National Grid USA

Impact Evaluation of 2006 Custom HVAC Installations – Part I

Executive Summary

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Introduction

This document summarizes work performed by RLW Analytics, Inc. (RLW) during 2007 and 2008 to quantify the actual energy and demand savings due to the installation of six Custom HVAC measures installed through National Grid's Design 2000*plus* (D2) and Energy Initiative (EI) Commercial and Industrial (C&I) energy efficiency programs in 2006.

Purpose of Study

The objective of this impact evaluation is to provide verification or re-estimation of electric energy and demand savings estimates for 11 Custom HVAC projects through site-specific inspection, monitoring, and analysis. RLW was selected to evaluate six (6) of the 11 Custom HVAC projects.

This impact study consists of the following four tasks:

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

Scope

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

Description of Methodology

Measurement and Evaluation Plans

National Grid randomly selected 11 Custom HVAC applications for the evaluation and assigned six of these to RLW. National Grid provided RLW with all available information on the six sample projects at the beginning of the study.

Following the notification of the awarded Custom HVAC applications and prior to beginning any site visits, RLW developed detailed measurement and evaluation plans for each of the six applications. These plans outlined on-site methods, strategies, monitoring equipment placement, calibration and analysis issues. National Grid provided comments and edits to clarify and improve the plans prior to them being finalized.

The site evaluation plan played an important role in establishing approved field methods and ensuring that the ultimate objectives were met. Each site visit culminated in an

independent engineering assessment of the actual (e.g. as observed and monitored) annual energy, on-peak energy, diversified summer peak demand, and diversified winter peak demand savings associated with each project.

Data Gathering, Analysis, and Reporting

Data collection included physical inspection and inventory, interview with facility personnel, observation of site operating conditions and equipment, and short-term metering of usage. At each site, RLW 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 energy management systems (EMS) 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 associated affected spaces.

A custom 8,760 hour analysis spreadsheet was developed for each site and refined with the input of the National Grid project manager and staff. This comprehensive hourly analysis was used to estimate hourly energy use and diversified coincident peak demand. A typical meteorological year (TMY2) dataset of ambient temperatures closest to each facility was used for all temperature sensitive calculations. Each site report details the analysis methods used specific to each project including algorithms, assumptions and calibration methods where applicable. One of the six sites was analyzed using eQuest.

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

Description of Sample Projects

Site 1 Ski Lodge, VFDs on Kitchen Fans and Heating Controls
EI Program, Appl #: 501313

This EI measure involved the installation of a complete Energy Management System (EMS) and 7 VFDs on kitchen exhaust fans and make-up air units in the original base lodge of a ski resort. The system was designed to allow for local and remote access of all the new control points and to automate schedules and new controls for all the HVAC units. The new system was designed to be expandable and have the capability to set up and store trend data of all the control points. In addition to the new EMS, 7 variable frequency drives (VFD) were installed on several pieces of HVAC equipment in the kitchens along with associated controls and new sensors that would be linked to the EMS. This facility is part of a ski resort that operates daily from November to April, and most weekends throughout the remainder of the year.

Site 2 University, Convert Cooling Loads to Central Chiller Plant
D2 Program, Appl #: 505349

This D2 application is the fourth in a series of four applications installed at this site between October 2005 and May 2006. This measure involves the addition of the cooling loads of the renovated 40,500 square foot math/physics building to a relatively new central chiller plant. The hypothetical baseline for this project consisted of a local air-cooled chiller and chilled water loop serving the math/physics building with no tie-in to the new central chilled water loop.

Energy is saved by the increase in the efficiency of producing chilled water in the central plant that houses two 600-ton high efficiency water cooled centrifugal water chillers with variable frequency drives, compared to a local 120-ton air-cooled chiller.

Site 3 Hospital, Convert AHUs from IGV to VFD
EI Program, Appl #: 507028

This EI measure involved the conversion of eight air handling units (AHUs) in a hospital from inlet guide vane (IGV) control to variable frequency drive (VFD) control. The application was based on flow control conversion of five 50-hp AHUs, two 30-hp AHUs and one 20-hp AHU which all operate 8,760 hours per year. This measure saves energy primarily via improved part-load efficiency under VFD control versus IGV control.

Site 4 School, Update EMS Schedules and Temperature Settings
EI Program, Appl #: 511678

This EI measure involved updating the EMS schedules and temperature set points on all 14 rooftop package units (RTUs) and 15 heating and ventilating units (HVUs) at a high school. The proposed strategy was to institute new occupied/unoccupied operating schedules and new temperature set points during unoccupied hours for all units. In the cooling mode the temperature settings were to be reset upward and in the heating mode the temperature settings were to be reset downward. Electric savings were expected to result from reduced cooling hours and supply fan use as well as a reduction in cooling load due to temperature setback.

Site 5 Office/Lab, Enthalpy Controlled Economizers
EI Program, Appl #: 515332

This EI measure repaired and calibrated non-functioning economizers on existing air handlers and rooftop units. New control boards were installed to allow EMS interface. A centrally located enthalpy sensor was installed and tied into EMS programming to permit universal control for all units. Programming was generated for each AHU/RTU to provide operating commands unique to each unit. This measure is interactive with two other measures installed at this facility: ECM-1 – "Cycle Supply Air Fans During Unoccupied Periods" (Site 6) and ECM-2 – "Reset Zone Temperature Set Points During Unoccupied Periods".

