Impact Evaluation of 2012 Custom HVAC Installations

Massachusetts Program Administrators and Energy Efficiency Advisory Council

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1 EXECUTIVE SUMMARY

This document summarizes the work performed by the DNV GL team, which consists of DNV GL, DMI and SBW Consulting, between 2013 and 2015 to quantify the actual energy and demand savings due to the installation of 69 custom heating, ventilation and air-conditioning (HVAC) measures installed through the Massachusetts Program Administrators' (PAs) C&I New Construction and Major Renovation and C&I Large Retrofit programs in 2012. The electric program PAs include: Cape Light Compact, Eversource (formerly NSTAR and WMECo), National Grid and Unitil. This evaluation effort received the oversight of the Energy Efficiency Advisory Council (EEAC) Consultants.

This is the second statewide evaluation of the large C&I custom HVAC programs in Massachusetts since 2009. The MA PAs have historically rotated impact evaluations of custom electric end uses on approximately a three year cycle. The previous impact evaluation of the custom HVAC end use was completed in 2011 and included projects from programs in 2009.

The scope of work of this impact evaluation covered the 2012 custom HVAC end use, which includes high efficiency HVAC equipment, HVAC controls as part of Energy Management Systems (EMS), operations and maintenance (O&M) and retrocommissioning of HVAC measures, and building shell improvements that impact HVAC loads. This impact evaluation includes only measures which primarily reduce electricity consumption.

1.1 Methods

The evaluation of 2012 custom HVAC installations used an approach similar to those of previous evaluations. The primary objective of determining realization rates at the statewide and PA end-use level was accomplished by conducting on-site M&V at a statistically selected sample of 69 participant sites from the 2012 program year. This impact study consists of the following five tasks:

1. Develop sample design.
2. Develop site measurement and evaluation plans.
3. On-site data gathering and site analysis.
4. Site report writing and follow-up.
5. Expansion analysis and evaluation report.

1.2 Sampling Strategy

The goal of the sample design was to monitor enough sites to produce aggregated realization rates by PA with reasonable precision. The PAs agreed that the target is 10% precision at the 90% confidence level for energy savings at the statewide level. The two PAs with the largest savings (Eversource-NSTAR and National Grid) were also segmented with sample sizes designed to meet a 10% precision target for PA specific reporting at the 90% confidence level. The sample design employed was a stratified ratio estimate approach, which is particularly efficient for programs with a wide variation in site-to-site savings and where a good predictor of site savings exists (the tracking savings).

1.3 Findings and Results

The site level evaluation results were aggregated using the final adjusted case weights. The PA realization rates were estimated and then applied to each PA's total tracking savings to determine their total measured savings. The statewide realization rate is the ratio of the total measured savings to the total tracking savings, each of which is calculated by summing across the PAs. Table 1-1 summarizes the statewide results of this analysis. The table shows the results for five of the six measures of savings.

Statewide on-peak kWh savings was not calculated because not all PAs provide tracking system data on this measurement.

The statewide realization rate for custom HVAC measures was found to be 88%. The relative precision for this estimate was found to be ±7.4% at the 90% level of confidence. The error ratio was found to be 0.47, which is nearly equivalent to the 0.48 found in the prior study, and somewhat better than the estimate of 0.6 used in the sample design for this study. For the on-peak summer kW, the overall realization rate was 88%, with a relative precision of ±12.6% at an 80% confidence level. For on-peak winter kW, the realization rate was a bit lower, at 85%. Summer and winter seasonal peak kW savings realization rates are also provided for use by Eversource-WMECo.

Table 1-1: 2012 Custom HVAC Statewide Results

Program Administrator	Parameter	Annual kWh	Summer On Peak kW	Winter On-Peak kW	Summer Seasonal kW	Winter Seasonal kW
Statewide – All PAs (n=69)	Tracking Savings	79,229,736	9,718	9,055	9,718	9,055
	Evaluated Savings	69,687,922	8,594	7,668	8,458	7,715
	Realization Ratio	88%	88%	85%	87%	85%
	Relative precision	±7.4%	±12.6%	±13.1%	±17.1%	±16.6%
	Error ratio	0.47	0.84	0.95	1.05	1.12

The results of DNV GL's analysis of realization rates by PA follow in Table 1-2. All relative precisions for kWh savings realization rates were calculated at the 90% confidence interval, while all relative precisions for kW savings realization rates were calculated at the 80% confidence interval.

All PAs, with the exception of Eversource-WMECo, had annual kWh savings realization rates less than 100%. The realization rates for percent on-peak kWh savings are provided in this table for National Grid.

Table 1-2: 2012 Custom HVAC Results by PA

Program Administrator	Parameter	Annual kWh	On-Peak kWh Percent	Summer On Peak kW	Winter On-Peak kW	Summer Seasonal kW	Winter Seasonal kW
Cape Light Compact (n=1)	Tracking Savings	344,410	N/A	131	8	131	8
	Evaluated Savings	287,425	N/A	503	484	503	484
	Realization Ratio	83%	N/A	385%	6076%	385%	6076%
	Relative precision	±0.0%	N/A	±0.0%	±0.0%	±0.0%	±0.0%
	Error ratio	0.00	N/A	0.00	0.00	0.00	0.00
National Grid (n=23)	Tracking Savings	17,372,884	N/A	1,823	1,736	1,823	1,736
	Evaluated Savings	13,087,095	N/A	1,274	1,167	1,065	1,148
	Realization Ratio	75%	106%	70%	67%	58%	66%
	Relative precision	±8.8%	±18.9%	±18.7%	±16.7%	±37.2%	±21.5%
	Error ratio	0.40	1.02	0.88	0.80	1.95	1.07
Eversource-NSTAR (n=42)	Tracking Savings	58,289,674	N/A	7,197	7,063	7,197	7,063
	Evaluated Savings	53,025,255	N/A	6,790	6,222	7,333	6,590
	Realization Ratio	91%	N/A	94%	88%	102%	93%
	Relative precision	±9.4%	N/A	±15.3%	±16.1%	±15.9%	±18.1%
	Error ratio	0.49	N/A	0.82	0.82	0.79	0.93
Unitil (n=1)	Tracking Savings	78,457	N/A	15	10	15	10
	Evaluated Savings	17,257	N/A	8	1	19	1
	Realization Ratio	22%	N/A	51%	12%	126%	14%
	Relative precision	±0.0%	N/A	±0.0%	±0.0%	±0.0%	±0.0%
	Error ratio	0.00	N/A	0.00	0.00	0.00	0.00
Eversource-WMECo (n=2)	Tracking Savings	3,144,311	N/A	552	238	552	238
	Evaluated Savings	3,148,539	N/A	300	184	-198	46
	Realization Ratio	100%	N/A	54%	77%	-36%	19%
	Relative precision	±7.1%	N/A	±6.0%	±28.0%	-±23.1%	±154.7%
	Error ratio	0.08	N/A	0.15	0.49	-0.56	2.68

1.4 Recommendations

1.4.1 Realization Rates

The statewide energy realization rate precision was ±7.4%. The energy realization rate precision levels for Eversource-NSTAR and National Grid were ±9.4% and ±8.8%, respectively. The sample was designed to target 10% precision at the 90% confidence level for both Eversource-NSTAR and National Grid as well as statewide. Both PA specific results should be applied since they exceed the design criteria for precision. This means that Eversource-NSTAR and National Grid will use their specific realization rates and the remaining PAs will use the statewide realization rate for 2015 annual reporting and any 2016–2018 program planning and subsequent year reporting, unless replaced by results from a subsequent study.

1.4.2 Program Improvement Recommendations

Improve Baseline or Pre-Retrofit Documentation

Several sites did not clearly document the pre-retrofit equipment operation or the basis for the base case in their project applications. For example, some technologies that use controls to change operations, such as, ventilation control measures, economizers and others, are very common and the supporting documentation and baseline assumptions provided for HVAC control measures, were not as comprehensive as with other technologies. For demand control ventilation and economizer measures the actual damper settings and ventilation air flow rates provided are key savings inputs, but were not always provided. A default to rated or code compliant design conditions was used by the evaluation to provide results for some projects. However, this use of design conditions could have the impact of either over or underestimating savings. It is recommended that PA's collect and document information on the actual HVAC system operations such as damper positions, outside air ventilation levels, etc. for existing equipment undergoing controls improvements.

Provide Sufficient Documentation

Documentation is essential for supporting baseline conditions and detailed calculations. Comprehensive documentation, meaning working savings calculation files and thorough explanation of baseline and installed case assumptions, is also necessary for evaluation purposes. In some cases where the savings calculations were not present or where pertinent electronic files were not available, the savings could not be reproduced by the evaluator with confidence. Missing information includes building simulation input files and working custom savings spreadsheets, both of which should be included in the PA files.

Clearly Document Calculations of Peak Demand Savings

Parameters for estimating the peak demand savings are often not clearly stated in the tracking savings calculations and documentation. Tracking demand savings are often estimated using weighted operational proportions. However, the source or logic of the weighted averaging is not always documented. Several sites did not provide calculations for, or a description of, how peak demand savings were estimated. The result of this is that peak demand savings estimates may be over or under estimated if savings are not averaged in the appropriate bins or using the correct hours. It is recommended that vendors provide full and clear documentation of peak savings calculations.

Encourage More Comprehensive Commissioning and Updating of Tracking Estimates with Findings from Commissioning

Commissioning is a useful tool to help improve savings estimates for HVAC controls projects. While all PAs currently use commissioning in some capacity, there are areas where this tool can be improved. First, PAs should consider employing a commissioning process on any large or complex project and particularly those with controls measures. The DNV GL team identified some sites that had savings of greater than 500,000 kWh, which did not appear to receive commissioning. Additionally, PAs should continue to follow-up on projects that are commissioned to ensure that the project and savings calculation has been done in accordance with the design intent, and that any savings calculation adjustments resulting from commissioning are made to the final tracking estimates.

Large National Grid projects that require commissioning are sometimes split into two separate applications if the required commissioning could not be completed in the calendar year. National Grid saw their projects with commissioning achieve higher savings realization rates as compared to the remaining sites in their sample. The weighted average realization rate for sites with commissioning was 78% compared to an estimate of 73% for the remaining sample. Four of the seven split sites had realization rates better than 90% after commissioning. Of the remaining 15 sites that didn't split into two applications for commissioning, only four had realization rates better than 90%. The two controls measures that were commissioned performed poorly in this evaluation. These were the result of over estimating pre-retrofit conditions more so than post-installation operation.

Conduct Pre-Installation Metering for More Retrofit Projects

Short term pre-installation metering could be used to confirm assumptions about pre-existing equipment for some retrofit projects, particularly control type projects. The evaluator may not be able to simulate pre-retrofit operating conditions; therefore metering by the implementation vendor prior to installation could improve confidence in the pre-retrofit assumptions. This would be most useful for demand control ventilation or other controls type projects. For example, three of the five demand control ventilation measures that were evaluated resulted in savings of less than 75% of the tracking estimates. Not all of this decrease could be attributed to baseline assumptions, but improvements in baseline assumptions may result in better savings estimates. Likewise, one of the four projects had a realization rate of over 200% due to higher baseline hours versus assumed baseline hours.

