak hour.

Table 26: Summary of Summer Seasonal Hours for Blended CT TMY3 Weather

Month	Mean THI	Mean WHI	# of Hours
June	80.1	79.2	6
July	81.1	79.7	38
August	80.9	80.4	9
Summer	80.9	79.7	53

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 2012/2013 season was 22,355 kW, 90% of which was 20,120 kW. There were a total of six hours during the winter 2012/2013 season when the load was 20,120 kW or greater. Table 27 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 Connecticut.

Table 27: Winter 2012/2013 Seasonal Peak Hours and System Loads

Date	Hour Ending	System Load (MW)	% of Peak	DBT
1/23/2013	18	20,633	92%	8
1/23/2013	19	20,775	93%	7
1/23/2013	20	20,402	91%	5
1/24/2013	18	20,601	92%	13
1/24/2013	19	20,764	93%	12
1/24/2013	20	20,400	91%	11
Average		**20,596**	**92%**	**9.3**

The 2012/2013 peak load data and the Connecticut 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 blended Connecticut 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 2012/2013 season that occurred outside of the 5 to 7 pm daily peak time period.

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

DBT Cutoff Point: 17.3°F

Table 28 provides a summary of the Dry Bulb Temperature (DBT) and number of winter seasonal hours for the blended Connecticut TMY3 weather file use in the analysis by month and for the winter season.

Table 28: Summary of Winter Seasonal Hours for Blended CT TMY3 Weather

Month	Mean DBT	# of Hours
December	N/A	0
January	14.5	4
Winter	14.5	4

APPENDIX B: RATIO EXPANSION

This appendix provides the specific ratio estimation computations DNV KEMA employed to develop estimates of evaluation verified gross impacts.

Ratio Estimation

DNV KEMA used the statistical procedure of ratio estimation to develop estimates of evaluation verified gross impacts. There are two basic steps in the process. The first step is to verify energy savings in a sample of measures. DNV KEMA accomplished this first step via CATI surveys and on-site visits. The second step is to expand the sample results to the population of measures. This is accomplished by calculating the ratios of verified-to-reported for the sample. The ratios are also referred to in this discussion as adjustment factors or rates.

Expansion of sample results to the population via ratio analysis

The calculation of the adjustment factors for tracking system gross savings uses appropriate case weights corresponding to the sampling rate. The directly calculated adjustment factors are the documentation adjustment, technology adjustment, quantity adjustment, operating hour's adjustment, and HVAC interaction adjustment. Each of these is calculated as a ratio estimator over the sample of interest[17]. The formulas for these factors are given below.

Notation: The following terms are used in calculating the adjustment factors:

G_{TRKj} = tracking estimate of gross savings for measure *j*

G_{DOCj} = tracking estimate of gross savings for measure *j*, adjusted for documentation discrepancies

G_{TECHj} = tracking estimate of gross savings for measure *j*, adjusted for documentation and technology discrepancies

G_{QTYj} = tracking estimate of gross savings for measure *j*, adjusted for documentation and technology discrepancies and non-installation (quantity discrepancies)

G_{HRSj} = tracking estimate of gross savings for measure *j*, adjusted for documentation and technology discrepancies, non-installation (quantity discrepancies) and evaluation logged operating hours

G_{VERj} = verified gross savings for measure *j*, including HVAC interactive effects

W_{Oj} = weighting factor for measure j used to expand the on-site sample to the full population

Documentation Adjustment

The documentation adjustment R_{DOC} is calculated using the on-site sample as

$$R_{DOC} = \frac{\sum_{j\varepsilon O} G_{DOCj} w_{Oj}}{\sum_{j\varepsilon O} G_{TRKj} w_{Oj}}$$

Technology Adjustment

[17] Cochran, Sampling techniques. 3rd ed. John Wiley and Sons, New York, N.Y", 1977, p.165

The documentation adjustment R_{TECH} is calculated using the on-site sample as

$$R_{TECH} = \frac{\sum_{j\varepsilon O} G_{TECHj} w_{Oj}}{\sum_{j\varepsilon O} G_{DOCj} w_{Oj}}$$

Quantity Adjustment

The documentation adjustment R_{QTY} is calculated using the on-site sample as

$$R_{QTY} = \frac{\sum_{j\varepsilon O} G_{QTYj} w_{Oj}}{\sum_{j\varepsilon O} G_{DOCj} w_{Oj}}$$

Operational Adjustment

The documentation adjustment R_{HRS} is calculated using the on-site sample as

$$R_{HRS} = \frac{\sum_{j\varepsilon O} G_{HRSj} w_{Oj}}{\sum_{j\varepsilon O} G_{QTYj} w_{Oj}}$$

HVAC Interaction Adjustment

The interactive adjustment R_{HVAC} is calculated using the on-site sample as

$$R_{HVAC} = \frac{\sum_{j\varepsilon O} G_{VERj} w_{Oj}}{\sum_{j\varepsilon O} G_{HRSj} w_{Oj}}$$

Standard errors

The ratio estimator is calculated using a SAS® macro provided by SAS for ratio estimation by domains. The procedure also returns the standard error of the estimate. The standard error is calculated recognizing the sample as drawn from a finite population: the measures completed within the analysis period with associated energy impacts in the program-tracking database. This calculation uses the Finite Population Correction (FPC) factor. This factor is a reduction to the calculated variance that accounts for the fact that a relatively large fraction of the population of interest has been observed directly and is not subject to uncertainty. It is appropriate to apply precision statistics, such as confidence intervals, based on the standard error calculated in this manner when quantifying the results of the program during the study period only.

About DNV GL

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