Improve use of Post Inspection to Verify Measure Operation

Evaluators identified a number of sites in which the controls or equipment installed were not operational. Post inspections are generally occurring on all custom projects, but the effectiveness of the post inspection could be improved by observing and documenting operating conditions at the time of the inspection rather than only verifying if the measure was installed. Evaluators have observed some improvement in the effectiveness of post installation inspection in more recent custom impact evaluations as compared to studies from five years ago. It is recommended that the PAs continue to use more rigorous post-installation inspections to further build on the efforts made in this area.

1.4.3 Evaluation Recommendations

Require Trend Data Acquisition

Stipulate in customer participation agreements that for sites receiving controls measures, either customer staff are to be trained or the controls contractor will be required to assist with subsequent EMS trending in the event customer is chosen as an evaluation site. It would be helpful to include in the contract specifically which trends should be made available to the PA and evaluators for evaluation. The engineers developing the project scopes could specify the required trends. Consider the feasibility of configuring controls systems to allow remote access by evaluators to allow for data downloads.

Consider Use of Desk Review Methodology

A recent MA custom gas evaluation performed desk reviews on a double sample of custom gas projects.[1] This was set up as a test to determine if a desk review process could predict changes in realization rates that would trigger an impact evaluation. The evaluators concluded that the results of the test were not strong enough to warrant adoption of this process as the primary means of determining when to conduct an impact evaluation. However, future impact evaluations, including custom HVAC, may benefit from a structured desk review of key parameters from the M&V sample for ongoing monitoring of program characteristics. An interesting option is to use the structured desk review on a rolling sample for the purpose of providing ongoing program implementation feedback and as well as a continuous indication of program change that could be reviewed as part of the annual evaluation planning. A continuous desk review process would characterize some program change indicators, including quality of engineering calculations and baselines used to estimate savings. The PAs have commissioned a study to design improve evaluation planning, where the desk review role in impact evaluation can be further considered.

[1] Energy & Resource Solutions and DNV GL, Project 43 Impact Evaluation of PY2013 Custom Gas Installations, September 2015

Consider Other Evaluation Methodologies

This impact evaluation of custom HVAC installations took over two years to complete for a couple reasons. First, the National Grid policy of splitting some applications into two program years to ensure they are properly commissioned was in its first year. This meant that this evaluation needed to span two years in order to evaluate the fully completed projects. Second, many custom HVAC projects have summer and winter saving measures, which required longer term metering to capture all impacts in both seasons. The former should not continue to be a factor in evaluation timing decisions as the evaluation team has decided on a methodology for accounting for the commissioning policy by including only fully commissioned projects from the start. However, the evaluation team still has to balance the requirement for high rigor evaluation with more timely results. As such, the evaluation team should investigate alternative options to evaluate large, influential measures such as custom HVAC. Ideas, including a rolling annual sample, are currently being discussed as part of a new effort to refine the gross impact evaluation framework.

2 INTRODUCTION

2.1 Study Objectives

The objective of this impact evaluation is to provide verification or re-estimation of electric energy and demand savings estimates for 69 Custom HVAC projects through site-specific inspection, monitoring, and analysis. The results of this study will be used to determine the final realization rates for Custom HVAC energy efficiency measures installed in 2015 and for 2016-2018 program planning. Realization rates were separately determined for Cape Light Compact, Eversource (NSTAR and WMECo separately), National Grid and Unitil, as well as at the statewide level. The evaluation sample for this study was designed in consideration of the 90% confidence level for energy (kWh) savings and the 80% confidence level for coincident peak summer demand reduction.

2.2 Background

This is the second statewide evaluation of the large C&I custom HVAC programs in Massachusetts since the study of 2009 custom HVAC projects. The MA PAs have historically rotated impact evaluations of custom electric end uses on approximately a three year cycle. The previous impact evaluation of the custom HVAC end use was completed in 2011.[2]

2.3 Scope

The scope of work of this impact evaluation covered the 2012 custom HVAC end use, which includes high efficiency HVAC equipment, HVAC controls as part of Energy Management Systems (EMS), operations and maintenance (O&M) and retrocommissioning of HVAC measures, and building shell improvements that impact HVAC loads. This impact evaluation includes only measures which primarily reduce electricity consumption.

This impact study consists of the following five tasks:

1. Develop sample design.
2. Develop site measurement and evaluation plans.
3. On-site data gathering and site analysis.
4. Site report writing and follow-up.
5. Expansion analysis and evaluation report.

2.4 Methods

2.4.1 Description of Sample Design

The primary focus of the sample design was to examine various precision scenarios for the custom HVAC measures in Massachusetts. The initial design approach was to support the estimation of annual kWh savings realization rates separately for National Grid and Eversource-NSTAR while including appropriate representation for Cape Light Compact, Eversource-WMECO, and Unitil. The study population of 245 Custom HVAC projects from the 2012 program year is summarized in Table 2-1.

[2] KEMA Inc, Impact Evaluation of 2009 Custom HVAC Installations, June 17, 2011

Table 2-1: Population Statistics

Program Administrator	Projects	Total Gross Savings (kWh)	Average Savings (kWh)	Minimum (kWh)	Maximum (kWh)	Standard Deviation	Coefficient of Variation
Cape Light Compact	7	344,410	49,201	4,145	159,193	52,991	1.08
National Grid	57	15,571,810	273,190	629	2,288,693	418,686	1.53
Eversource-NSTAR	163	58,289,674	357,605	1,678	4,206,045	588,299	1.65
Unitil	2	78,457	39,228	39,228	39,228	0	0.00
Eversource-WMECo	16	3,144,311	196,519	1,294	1,108,800	280,196	1.43
Totals	**245**	**77,428,662**					

The goal of the study was to design a sample that will allow DNV GL to estimate realization rates for a number of measurements (annual kWh, percent of kWh savings on-peak, summer on-peak and seasonal kW, and winter on-peak and seasonal kW) with a relative precision of ±10% at the statewide level and also for Eversource-NSTAR and National Grid separately. While the primary variable of interest for the sample design was annual kWh savings, the PAs also were interested in coincident peak summer kW because it is used in the ISO-NE Forward Capacity Market (FCM). The target for annual kWh was set at the traditional ±10% at 90% confidence, while the target for summer kW was set at ±10% precision at 80% confidence during the design. The summer kW target is based on the ISO-NE overall portfolio precision requirements, but need not be achieved in each individual study because the FCM precision may be calculated for each PA's overall portfolio of demand resources. Both energy and summer demand savings sample design considerations are assessed in the following sections.

All of the sample design results for annual kWh were calculated at the 90% confidence level, while results for summer kW were calculated at the 80% confidence level.

2.4.1.1 Annual kWh Sample Design

DNV GL presented several preliminary sample designs stratified by annual kWh for the Massachusetts PAs for the custom HVAC end use. The parameters considered in the sample design are the number of sample observations planned and the anticipated error ratio of quantity being estimated. The error ratio is a measure of the strength of the relationship between the known characteristic (i.e., tracking system savings) and the quantity being estimated (i.e., evaluated savings).

The error ratio from the 2011 study was found to be 0.48 for the statewide result based on 29 sample sites, including 0.38 for National Grid and 0.72 for Eversource-NSTAR. Samples for this study were designed using an error ratio of 0.6. Table 2-2 shows the stratum cut points and distribution of sample sites for the selected sample design.

Table 2-2: Sample Design Selected with Stratum Cut Points

Program Administrator	Stratum	Maximum Total Gross Savings (kWh)	Projects	Total Gross Savings (kWh)	Planned Sample Size
Cape Light Compact	1	94,465	7	344,410	1
National Grid	1	95,379	25	1,092,737	4
National Grid	2	155,734	9	1,286,352	3
National Grid	3	244,013	7	1,586,465	3
National Grid	4	360,197	5	1,606,562	3
National Grid	5	473,151	4	1,671,073	3
National Grid	6	703,348	3	1,924,763	3
National Grid	7	2,288,693	4	6,403,858	4
Eversource-NSTAR	1	85,000	81	3,237,571	5
Eversource-NSTAR	2	154,866	23	4,190,320	5
Eversource-NSTAR	3	340,566	14	4,383,553	5
Eversource-NSTAR	4	499,210	12	5,128,158	5
Eversource-NSTAR	5	771,627	8	5,050,786	4
Eversource-NSTAR	6	894,379	7	6,165,935	4
Eversource-NSTAR	7	1,083,312	5	5,001,405	4
Eversource-NSTAR	8	1,285,995	6	7,180,530	4
Eversource-NSTAR	9	4,206,045	7	17,951,416	7
Unitil	1	39,228	2	78,457	1
Eversource-WMECo	1	6,541	13	1,178,431	1
Eversource-WMECo	2	437,485	3	1,965,880	1

Table 2-3 lists the calculated precision estimates for this scenario, following stratification. A precision of ±8.2% was estimated for the overall results from all five PAs at the 90% confidence level. While the expected precision for Cape Lighting Compact, Unitil and Eversource-WMECo are extremely high, its influence on the overall precision is minimal due to its relative size.

Table 2-3: Estimated kWh Precision for Selected Sample Design

Program Administrator	Projects	Total Gross Savings (kWh)	Error Ratio	Planned Sample Size	Expected Relative Precision
Cape Light Compact	7	344,410	0.6	1	±122.7%
National Grid	57	15,571,810	0.6	23	±10.5%
Eversource-NSTAR	163	58,289,674	0.6	43	±9.6%
Unitil	2	78,457	0.6	1	±69.8%
Eversource-WMECo	16	3,144,311	0.6	2	±78.3%
Totals	**245**	**77,428,662**		**70**	**±8.2%**

2.4.1.2 Summer kW Sample Design

DNV GL examined the estimated summer kW precision that could be achieved with a sample of this size. The error ratios for summer kW savings realization rates in the prior 2011 study ranged from 0.64 for National Grid to 0.81 for Eversource-NSTAR with a statewide value of 0.68. For this study, an assumed error ratio of 0.8 was used in the model. Given the ISO-NE requirement of 80/10 precision, this analysis was run at an 80% confidence level.

Table 2-4 estimates the summer kW precision using these parameters. Overall, the expected relative precision is ±9.2% at the 80% confidence level. In addition, both National Grid and Eversource-NSTAR had expected relative precisions of better than 80/11.

Table 2-4: Estimated Precision for Summer kW using Selected Sample Size

Program Administrator	Projects	Summer kW Savings	Error Ratio	Planned Sample Size	Expected Relative Precision
Cape Light Compact	7	131	0.8	1	±127.5%
National Grid	57	1,665	0.8	23	±10.9%
Eversource-NSTAR	163	7,197	0.8	43	±10.0%
Unitil	2	15	0.8	1	±72.5%
Eversource-WMECo	16	552	0.8	2	±81.4%
Totals	**245**	**9,560**		**70**	**±9.2%**

2.4.1.3 Final Sample

Following the sample design and subsequent sample draw, National Grid provided the DNV GL team with a list of projects that had been divided into split applications. This split application process was implemented in 2012 by National Grid. The process involves splitting an application into two parts if commissioning is not completed in the same calendar year as the measure is installed. In cases such as these, National Grid claims 80% of the estimated savings in year 1 (called the parent application), and the remaining savings in year 2 (called the child application) after which the final commissioned project savings can be determined. The sum of the savings between the parent and child applications represents the full, final commissioned savings for the project. The DNV GL team included all split 2012 projects in the sample, and added the 2013 fully commissioned savings to the original project application. This affected about a dozen applications, and resulted in an additional 1.8 million kWh savings added to the 2012 population.

Going forward, custom impact evaluations will account for these commissioning projects differently by only including fully commissioned projects from the start. This means that custom impact evaluations will include child applications from a given studied program year and the corresponding parent application from the prior year and evaluate the total savings. Likewise, all new parent applications, where the commissioning has not been completed in the same calendar year will be omitted from the program year being evaluated. This has the effect of including full sets of projects, while not ignoring parts of some split projects where the project was not fully completed in the year of the primary sampling.

Table 2-5 presents the list of 69 projects selected as the final sample for custom HVAC. The final sample required the selection of ten back-up sample points. Back-up sample points were chosen following refusal or unresponsiveness on the part of the customer. Also presented in this table are the site assignments by evaluating contractor on the DNV GL team. National Grid sites in bold are those that were originally split due to commissioning.

Table 2-5: Final Sample Selection

DNV GL Site ID	Program Administrator	Application ID	Evaluating Contractor	Measure Type	Measure Description
1	Cape Light Compact	D030103533	DNV GL	Controls	Rooftop unit optimizer controls

DNV GL Site ID	Program Administrator	Application ID	Evaluating Contractor	Measure Type	Measure Description
26	Eversource-NSTAR	BS11770	DNV GL	DCV	VAV control and DCV
27	Eversource-NSTAR	BS11777	SBW	Controls	Controls to reduce fan runtime
28	Eversource-NSTAR	BS12048	DMI	Controls	EMS controls
29	Eversource-NSTAR	BS12078	SBW	Heat Recovery	Glycol loop heat recovery
30	Eversource-NSTAR	BS11343	SBW	Data Center Cooling	Optimize CRAC units
31	Eversource-NSTAR	BS11720	DMI	Controls	Chiller plant controls
33	Eversource-NSTAR	BS12424	SBW	Free Cooling	Heat exchanger for free cooling
34	Eversource-NSTAR	CS8733	DNV GL	Chiller and Controls	Chiller replacement and controls
35	Eversource-NSTAR	BS11856	SBW	Controls	EMS control of AHUs
36	Eversource-NSTAR	BS12197	SBW	Controls	EMS temp setback for 6 AHUs and 16 FCUs
37	Eversource-NSTAR	BS12224	DMI	DCV	CO control of 6 garage fans (3-15hp)
38	Eversource-NSTAR	BS12310	SBW	VSD and Controls	AHU VFDs; Unoccupied temp and CFM setback
39	Eversource-NSTAR	BS9840	SBW	VSD and Controls	AHU VFDs; Unoccupied temp and CFM setback
41	Eversource-NSTAR	BS12388	DMI	VSD and Controls	AHU VFDs; Unoccupied temp and CFM setback
42	Eversource-NSTAR	CS8904	DNV GL	Data Center Cooling	6 CRAH units with variable speed EC motors
43	Eversource-NSTAR	CS9012	DNV GL	Electric to Gas Conversion	ECM 1: New campus center with CHW from existing central plant; ECM 2: Demand control ventilation
44	Eversource-NSTAR	CS9078	DMI	VAV RTUs	New Rooftop Units with VAV Conversion and removal of electric preheat and reheat coils
45	Eversource-NSTAR	BS11061	DMI	RCx	Reduce minimum CFM set points in both occupied and unoccupied zones served by two large AHUs
46	Eversource-NSTAR	BS11624	SBW	Data Center Cooling	Centralized CRAC control system, add'l sensors to allow reduction in CRAC fan flow
47	Eversource-NSTAR	BS11921	DMI	Controls	New BAS for campus
48	Eversource-NSTAR	BS12201	DMI	Controls	Setbacks for 10 AHUs
50	Eversource-NSTAR	BS12059	DMI	Controls	Modulating 2-way control valves, controls added to BMS to stage chillers, pumps and related equipment
52	Eversource-NSTAR	CS8898	DNV GL	Data Center Cooling	6 CRAH units installed with VFD fans, 4 UPS' installed
53	Eversource-NSTAR	BS10572	DNV GL	Free Cooling	Free cooling tower installed to provide chilled water when OA is below 45 to datacenter. Added water side economizer to the cooling tower.
54	Eversource-NSTAR	BS11727	DMI	Controls	Upgrades to AHU controls
55	Eversource-NSTAR	BS12311	SBW	VSD and Controls	Condenser pump VFDs; Unoccupied temp and CFM setback; enable airside economizers and disable chiller in winter
56	Eversource-NSTAR	CS8995	DNV GL	Data Center Cooling	Modular in-row based cooling for data center
57	Eversource-NSTAR	BS11941	DMI	Chilled Water	chilled water plant, exhaust cones, vivarium airflow reduction, autoclave switching
58	Eversource-NSTAR	BS12089	SBW	Chilled Water Piping	Chilled water piping improvements to replace satellite air-cooled chiller with central chilled water, VFDs on central plant condenser pumps & controls re-commissioning
59	Eversource-NSTAR	BS12130	DMI	Controls	Unoccupied setback of 12 AHUs

DNV GL Site ID	Program Administrator	Application ID	Evaluating Contractor	Measure Type	Measure Description
60	Eversource-NSTAR	BS12157	SBW	Electric to Gas Conversion	Electric to gas boiler conversion
61	Eversource-NSTAR	BS10741	DMI	RCx	RCx. Reduce minimum CFM set points in both occupied and unoccupied zones served by five large AHUs
62	Eversource-NSTAR	BS11023	DNV GL	VSD and Controls	HVAC Performance Upgrade; VFDs on CHW & Glycol HW Pumps; CHWST reset; Ltg Occ Sensors
63	Eversource-NSTAR	BS11911	DNV GL	DCV	CO and CO2 ventilation controls
64	Eversource-NSTAR	BS12007	DNV GL	RCx	Shutdown 6 AHUs
65	Eversource-NSTAR	BS12259	DMI	Controls	Upgrade controls - reduced ventilation and fan operating hours
67	Eversource-NSTAR	BS9084	DNV GL	VSD and Controls	Motors, EMS & HVAC Controls, VSDs, Kitchen Fume Hood Controls, HVAC Equipment or Systems
75	Eversource-NSTAR	BS11963	DMI	Controls	AHU scheduling and space temperature setbacks during unoccupied hours, air handling unit static pressure reset and demand control ventilation, environmental chamber refrigeration controls, and hot water pump variable flow control.
77	Eversource-NSTAR	BS10619	DMI	VSD and Controls	HVAC systems with VFDs and EMS controls
78	Eversource-NSTAR	BS10699	DMI	Controls	New controls on chilled water system
79	Eversource-NSTAR	BS12329	DNV GL	DCV	CO ventilation controls
80	Eversource-NSTAR	BS11842	DNV GL	Free Cooling	Upgrade controls to expand free cooling capacity in existing chiller plant
70	Eversource-WMECo	WM12H008	DNV GL	Chiller	Water cooled centrifugal chiller with VFD
76	Eversource-WMECo	WM12C005	DNV GL	Chilled Water	Chilled beam
2	National Grid	1457023	DNV GL	VSD and Controls	Kitchen hood controls and drive, supply fan VFD, LED lighting
3	National Grid	2058888	DNV GL	DCV	Demand controlled ventilation
4	National Grid	2067831	SBW	Controls	Install thermostatically controlled terminal boxes in additional occupied space
5	National Grid	2161174	SBW	VSD and Controls	VFD on makeup air unit, replace constant volume terminal boxes with VAV boxes & schedule airflow with laboratory occupancy.
6	**National Grid**	**2064759**	**SBW**	**RCx**	**Retrocommissioning and controls upgrades**
7	**National Grid**	**568954**	**DMI**	**Controls**	**BMS controls upgrades**
8	National Grid	981830	DMI	Free Cooling	Retrofit two new CRAC units with waterside economizer coil
10	National Grid	2321359	SBW	VSD and Controls	Setback & occupancy controls on heat pumps, VFDs on condenser pumps & outside lighting controls in classrooms and office spaces
11	National Grid	825427	DNV GL	Controls	ECM 1:Test, adjust, balance (TAB) air flow; ECM 2: Reduce minimum air change rate for labs; ECM 3: Unocc. lab setbacks; ECM 4: Reduced face velocity in fume hoods; ECM 5a: Exhaust air flow control; ECM 7: Office airflow setback
12	National Grid	1931012	SBW	Electric to Gas Conversion	Replacement of electric boiler with gas boiler serving adjacent High School and Middle School
14	National Grid	660123	DMI	MBCx	Monitoring based commissioning
15	National Grid	1898674	SBW	Free Cooling	Repair economizers
16	**National Grid**	**1966812**	**SBW**	**Free Cooling**	**New cooling tower for free cooling**

DNV GL Site ID	Program Administrator	Application ID	Evaluating Contractor	Measure Type	Measure Description
17	National Grid	2050465	SBW	VSD and Controls	On two non-patient floors of hospital: VFDs on fans (supply, return, transfer and kitchen exhaust); replacement of CV terminal boxes with VAVs; air distribution damper controls; night setback controls on fans & temperature set points.
18	National Grid	1930894	DMI	Data Center Cooling	Hot aisle/cold aisle data center configuration. RTU DX cooling
20	National Grid	809326	SBW	RCx	Retrocommissioning
21	**National Grid**	**1963238**	**SBW**	**VSD and Controls**	**Controls on 8 AHUs, VFD's on supply fans**
22	National Grid	2322663	DMI	RCx	Reduced RTU and AHU operating hours due to RCx.
23	**National Grid**	**912699**	**DNV GL**	**VSDs**	**VFDs on recirculation fans and condensing units in AHUs.**
24	**National Grid**	**923607**	**DMI**	**Controls**	**Cleanroom measure: Particle count recirculation control, filter ceiling change out, reduced air changes**
72	National Grid	2311151	DMI	Controls	BAS scheduling and optimal start.
73	**National Grid**	**1989634**	**DNV GL**	**Chilled Water**	**New chillers, pumps, cooling towers and AHUs with VFDs**
74	National Grid	1859550	SBW	Controls	EMS upgrade
68	Unitil	36561	DNV GL	Heat Pumps	50 - 3/4 ton Water source heat pumps

2.4.2 Description of Methodology

This section describes the methodology generally for both the development of site evaluation plans, the execution of the plans, and the final process for producing program results.

2.4.2.1 Measurement and Evaluation Plans

Following the final sample selection of custom HVAC applications and prior to beginning any site visits, the DNV GL team developed detailed measurement and evaluation plans for each of the 69 projects. The plans outlined: on-site methods and strategies; monitoring equipment selection, placement, calibration; and analysis issues. The PAs provided comments and edits to clarify and improve the plans prior to the plans being finalized.

Evaluators utilized the savings analysis methodologies from the Technical Assistance Study (TA) whenever possible. However, in a small number of cases, the TA methodology was unavailable or found to be incorrect or inappropriate. In those cases, the evaluators performed an analysis more appropriate to the measure being evaluated. In most cases, adjustments to savings methodologies were presented and agreed to in the measurement and evaluation plans.

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

2.4.2.2 On-Site Data Gathering, Analysis and Reporting

Data collection included physical inspection and inventory, interview with facility personnel, observation of site operating conditions and equipment, short-term metering of usage and EMS trends. At each site, the DNV GL team performed a facility walk-through that focused on verifying the post-retrofit or installed conditions of each energy conservation measure (ECM). Several of the facilities utilized EMS controls, which were either part of the application itself or controlled equipment that was included in the application. Evaluators viewed EMS screens to verify schedules and operating parameters where applicable. Instrumentation such as power recorders, Time-Of-Use (TOU) lighting loggers, TOU current loggers, and temperature loggers were installed to monitor the usage of the installed HVAC equipment and conditions of the associated affected spaces. EMS trends were also collected, when available.

Savings analyses were used to estimate hourly energy use and diversified coincident peak demand. A typical meteorological year (TMY3) dataset of ambient temperatures from Chicopee Falls, MA was used for all temperature sensitive calculations. A single weather station was used for all sites due to the requirement that Eversource-WMECo uses the seasonal definition for summer and winter peak impacts. Evaluators have been using one weather station for custom electric impact studies so that evaluated savings generated from 8,760 hourly TMY3 datasets may be additive across all sites. The ability to add peak savings values across sites using different TMY3 datasets is problematic due to the differences in how each individual TMY3 dataset is created. Each site report details the specific analysis methods used specific for each project including algorithms, assumptions and calibration methods where applicable. Several sites were analysed using building simulation models, including eQUEST.

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

2.4.2.3 Analysis Procedures

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

The results presented in the following section include realization rates (and associated precision levels) for annual kWh savings, on-peak kWh savings, and on-peak demand (kW) savings at the times of the winter and summer peaks, as defined by the ISO New England Forward Capacity Market (FCM). All coincident summer and winter peak reductions were calculated using the following FCM definitions:

- Coincident Summer On-Peak kW Reduction is the average demand reduction that occurs over all hours between 1 PM and 5 PM on non-holiday weekdays in June, July and August.
- Coincident Winter On-Peak kW Reduction is the average demand reduction that occurs over all hours between 5 PM and 7 PM on non-holiday weekdays in December and January.
- Seasonal Peak[3]: Non-holiday week days when the Real-Time System Hourly Load is equal to or greater than 90% of the most recent “50/50” System Peak Load Forecast for the summer and winter seasons.

[3] Only Eversource-WMECo uses the seasonal peak definition. All other PAs use the on-peak definitions for summer and winter peak savings.

3 RESULTS

The 2012 custom HVAC analysis consisted of population and sample sites from 2012, and also includes final commissioning estimates for some National Grid projects completed in 2013. The sample was post-stratified based on the final disposition of sample points. Case weights were recalculated based on this final sample and are shown in Table 3-1. The weights reflect the number of projects that each of the sample points represents in their respective populations and allow for the aggregation of results across the strata and PAs.

Table 3-1: Final 2012 Custom HVAC Case Weights

Program Administrator	Stratum	Maximum Total Gross Savings (kWh)	Projects	Total Gross Savings (kWh)	Projects in Sample	Case Weights
Cape Light Compact	1	159,193	7	344,410	1	7
National Grid	1	211,158	37	3,014,375	9	4
National Grid	2	473,151	11	3,729,497	6	2
National Grid	3	1,074,218	6	4,621,920	5	1
National Grid	4	2,288,693	3	6,007,092	3	1
Eversource-NSTAR	1	285,428	105	7,713,319	11	10
Eversource-NSTAR	2	527,684	27	10,274,024	9	3
Eversource-NSTAR	3	950,380	15	12,052,942	9	2
Eversource-NSTAR	4	1,654,562	10	11,952,535	8	1
Eversource-NSTAR	5	4,206,045	6	16,296,854	5	1
Unitil	1	39,229	2	78,457	1	2
Eversource-WMECo	1	1,108,800	16	3,144,311	2	8

3.1 Site Level Results

Figure 3-1 presents a scatter plot of weighted evaluated annual MWh savings plotted against the PA weighted tracking savings. The dashed line represents a realization rate of 100%. The slope of the solid line in this graph is an indication of the statewide realization rate and how it relates to a realization rate of 100%. This sample data is scattered widely around the trend line, which is indicative of the variation in savings between the tracking estimates and evaluated savings.

Figure 3-1: Evaluated Savings vs. Tracking Savings (Weighted)

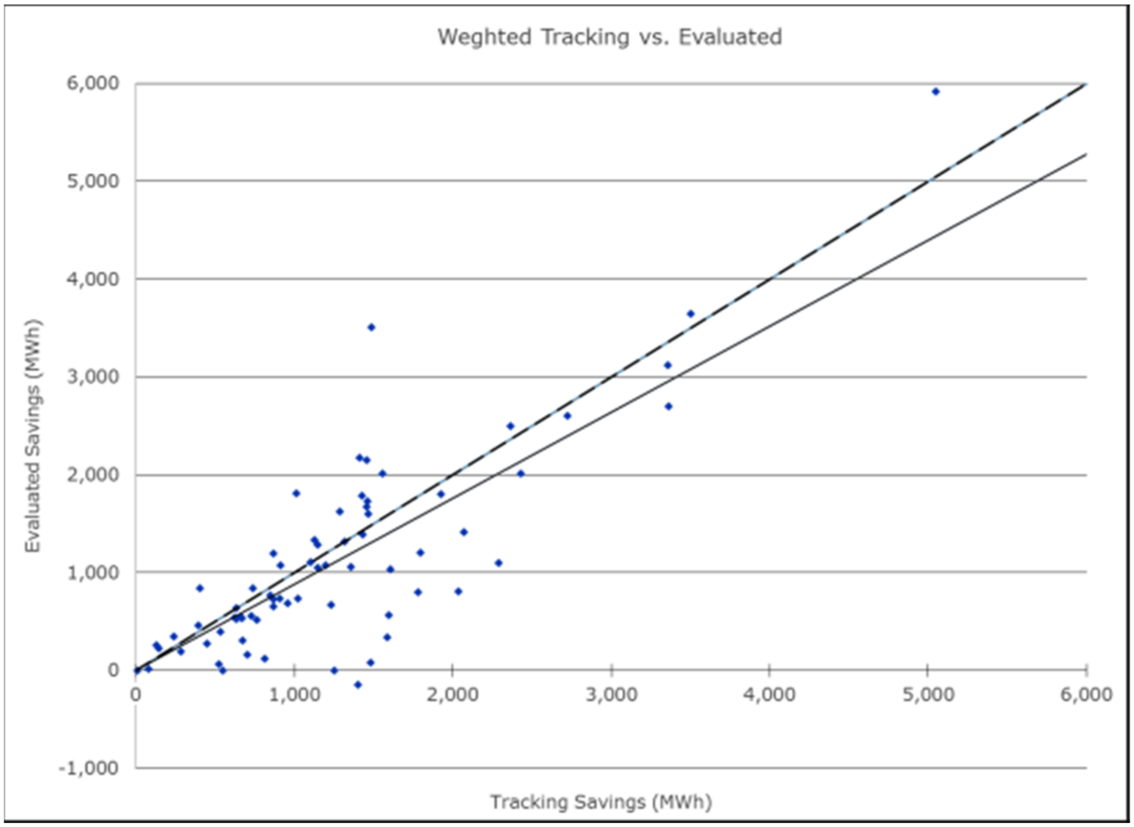

Table 3-2 presents a summary of the site level results for this impact evaluation. National Grid sites in bold are sites which underwent commissioning.

Table 3-2: Detailed Site Results

			Tracking Estimated Savings				Evaluation Savings					
DNV GL Site ID	Program Administrator	Application ID	kWh/yr	On-Peak %	Peak Coinc. Sum. kW	Wint. kW	kWh/yr	On-Peak %	On-Peak Sum. kW	Wint. kW	Seasonal Sum. kW	Wint. kW
1	Cape Light Compact	D030103533	94,465	N/A	4.1	0.2	78,835	70%	15.7	15.1	15.7	15.1
26	Eversource-NSTAR	BS11770	55,891	N/A	21.0	16.0	41,307	95%	9.1	46.8	5.9	24.4
27	Eversource-NSTAR	BS11777	13,447	N/A	1.5	1.5	26,889	100%	3.0	0.0	0.0	0.0
28	Eversource-NSTAR	BS12048	15,306	48%	1.8	1.8	23,315	10%	0.4	0.0	0.0	0.0
29	Eversource-NSTAR	BS12078	85,000	N/A	10.0	4.0	13,036	61%	6.6	0.0	12.6	0.0
30	Eversource-NSTAR	BS11343	146,914	N/A	0.0	60.0	-15,470	42%	0.0	-4.3	0.0	-1.9
31	Eversource-NSTAR	BS11720	147,650	49%	2.1	15.0	227,401	27%	14.2	5.5	14.6	0.0
33	Eversource-NSTAR	BS12424	154,866	N/A	0.0	56.4	8,668	62%	0.0	2.1	0.0	2.1
34	Eversource-NSTAR	CS8733	152,737	N/A	21.3	21.3	224,828	43%	0.0	50.3	0.0	97.7
35	Eversource-NSTAR	BS11856	336,818	N/A	22.1	46.0	602,469	51%	65.9	131.1	61.8	120.1
36	Eversource-NSTAR	BS12197	340,566	N/A	78.7	0.0	244,975	52%	62.7	10.8	77.9	9.1
37	Eversource-NSTAR	BS12224	285,428	36%	26.0	26.0	272,686	46%	31.1	31.1	31.1	31.1
38	Eversource-NSTAR	BS12310	288,179	N/A	-5.7	10.8	216,908	47%	21.8	54.6	14.9	53.9
39	Eversource-NSTAR	BS9840	304,047	N/A	-1.1	248.4	358,136	66%	6.5	112.3	5.6	222.7

DNV GL Site ID	Program Administrator	Application ID	Tracking Estimated Savings				Evaluation Savings					
			kWh/yr	On-Peak %	Peak Coinc. Sum. kW	Wint. kW	kWh/yr	On-Peak %	On-Peak Sum. kW	Wint. kW	Seasonal Sum. kW	Wint. kW
41	Eversource-NSTAR	BS12388	486,352	35%	48.8	65.3	576,191	46%	72.6	61.8	53.7	61.3
42	Eversource-NSTAR	CS8904	398,587	N/A	45.5	45.1	357,548	46%	40.8	40.8	40.8	40.8
43	Eversource-NSTAR	CS9012	439,061	N/A	214.7	76.9	439,061	46%	214.7	76.9	214.7	76.9
44	Eversource-NSTAR	CS9078	417,000	N/A	N/A	N/A	0	0%	0.0	0.0	0.0	0.0
45	Eversource-NSTAR	BS11061	771,627	18%	23.2	19.2	975,029	34%	69.9	83.0	83.9	95.1
46	Eversource-NSTAR	BS11624	676,189	N/A	77.2	77.2	801,268	47%	103.3	84.9	110.8	82.4
47	Eversource-NSTAR	BS11921	543,937	17%	15.8	47.5	438,968	23%	24.7	35.3	21.7	41.3
48	Eversource-NSTAR	BS12201	688,099	23%	11.1	13.9	628,041	17%	-0.1	32.1	0.0	55.0
50	Eversource-NSTAR	BS12059	890,000	77%	120.3	120.3	2,106,532	46%	378.0	269.0	47.8	333.2
52	Eversource-NSTAR	CS8898	878,494	N/A	156.0	156.0	959,357	46%	109.5	109.5	109.5	109.5
53	Eversource-NSTAR	BS10572	950,380	N/A	0.0	145.0	202,285	46%	0.0	48.2	0.0	48.2
54	Eversource-NSTAR	BS11727	983,191	47%	54.4	102.2	538,823	45%	4.7	62.5	13.2	84.2
55	Eversource-NSTAR	BS12311	1,083,312	N/A	44.6	140.9	848,743	42%	55.7	124.0	79.1	126.3
56	Eversource-NSTAR	CS8995	933,582	N/A	107.0	107.0	1,206,042	46%	137.7	137.7	137.7	137.7
57	Eversource-NSTAR	BS11941	1,162,979	N/A	106.3	90.9	1,341,185	45%	194.9	99.0	154.9	91.1
58	Eversource-NSTAR	BS12089	1,285,995	N/A	300.6	67.4	826,678	52%	172.4	32.7	187.4	39.6
59	Eversource-NSTAR	BS12130	1,274,642	41%	74.8	125.2	450,363	29%	28.7	19.0	21.0	24.8
60	Eversource-NSTAR	BS12157	1,145,835	N/A	0.0	359.0	1,110,758	64%	0.0	452.2	0.0	326.1
61	Eversource-NSTAR	BS10741	4,206,045	42%	464.4	480.1	4,928,156	43%	637.2	460.1	786.2	459.2
62	Eversource-NSTAR	BS11023	2,796,373	N/A	217.1	136.0	2,598,091	41%	290.9	217.3	298.2	217.1
63	Eversource-NSTAR	BS11911	1,654,562	N/A	377.0	377.0	1,132,753	81%	276.4	233.7	306.3	118.1
64	Eversource-NSTAR	BS12007	2,802,699	N/A	321.0	321.0	2,248,319	46%	256.7	256.7	256.7	256.7
65	Eversource-NSTAR	BS12259	1,968,933	50%	224.8	224.8	2,083,112	40%	191.2	156.4	303.5	130.0
67	Eversource-NSTAR	BS9084	2,024,500	N/A	123.4	123.4	1,674,924	43%	117.3	109.1	117.3	109.1
75	Eversource-NSTAR	BS11963	186,510	N/A	14.9	14.9	83,719	40%	8.5	7.3	13.8	6.9
77	Eversource-NSTAR	BS10619	1,625,674	N/A	185.6	185.6	647,003	46%	73.9	73.9	73.9	73.9
78	Eversource-NSTAR	BS10699	856,595	55%	327.7	47.7	1,073,861	50%	295.2	72.7	724.7	64.4
79	Eversource-NSTAR	BS12329	42,468	N/A	2.4	2.4	87,884	79%	27.8	13.3	26.7	6.7
80	Eversource-NSTAR	BS11842	381,338	N/A	13.4	40.0	427,634	51%	16.4	83.0	24.1	133.2
70	Eversource-WMECo	WM12H008	437,485	N/A	69.0	72.0	455,195	47%	36.2	45.5	-28.2	0.0
76	Eversource-WMECo	WM12C005	83,468	N/A	2.3	6.9	66,458	45%	2.7	15.4	2.7	15.4
2	National Grid	1457023	58,516	65%	2.8	2.8	85,189	46%	17.9	6.9	44.2	6.9
3	National Grid	2058888	2,459	50%	0.7	0.2	334	70%	0.3	0.0	0.4	0.0
4	National Grid	2067831	68,855	24%	-3.4	1.3	46,227	52%	8.4	5.1	4.8	5.1
5	National Grid	2161174	95,379	47%	10.9	10.9	111,569	42%	15.9	8.8	28.3	9.7
6	**National Grid**	**2064759**	**154,000**	**47%**	**25.3**	**13.8**	**155,529**	**57%**	**45.1**	**9.9**	**30.7**	**-2.8**
7	**National Grid**	**568954**	**163,930**	**50%**	**0.0**	**84.2**	**74,688**	**70%**	**0.0**	**20.4**	**0.0**	**12.3**
8	National Grid	981830	133,758	58%	0.2	23.2	0	0%	0.0	0.0	0.0	0.0
10	National Grid	2321359	244,013	30%	26.9	13.5	149,130	79%	37.2	31.6	35.3	34.7
11	National Grid	825427	205,641	34%	22.6	14.6	185,819	45%	27.1	14.3	32.7	9.0
12	National Grid	1931012	345,586	0%	0.0	0.0	288,295	0%	0.0	0.0	0.0	0.0
14	National Grid	660123	340,919	45%	44.0	44.0	288,041	56%	43.2	20.5	13.7	54.4

DNV GL Site ID	Program Administrator	Application ID	Tracking Estimated Savings kWh/yr	On-Peak %	Peak Coinc. Sum. kW	Wint. kW	Evaluation Savings kWh/yr	On-Peak %	On-Peak Sum. kW	Wint. kW	Seasonal Sum. kW	Wint. kW
15	National Grid	1898674	396,823	46%	89.9	22.3	302,615	47%	9.3	3.5	0.0	0.0
16	**National Grid**	**1966812**	**795,362**	**37%**	**0.0**	**118.4**	**572,453**	**43%**	**5.4**	**137.4**	**5.8**	**207.0**
17	National Grid	2050465	473,151	25%	62.7	37.7	394,967	37%	30.0	24.7	30.0	27.9
18	National Grid	1930894	586,094	46%	97.6	38.6	133,315	46%	14.4	10.7	9.9	9.9
20	National Grid	809326	635,321	46%	217.1	0.0	431,175	16%	29.3	2.7	29.5	13.2
21	**National Grid**	**1963238**	**915,908**	**47%**	**66.9**	**102.2**	**924,382**	**39%**	**84.5**	**43.7**	**68.5**	**-42.2**
22	National Grid	2322663	1,794,077	8%	0.0	0.0	1,207,283	-19%	-215.5	14.0	-569.6	14.5
23	**National Grid**	**912699**	**1,924,322**	**44%**	**197.3**	**170.3**	**1,802,999**	**47%**	**205.1**	**206.5**	**206.8**	**206.2**
24	**National Grid**	**923607**	**2,288,693**	**25%**	**305.0**	**305.0**	**1,098,018**	**74%**	**204.5**	**204.5**	**204.5**	**204.5**
72	National Grid	2311151	284,695	25%	0.0	0.0	34,408	0%	0.0	0.0	0.0	0.0
73	**National Grid**	**1989634**	**615,017**	**48%**	**63.6**	**85.4**	**697,085**	**46%**	**38.4**	**107.6**	**32.0**	**113.3**
74	National Grid	1859550	211,158	30%	23.5	11.8	291,398	32%	38.1	21.6	73.1	25.5
68	Unitil	36561	39,228	N/A	7.5	5.0	8,629	58%	3.8	0.6	9.4	0.7

Table 10 summarizes the energy savings realization rates and primary reasons for discrepancies between the tracking and evaluation estimates of annual energy savings. The site energy savings realization rates ranged from a low of -11% for Site 30 to a high of 207% for Site 79.

Table 3-3: Primary Site Discrepancies

DNV GL Site ID	Program Administrator	Application ID	kWh RR	Primary Reasons for Discrepancies
1	Cape Light Compact	D030103533	83%	The reduction in energy savings is due to a reduction in the number of units contributing to savings and the fan operating profiles observed compared to the original assumptions used. Other variances included damper positioning, fan speeds, and discharge air temperatures during occupied and unoccupied periods.
26	Eversource-NSTAR	BS11770	74%	The savings variance is attributed to changes in schedules and loads identified during the site monitoring. Changes were made in eQuest models including occupancy, lighting, equipment, cooling/heating, and fan schedules, in CHW/CW pump flows, in AHU CFM, and in fan-flow ratios.
27	Eversource-NSTAR	BS11777	200%	Fans are shut off much more than expected
28	Eversource-NSTAR	BS12048	152%	The tracking study did not provide any backup to the claimed savings
29	Eversource-NSTAR	BS12078	15%	Tracking assumed heat savings to be fixed at a high level, evaluators found it never reached that high a level and moreover it varied with outdoor air temperature.
30	Eversource-NSTAR	BS11343	-11%	Compressor savings did not manifest at low outdoor air temperatures as expected, moreover there was a drycooler penalty
31	Eversource-NSTAR	BS11720	154%	The primary reason for the increase in savings is a higher than predicted demand and hours reduction due to the use of automatic chiller staging
33	Eversource-NSTAR	BS12424	6%	Tracking calculations exaggerated baseline chiller part-load chiller kW and underestimated chiller run hours during assumed free-cooling periods
34	Eversource-NSTAR	CS8733	147%	The savings variance is due to longer cooling season than baseline estimates, differences in baseline and installed chiller efficiencies, and monitored as opposed to estimated cooling loads. Tracking savings also did not include the elimination of basin heaters.
35	Eversource-NSTAR	BS11856	179%	Use of three years of post-retrofit data rather than one partial year.
36	Eversource-NSTAR	BS12197	72%	Correction of error in pre-retrofit energy calculation, increase in estimated percent occupancy, addition of fan savings to the calculation.
37	Eversource-NSTAR	BS12224	96%	No significant changes.
38	Eversource-NSTAR	BS12310	75%	Airflow reduction on fewer air handlers, schedule changes, fan power input changes, minor modeling errors corrected.
39	Eversource-NSTAR	BS9840	118%	Changes to model structure, inputs (hot water set points), perimeter heat changed from fin tube to fan coil, no replacement of electric humidification system
41	Eversource-NSTAR	BS12388	118%	There was a higher than predicted exhaust fan pre-retrofit demand, lower than predicted exhaust fan installed case operating hours and lower than predicted pre-retrofit pump efficiency
42	Eversource-NSTAR	CS8904	90%	The monitored fan power was 111% of the predicted installed fan power.

DNV GL Site ID	Program Administrator	Application ID	kWh RR	Primary Reasons for Discrepancies
43	Eversource-NSTAR	CS9012	100%	No savings variances were identified for this project. Savings are derived from not installing a dedicated chiller but drawing cooling from an existing central plant.
44	Eversource-NSTAR	CS9078	0%	The energy efficiency measure, VAV air handling units, supported by this application is required by the energy code, and therefore the savings should not have been claimed for the New Construction project.
45	Eversource-NSTAR	BS11061	126%	Lower proposed case airflows than predicted by the tracking study
46	Eversource-NSTAR	BS11624	118%	Pumps savings greater than expected and dry cooler savings had not been considered
47	Eversource-NSTAR	BS11921	81%	There were different post-retrofit AHU schedules than what was assumed in the tracking analysis (lower hours reduction).
48	Eversource-NSTAR	BS12201	91%	There is a variation between the tracking schedule assumptions and what is currently programmed. The TA claimed savings from automatically turning AHUs off during unoccupied hours, but the evaluation found that some units did not turn off as scheduled while others operate for more hours than assumed in the tracking analysis.
50	Eversource-NSTAR	BS12059	237%	The performance improvement from reducing the number of chillers operating was much greater than predicted
52	Eversource-NSTAR	CS8898	109%	The savings variance is due to differences in monitored cooling and UPS loads when compared with tracking estimates.
53	Eversource-NSTAR	BS10572	21%	Measure no longer installed. Savings were calculated for first two years of life.
54	Eversource-NSTAR	BS11727	55%	The decrease in savings result from the variation between the tracking schedule assumptions and what is currently programmed; variation between the TA's fan kW calculations and the evaluation, and approximated post-commissioning savings adjustment factors.
55	Eversource-NSTAR	BS12311	78%	Changes to fan/condenser pump kW and schedules, more chiller operation in winter than anticipated.
56	Eversource-NSTAR	CS8995	129%	The cooling tower fans were monitored at 180% of proposed operation. The tracking estimates also assumed no chiller operation below 48°F while monitoring found chiller operation below that temperature.
57	Eversource-NSTAR	BS11941	115%	The measures with the most significant impact on the realization ratio were ECM 1: Optimized Winter Cooling, whose savings were reduced due to less use of free cooling and a higher minimum flow ratio, and ECM 6: CH-4 Reduced Flow, whose savings increased due to increased run hours on CH-4.
58	Eversource-NSTAR	BS12089	64%	Loads on condenser water pumps and chilled water pumps now much greater than expected
59	Eversource-NSTAR	BS12130	35%	Lower than predicted energy savings are due to lower than predicted fan demand reduction, fewer unoccupied (saved) hours, and TA calculation error.
60	Eversource-NSTAR	BS12157	97%	Correction of model correlation error
61	Eversource-NSTAR	BS10741	117%	Lower proposed case occupied airflows than predicted by the tracking study
62	Eversource-NSTAR	BS11023	93%	Tracking savings included demand controlled ventilation and lighting occupancy sensors that were not installed. Also, two dedicated server room HVAC units were not installed. The remaining savings variance is due to monitored fan and pump operation [schedule and power] entered in eQuest modeling overriding eQuest modeling estimates.
63	Eversource-NSTAR	BS11911	68%	Total existing motor kW is 16% less than tracking estimates while proposed operation is 12% greater than anticipated.
64	Eversource-NSTAR	BS12007	80%	The evaluation total connected motor load is 20% less than the tracking value. All baseline motors operated at 100% of nameplate value.
65	Eversource-NSTAR	BS12259	106%	The increase in savings is due primarily to decreased night time cycling of the FCUs and HPs.
67	Eversource-NSTAR	BS9084	83%	The proposed unoccupied schedules have not been fully implemented across the campus. Setbacks are not as deep as proposed. Also, inoperable systems are being repaired and brought back into service as the retro-commissioning project continues at the site. Tracking savings are not adjusted to account for this additional equipment.
75	Eversource-NSTAR	BS11963	45%	The primary reason for the decrease in savings is the lower than predicted air handling unit supply fan power. The lower fan demand was partially because the tracking study did not account for VSD control of the supply fan. Additionally, the tracking study assumed that the return fan would be included in the air handling unit scheduling controls, but the evaluation found that the return fan runs continuously in the installed case.

DNV GL Site ID	Program Administrator	Application ID	kWh RR	Primary Reasons for Discrepancies
77	Eversource-NSTAR	BS10619	40%	The TA claimed savings for replacing existing broken variable speed drives and installing new drives on CV fans, but the evaluation found all fans operating at constant speeds with no modulation.
78	Eversource-NSTAR	BS10699	125%	Increase in savings is due primarily to better-than-predicted performance improvement
79	Eversource-NSTAR	BS12329	207%	The greater energy savings is due to significantly lower operating hours in the installed case and greater operating hours in the pre-retrofit case.
80	Eversource-NSTAR	BS11842	112%	The tracking savings used a 33.6°F wet bulb temperature as the free-cooling switchover point in the baseline scenario. The facility personnel confirmed that the baseline 450-ton heat exchanger was rapidly losing capacity and control set points were drifting lower. The free-cooling switchover was approaching 30°F by the time the measure was implemented. 31°F was used in the evaluation calculations.
70	Eversource-WMECo	WM12H008	104%	The savings variance is due the difference between the monitored and estimated chiller performance. Incremental hourly/daily chiller loads are modeled according temperatures and performance on the chiller curves.
76	Eversource-WMECo	WM12C005	80%	Chill beam tracking savings are based upon Trane Trace models which were not provided. VFD and dual enthalpy savings were calculated using a deemed savings approach with no baseline conditions provided. The evaluation savings are based upon monitored data and estimates of baseline performance.
2	National Grid	1457023	146%	The primary reasons for the increased savings were that the supply and exhaust fans were found to operate constantly (pre and post), and at much lower kWs in the post-condition than expected. There was also a reduction in lighting savings due to a drop in operating hours, which partially offset the large increase in savings from the fans.
3	National Grid	2058888	14%	The facility occupants manually operate the HVAC system via the thermostat. The facility has limited occupancy and operating hours are less than tracking estimates. No actual ventilation values or conditions were provided in the tracking documentation.
4	National Grid	2067831	67%	Changes made to applications 1963238, a related project at the same site, which is the pre-retrofit condition for this project; changes made to HVAC schedules and setbacks for this measure; possible incorrect method used in TA analysis for kW savings.
5	National Grid	2161174	117%	Improved post-installation fan kW values; cooling energy savings reduction due to algorithm improvements, partial offset fan energy savings increase.
6	National Grid	2064759	101%	Commissioning process adjusted savings down due to unexpected higher unoccupied fan speeds.
7	National Grid	568954	46%	Pre-Retrofit Chiller Perf - The pre-retrofit demand was lower than predicted due to lower CHW load and better than predicted chiller part load performance. TA estimated chiller performance and loading. Evaluation used metered load data for determining pre-retrofit chiller performance.
8	National Grid	981830	0%	The two CRAC units do not switch into ‘free cooling’ or water-side economizer mode. The units operate in mechanical cooling mode year round.
10	National Grid	2321359	61%	Heat pumps savings and cooling tower savings negligible; no pump savings; lighting savings only half of expected; ERV savings almost 4X more than expected
11	National Grid	825427	90%	This is an interactive 6 measure project modeled through eQuest. No working eQuest baseline or sequential files were provided. Monitored system power differed from some documented text, but the precise reasons for the differences could not be firmly established. The most likely reason is different incremental power requirements at different times [time-of-day scheduling] and with weather dependency.
12	National Grid	1931012	83%	Changes made to model structure, schedule changes, reduction to savings during summer months.
14	National Grid	660123	86%	The decrease in savings is due to shorter pre-retrofit AHU schedules and lower maximum flow rates (less pre-retrofit energy use) than what was assumed in the tracking analysis.
15	National Grid	1898674	76%	Changes made to application 1963238, a related project at the same site, which is the pre-retrofit condition for this project.
16	National Grid	1966812	72%	Energy impacts of multiple pieces of equipment ignored in tracking savings; control set points changed
17	National Grid	2050465	83%	Supply and kitchen exhaust fans do not turn off as proposed

DNV GL Site ID	Program Administrator	Application ID	kWh RR	Primary Reasons for Discrepancies
18	National Grid	1930894	23%	TA expected the average cooling load to be 4.54 kW per rack (590 kW total), while the evaluator found cooling load to be 2.30 kW (299 kW total). This resulted in only two of the three RTUs operating to meet the reduced load.
20	National Grid	809326	68%	Occupancy on/off control measure not implemented on all the units as had been expected
21	National Grid	1963238	101%	Changes to schedules and night setback temperatures. These changes also affected applications 1898674 and 2067831.
22	National Grid	2322663	67%	The primary reason for the decrease in savings is the variation between the tracking schedule assumptions and what is currently programmed. Across all units, runtime increased by a net of 168.5 hours from the tracking analysis to the installed.
23	National Grid	912699	94%	The major contributors to the savings variance are the reduction in process loads with a corresponding cooling load reduction, and increases in average operating fan kW to maintain proper air flow and space pressurization
24	National Grid	923607	48%	TA estimated much greater pre-retrofit occupied fan demand, much lower installed occupied fan demand, and a greater number of annual occupied hours
72	National Grid	2311151	12%	The pre-retrofit fan kW was overestimated and optimal start sequences were not functioning as intended
73	National Grid	1989634	113%	Monitored cooling tower kW is 60% of the proposed tracking estimate. The tracking savings are based upon a 50°F free cooling temperature set point. The site evaluation found HVAC and process chiller operation throughout the winter and at temperatures below 0°F. Monitored annual ton-hours are 20% less than tracking estimates. Cooling HVAC operation is 17% greater than anticipated.
74	National Grid	1859550	138%	Changes to model influenced the result, including fewer occupancy hours
68	Unitil	36561	22%	The tracking documentation did not include the variables used in the savings calculations and did not provide manufacturers' design specifications. Evaluation savings were based upon monitored operation and manufacturers' efficiencies.

3.2 Retrospective Realization Rates

The site level evaluation results were aggregated using the final adjusted case weights. The PA realization rates were estimated and then applied to each PA's total tracking savings to determine their total measured savings. The statewide realization rate is the ratio of the total measured savings to the total tracking savings, each of which is calculated by summing across the PAs. Table 3-4 summarizes the statewide results of this analysis. The table shows the results for five of the six measures of savings. State wide on-peak kWh savings was not calculated because not all PAs provide tracking system data on this measurement.

The statewide realization rate for custom HVAC measures was found to be 88%. The relative precision for this estimate was found to be ±7.4% at the 90% level of confidence. The error ratio was found to be 0.47, which is nearly equivalent to the 0.48 found in the prior study, and somewhat better than the estimate of 0.6 used in the sample design for this study. For the on-peak summer kW, the overall realization rate was 88%, with a relative precision of ±12.6% at an 80% confidence level. For on-peak winter kW, the realization rate was a bit lower, at 85%. Summer and winter seasonal peak kW savings realization rates are also provided for use by Eversource-WMECo.

Table 3-4: 2012 Custom HVAC Statewide Results

Program Administrator	Parameter	Annual kWh	Summer On Peak kW	Winter On-Peak kW	Summer Seasonal kW	Winter Seasonal kW
Statewide – All PAs (n=69)	Tracking Savings	79,229,736	9,718	9,055	9,718	9,055
	Evaluated Savings	69,687,922	8,594	7,668	8,458	7,715
	Realization Ratio	88%	88%	85%	87%	85%
	Relative precision	±7.4%	±12.6%	±13.1%	±17.1%	±16.6%
	Error ratio	0.47	0.84	0.95	1.05	1.12

The results of DNV GL's analysis of realization rates by PA follow in Table 3-5. All relative precisions for kWh savings realization rates were calculated at the 90% confidence interval, while all relative precisions for kW savings realization rates were calculated at the 80% confidence interval.

All PAs, with the exception of Eversource-WMECo, had annual kWh savings realization rates less than 100%. The realization rates for percent on-peak kWh savings are provided in this table for National Grid.

Table 3-5: 2012 Custom HVAC Results by PA

Program Administrator	Parameter	Annual kWh	On-Peak kWh Percent	Summer On Peak kW	Winter On-Peak kW	Summer Seasonal kW	Winter Seasonal kW
Cape Light Compact (n=1)	Tracking Savings	344,410	N/A	131	8	131	8
	Evaluated Savings	287,425	N/A	503	484	503	484
	Realization Ratio	83%	N/A	385%	6076%	385%	6076%
	Relative precision	±0.0%	N/A	±0.0%	±0.0%	±0.0%	±0.0%
	Error ratio	0.00	N/A	0.00	0.00	0.00	0.00
National Grid (n=23)	Tracking Savings	17,372,884	N/A	1,823	1,736	1,823	1,736
	Evaluated Savings	13,087,095	N/A	1,274	1,167	1,065	1,148
	Realization Ratio	75%	106%	70%	67%	58%	66%
	Relative precision	±8.8%	±18.9%	±18.7%	±16.7%	±37.2%	±21.5%
	Error ratio	0.40	1.02	0.88	0.80	1.95	1.07
Eversource-NSTAR (n=42)	Tracking Savings	58,289,674	N/A	7,197	7,063	7,197	7,063
	Evaluated Savings	53,025,255	N/A	6,790	6,222	7,333	6,590
	Realization Ratio	91%	N/A	94%	88%	102%	93%
	Relative precision	±9.4%	N/A	±15.3%	±16.1%	±15.9%	±18.1%
	Error ratio	0.49	N/A	0.82	0.82	0.79	0.93
Unitil (n=1)	Tracking Savings	78,457	N/A	15	10	15	10
	Evaluated Savings	17,257	N/A	8	1	19	1
	Realization Ratio	22%	N/A	51%	12%	126%	14%
	Relative precision	±0.0%	N/A	±0.0%	±0.0%	±0.0%	±0.0%
	Error ratio	0.00	N/A	0.00	0.00	0.00	0.00
Eversource-WMECo (n=2)	Tracking Savings	3,144,311	N/A	552	238	552	238
	Evaluated Savings	3,148,539	N/A	300	184	-198	46
	Realization Ratio	100%	N/A	54%	77%	-36%	19%
	Relative precision	±7.1%	N/A	±6.0%	±28.0%	-±23.1%	±154.7%
	Error ratio	0.08	N/A	0.15	0.49	-0.56	2.68

3.3 Measure Level Results

Table 3-6 presents an un-weighted summary of custom HVAC results by measure type. Sites were grouped by DNV GL into the eight generalized categories shown in the table. Many sites contained multiple measures, so each site was characterized based on the measure that accounted for the majority of savings. The “Other" measure category consists of measures such as electric to gas conversion, heat pumps, heat recovery, and VAV RTUs. Note that the VAV RTU measure, included in “Other,” resulted in zero savings due to installed measure representing code.

Table 3-6: 2012 Custom HVAC Results by Measure

Measure Type	Number of Sites	Tracking kWh	Evaluated kWh	Un-weighted kWh Realization Rate
EMS Scheduling and Controls	21	11,908,717	10,626,156	89%
VSDs and Controls	13	12,319,726	10,388,232	84%
Retrocommissioning	7	10,704,688	10,233,533	96%
Chiller and Chiller Plant	6	3,737,681	3,611,429	97%
Data Center Cooling	6	3,619,860	3,442,060	95%
Free Cooling	6	2,812,527	1,513,655	54%
Demand Controlled Ventilation	5	2,040,808	1,534,963	75%
Other	5	2,126,124	1,571,483	74%
All	**69**	**49,270,131**	**42,921,512**	**87%**

DNV GL used the un-weighted results as a first pass in the investigation of the measure level results. Following this cursory review, the evaluation team performed a deeper review of selected measures. The following contains some findings on specific measure groupings.

3.3.1 Free Cooling Measures

Free cooling measures appeared to have a large impact on the reduction in savings overall. In total, one of the six free cooling measures was found to be achieving the expected savings. When weighted, using the site case weights from Table 3-1, the combined realization rate of the six projects was 46% as compared to the remaining projects in the sample (91%). There are some reasons for this finding, which impacted both Eversource-NSTAR and National Grid the same.

- Two sites are no longer realizing savings from this measure. The computer room air conditioning units from site 981830 do not switch into free cooling mode. The evaluation found that these units are operating in mechanical cooling mode all year round. The free cooling tower installed as part of Site BS10572 has been dismantled and removed in favor of a new system at the facility. The measure operated for the first two years of its measure life, with zero savings being applied to the remainder of the measure life.
- One site (BS12424) resulted in a significant reduction in savings due to an incorrect estimate of chiller part-load efficiency for the baseline system as well as overestimating the assumed free cooling hours at the facility.
- Two other sites lost savings due to the interactivity associated with other measures and equipment at their respective facilities. Site 1898674 was impacted by changes to another project at the site, which lowered the baseline energy use for this measure due to interactivity between measures. Site 1966812 was affected by the tracking savings not including the energy impacts of multiple pieces of equipment at the site. When included, these energy impacts resulted in a reduction in savings.

3.3.2 Demand Controlled Ventilation

Demand controlled ventilation (DCV) measures displayed a wide range of savings results from 14% to 207%. Of the five DCV sites, only one exceeded a 100% realization rate, while one other came close at 96%. When weighted, the combined realization rate of the five projects was 91% as compared to the remaining projects in the sample (88%). Even though DCV measures performed reasonably well in this evaluation, there are some observations to report.

- DCV measures save energy by reducing the amount of outside air brought into a space for ventilation. As a control measure, savings are dependent on pre-installation or baseline estimates of ventilation rates. Without pre-installation measurements for retrofit type applications, it is difficult to assess the pre-retrofit ventilation rates. This is usually done through discussions with facility personnel. If ventilation is a large percentage of the overall electric use, a drop in savings could be seen a comparison of pre/post electric interval data. However, this rarely is the case due to other high electricity uses on the same meter. In many cases, evaluators have to rely on the TA study, code ventilation rates or the customer's reported information, resulting in some uncertainty in the calculated savings.
- One project (2058888) did not document the ventilation rates used in the tracking analysis. For this site, evaluators referred to code ventilation rates for the baseline condition. It is possible that this decision underestimated savings for this site, but there was no documentation to support higher ventilation rates for this site.

3.4 Assessment of Project Baselines

Determination of baseline or pre-retrofit conditions is important to the accurate estimation of actual savings resulting from the installation of energy efficient measures. As part of each custom impact evaluation, the DNV GL evaluator makes an assessment regarding the validity of the baseline systems used in the tracking savings estimates, and also whether or not a measure was appropriately categorized as retrofit or new construction.

3.4.1 Retrofit Projects

In this impact evaluation, DNV GL found that 59 of the 69 sampled sites were classified by the PAs as retrofit measures. This typically means that the pre-existing condition was used as the baseline system for energy efficiency savings calculations. This evaluation concluded that all but two of the projects classified as retrofit were classified correctly. The two projects that were not were instances in which they were mislabelled, but their tracking savings estimates were calculated correctly by using the a new construction baseline. Of the 59 retrofit projects evaluators made the following assessments:

- 45 projects included controls installation/upgrades, VSDs or free cooling systems added to existing equipment or control systems. Evaluators maintained the retrofit baseline for each of these projects.
- Similarly, eight sites were retrocommissioning related projects. These are projects in which existing equipment or controls are re-commissioned based on current operating conditions at the facility. Evaluators maintained the retrofit baseline for each of these projects.
- Two sites replaced existing, functioning equipment. One site kept the existing equipment as back-up for the new system. Evaluators maintained the retrofit baseline for both projects.
- One site added insulation to existing piping, which runs through a data center cold air underfloor supply plenum. Evaluators maintained the retrofit baseline for this project.
- One site added piping to connect a campus building to a central plant, which resulted in removal of the functional air-cooled chiller from the campus building. Evaluators maintained the retrofit baseline for this project.

- One project, which included new heat pumps, was classified as a retrofit project, but was treated as a new construction project by both the TA study and the evaluation team. This project used code compliant heat pumps for the baseline system.
- One project, which included hot aisle/cold aisle containment in a data center was tracked as a retrofit project, but was treated as new construction by both the TA study and the evaluation team.

3.4.2 New Construction Projects

Ten of the sampled sites were classified by the PAs as new construction projects. This typically means that a hypothetical, standard efficiency system was used as the baseline system for energy efficiency savings calculations. Of the ten retrofit projects evaluators made the following assessments:

- Three chiller sites had applicable code requirements. Each of these sites included code compliant chillers as the baseline. Evaluators maintained the baseline for each of these projects.
- Four sites were related to data center cooling. There was no specific code requirement for these measures, but there were questions concerning the baseline systems chosen. In one case, the baseline system consisted of more computer room air handlers than in the proposed system. Ultimately, the evaluation maintained the baseline systems for each of these projects. However, additional study of data center cooling common practice should be considered for future research as data centers continue to be significant participants in custom HVAC programs.
- One site was a food packaging plant, which used RTUs as the baseline cooling system. The new cooling system included two new chillers. The customer commented that the RTU system was consistent with normal practice for this type of facility. Evaluators maintained the assumed baseline for this project.
- One site was classified as a new construction project, but used existing chillers as the baseline system. The measure was the addition of a smaller chiller to handle reduced winter loads in place of the larger chillers, which operate during the summer. Evaluators agreed with the existing system as the baseline for this measure, since the new chiller is replacing the existing chiller during the winter months. Without the new chiller, the site would continue to operate the existing chiller to serve the winter loads.
- One site was classified as new construction, but a code baseline was not used. The energy efficiency measure, VAV air handling units, proposed by this application is required by energy code, and zero savings were assumed for this site.

3.5 Comparison to Prior Results

This is the second statewide impact evaluation of custom HVAC projects. The first custom HVAC evaluation was completed in 2011 and included projects installed during the 2009 program year. The statewide energy savings realization rate was found to be 88% in this study, which is significantly lower than the prior result of 110%. The statewide summer and winter on-peak kW savings realization rates for this study (88% and 84%, respectively) were more consistent with the prior results (88% and 86%, respectively).

Both Eversource-NSTAR and National Grid showed significant decreases in their energy savings realization rates from the prior study. Eversource-NSTAR decreased from 124% to 91%, while National Grid decreased from 101% to 75%.

3.5.1 Sites with Largest Influence

DNV GL reviewed all sites to determine those that had the largest influence on the results based on a combination of site savings and sample weight. The next sections summarize these sites for both Eversource-NSTAR and National Grid. The other PAs only had one or two sites, which did not influence the overall results significantly.

3.5.1.1 Eversource-NSTAR

Table 3-7 presents a list of the ten Eversource-NSTAR sites that had the largest influence on their overall realization rate in order of their impact after weighting. Note that there was one site with negative savings due to a penalty that was not included in the TA study, and a site with zero savings due to the proposed measure being required by code. One site is the free cooling site that has been removed. The remaining sites differed mostly for operational reasons.

Table 3-7: Eversource-NSTAR Largest Influencers

Application ID	Measure Type	Tracking kWh/yr	Evaluated kWh/yr	Influence	Primary Reason
BS12059	Controls	890,000	2,106,532	Positive	Underestimated performance improvement
BS11343	Data Center Cooling	146,914	-15,470	Negative	Dry cooler penalty unaccounted for in TA estimate
BS12424	Free Cooling	154,866	8,668	Negative	Overestimated free cooling hours
CS9078	VAV RTUs	417,000	0	Negative	Proposed measure required by code
BS10572	Free Cooling	950,380	202,285	Negative	Measure removed after two years
BS10619	VSD and Controls	1,625,674	647,003	Negative	Fans operate at constant speed rather than variable
BS12130	Controls	1,274,642	450,363	Negative	Lower fan power reduction, fewer unoccupied hours, TA calculation error
BS11963	Controls	186,510	83,719	Negative	Overestimated fan savings. Return fan operates continuously
BS10741	RCx	4,206,045	4,928,156	Positive	Underestimated reduction in airflow
BS11856	Controls	336,818	602,469	Positive	More data to support post-retrofit energy use

3.5.1.2 National Grid

Table 3-8 presents a list of the ten National Grid sites that had the largest influence on their overall realization rate in order of their impact after weighting. National Grid had one site with zero savings due to the measure not operating (free cooling). One site resulted in fewer saving due to interactivity with other equipment that was not captured by the TA study. One site lost savings from not implementing the occupancy on/off control measure on all units that were proposed. The remaining sites differed mostly for operational reasons.

Table 3-8: National Grid Largest Influencers

Application ID	Measure Type	Tracking kWh/yr	Evaluated kWh/yr	Influence	Primary Reason
923607	Controls	2,288,693	1,098,018	Negative	TA overestimated fan demand savings and occupied hours
2322663	RCx	1,794,077	1,207,283	Negative	Post-retrofit schedules include more hours than proposed
981830	Free Cooling	133,758	0	Negative	Units operate in mechanical cooling mode year round
1930894	Data Center Cooling	586,094	133,315	Negative	TA overestimated cooling loads
2311151	Controls	284,695	34,408	Negative	TA overestimated pre-retrofit fan demand and optimal start sequences not functioning correctly
568954	Controls	163,930	74,688	Negative	Pre-retrofit chiller use was lower than predicted based on metered pre-data
1859550	Controls	211,158	291,398	Positive	Fewer post-retrofit occupancy hours
1966812	Free Cooling	795,362	572,453	Negative	Interactivity with other equipment not included in TA study
809326	RCx	635,321	431,175	Negative	Occupancy on/off control measure not implemented on all units
2321359	VSD and Controls	244,013	149,130	Negative	Overestimated heat pump, cooling tower, pump and lighting savings

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Realization Rates

The statewide energy realization rate precision was ±7.4%. The energy realization rate precision levels for Eversource-NSTAR and National Grid were ±9.4% and ±8.8%, respectively. The sample was designed to target 10% precision at the 90% confidence level for both Eversource-NSTAR and National Grid as well as statewide. Both PA specific results should be applied since they exceed the design criteria for precision. This means that Eversource-NSTAR and National Grid will use their specific realization rates and the remaining PAs will use the state wide realization rate for 2015 annual reporting and any 2016–2018 program planning and subsequent year reporting, unless replaced by results from a subsequent study.

4.2 Program Improvement Recommendations

Improve Baseline or Pre-Retrofit Documentation

Several sites did not clearly document the pre-retrofit equipment operation or the basis for the base case in their project applications. For example, some technologies that use controls to change operations, such as, ventilation control measures, economizers and others, are very common and the supporting documentation and baseline assumptions provided for HVAC control measures, were not as comprehensive as with other technologies. For demand control ventilation and economizer measures the actual damper settings and ventilation air flow rates provided are key savings inputs, but were not always provided. A default to rated or code compliant design conditions was used by the evaluation to provide results for some projects. However, this use of design conditions could have the impact of either over or underestimating savings. It is recommended that PA's collect and document information on the actual HVAC system operations such as damper positions, outside air ventilation levels, etc. for existing equipment undergoing controls improvements. Sites with baseline documentation issues included:

- 1930894
- 2058888
- BS12048
- CS9078
- BS11963

- BS10619
- WM12C005

Provide Sufficient Documentation

Documentation is essential for supporting baseline conditions and detailed calculations. Comprehensive documentation, meaning working savings calculation files and thorough explanation of baseline and installed case assumptions, is also necessary for evaluation purposes. In some cases where the savings calculations were not present or where pertinent electronic files were not available, the savings could not be reproduced by the evaluator with confidence. Missing information includes building simulation input files and working custom savings spreadsheets, both of which should be included in the PA files.

Clearly Document Calculations of Peak Demand Savings

Parameters for estimating the peak demand savings are often not clearly stated in the tracking savings calculations and documentation. Tracking demand savings are typically estimated using weighted operational proportions. However, the source or logic of the weighted averaging is not always documented. The result of this is that peak demand savings estimates may be over or under estimated if savings are not averaged in the appropriate bins or using the correct hours. It is recommended that vendors provide full and clear documentation of peak savings calculations. Several sites did not provide calculations for, or a description of how peak demand savings were estimated, including:

- 923607
- BS11720
- BS11921
- BS12059
- 2311151
- BS10619

Encourage More Comprehensive Commissioning and Updating of Tracking Estimates with Findings from Commissioning

Commissioning is a useful tool to help improve savings estimates for HVAC controls projects. While all PAs currently use commissioning in some capacity, there are areas where this tool can be improved. First, PAs should consider employing a commissioning process on any large or complex project and particularly those with controls measures. The DNV GL team identified some sites that had savings of greater than 500,000 kWh, which did not appear to receive commissioning, including:

- 1930894
- BS11061
- BS12201
- BS12059
- BS11727
- BS10619

Additionally, PAs should continue to follow-up on projects that are commissioned to ensure that it has been done in accordance with the design intent, and that any adjustments should are made to the tracking estimates.

Large National Grid projects that require commissioning are sometimes split into two separate applications if the required commissioning could not be completed in the calendar year. National Grid saw their projects with commissioning achieve higher savings realization rates as compared to the remaining sites in their sample. The weighted average realization rate for sites with commissioning was 78% compared to an estimate of 73% for the remaining sample. Four of the seven split sites had realization rates better than 90% after commissioning. Of the remaining 15 sites that didn't split into two applications for commissioning, only four had realization rates better than 90%. The two controls measures that were commissioned (568954 and 923607) performed poorly in this evaluation. These were the result of over estimating pre-retrofit conditions more so than post-installation operation.

Conduct Pre-Installation Metering for Retrofit Projects

Short term pre-installation metering could be used to confirm assumptions about pre-existing equipment for some retrofit projects, particularly control type projects. The evaluator may not be able to simulate pre-retrofit operating conditions; therefore metering by the implementation vendor prior to installation could improve confidence in the pre-retrofit assumptions. This would be most useful for demand control ventilation or other controls type projects. For example, three of the five demand control ventilation measures that were evaluated resulted in savings of less than 75% of the tracking estimates. Not all of this decrease could be attributed to baseline assumptions, but improvements in baseline assumptions may result in better savings estimates. Likewise, one of the four projects had a realization rate of over 200% due to higher baseline hours versus assumed baseline hours.

Improve use of Post Inspection to Verify Measure Operation

Evaluators identified a number of sites in which the controls or equipment installed were not operational. Post inspections are generally occurring on all custom projects, but the effectiveness of the post inspection could be improved by observing and documenting operating conditions at the time of the inspection rather than only verifying if the measure was installed. Evaluators have observed some improvement in the effectiveness of post installation inspection in more recent custom impact evaluations as compared to studies from five years ago. It is recommended that the PAs continue to use more rigorous post-installation inspections to further build on the efforts made in this area.

4.3 Evaluation Recommendations

Require Trend Data Acquisition

Stipulate in customer participation agreement that for sites receiving controls measures, either customer staff are to be trained or the controls contractor will be required to assist with subsequent EMS trending in the event customer is chosen as an evaluation site. It would be helpful to include in the contract specifically which trends should be made available to the PA and evaluators for evaluation. The engineers developing the project scopes could specify the required trends. Consider the feasibility of configuring controls systems to allow remote access by evaluators to allow for data downloads.

Use Error Ratio from this Study for Future Sample Design Planning

The use of the 0.60 error ratio in the sample design was found to be higher than the actual resulting error ratio of 0.47 for the state. This study's error ratio was also consistent with the prior 2011 study, which found this value to be 0.48. Future custom HVAC sample designs could continue to use the 0.60 error ratio estimate as a conservative value, or consider using a 0.50 error ratio, which would have effect of reduced sample sizes.

Consider Use of Desk Review Methodology

A recent MA custom gas evaluation performed desk reviews on a double sample of custom gas projects.[4] This was set up as a test to determine if a desk review process could predict changes in realization rates that would trigger an impact evaluation. The evaluators concluded that the results of the test were not

[4] Energy & Resource Solutions and DNV GL, Project 43 Impact Evaluation of PY2013 Custom Gas Installations, September 2015

strong enough to warrant adoption of this process as the primary means of determining when to conduct an impact evaluation. However, future impact evaluations, including custom HVAC, may benefit from a structured desk review of key parameters from the M&V sample for ongoing monitoring of program characteristics. An interesting option is to use the structured desk review on a rolling sample for the purpose of providing ongoing program implementation feedback and as well as a continuous indication of program change that could be reviewed as part of the annual evaluation planning. A continuous desk review process would characterize some program change indicators, including quality of engineering calculations and baselines used to estimate savings. The PAs have commissioned a study to design improve evaluation planning, where the desk review role in impact evaluation can be further considered.

Consider Other Evaluation Methodologies

This impact evaluation of custom HVAC installations took over two years to complete for a couple reasons. First, the National Grid policy of splitting some applications into two program years to ensure they are properly commissioned was in its first year. This meant that this evaluation needed to span two years in order to evaluate the fully completed projects. Second, many custom HVAC projects have summer and winter saving measures, which required longer term metering to capture all impacts in both seasons. The former should not continue to be a factor in evaluation timing decisions as the evaluation team has decided on a methodology for accounting for the commissioning policy by including only fully commissioned projects from the start. However, the evaluation team still has to balance the requirement for high rigor evaluation with more timely results. As such, the evaluation team should investigate alternative options to evaluate large, influential measures such as custom HVAC. Ideas, including a rolling annual sample, are currently being discussed as part of a new effort to refine the gross impact evaluation framework.

5 APPENDIX A: REFERENCES

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

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

6 APPENDIX B: SITE REPORTS