This measure saves electricity by using outside air to cool the building when the outside air temperature is cold enough replacing the need for mechanical cooling during these hours.

Site 6 Office/Lab, EMS Operating Schedules on AHUs
EI Program, Appl #: 515333

This EI measure established and implemented occupancy schedules to permit air handler fan systems to be shut off during unoccupied periods. Fans would be permitted to cycle during unoccupied modes only to maintain space temperature requirements. This measure saves electricity by reducing the operation of 27 rooftop units (RTUs) by scheduling units via the energy management system (EMS). Prior to the installation of this measure, all units were on 24 hours a day, seven days a week.

Results

Major Findings and Observable Trends

Figure 1 displays a scatter plot of the evaluation results for annual energy savings. As evidenced by the figure, most projects trended at or below 100% realization. One project had a particularly low realization rate of 16%. This was also the smallest site in the sample. Five of the six projects had realizations rates at or above 95%. Only one project had a realization rate above 100%. This was the second largest project of the six based on savings. The realization rate for this project was 211%. The non-weighted realization rate for the six sample points is 98%.

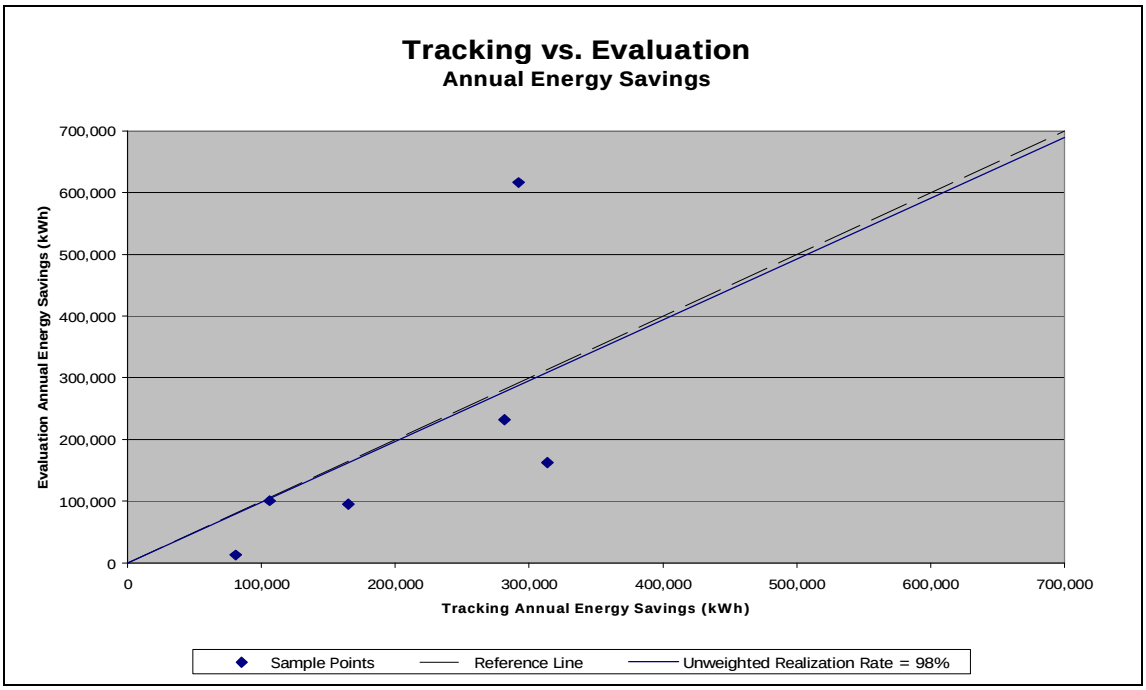

Figure 1 - Scatter Plot of Evaluation Results for Annual kWh Savings

Presentation of Results

Table 1 presents a tabular summary of the site level results.

SITE ID	EI / D2	PROJECT DESCRIPTON & APPLICATION ID	TRACKING EST. SVGS				EVALUATION SVGS					
				On-	Peak Coinc.			On-	Current Peak Coinc.		FCM Peak Coinc.	
			kWh/yr	Peak %	Sum. kW	Wint. kW	kWh/yr	Peak %	Sum. kW	Wint. kW	Sum. kW	Wint. kW
1	EI	Ski Lodge, VFDs and Heating Controls Appl #: 501313	313,830	48%	3.2	102.5	162,398	54%	5.3	57.0	2.7	50.2
2	D2	University, Additional Cooling Loads Appl #: 505349	164,830	46%	50.5	0.0	95,381	53%	38.2	0.0	37.8	0.0
3	EI	Hospital, VFDs on AHUs Appl #: 507028	281,563	39%	22.5	49.3	231,990	41%	21.4	19.6	21.4	21.5
4	EI	School, EMS Schedules and Temperature Set Points Appl #: 511678	80,808	100%	0.0	0.0	13,058	141%	-13.7	2.6	8.8	4.3
5	EI	Office/Lab, Economizers Appl #: 515332	106,004	50%	0.0	0.0	100,960	83%	0.0	0.0	15.9	7.5
6	EI	Office/Lab, EMS Schedules Appl #: 515333	292,119	0%	0.0	0.0	616,212	17%	0.0	94.8	2.8	38.6
TOTALS			1,239,154	38%	76.2	151.9	1,219,998	36%	51.3	174.1	89.5	122.2

Table 1 - Detailed Site Results

Summary of Discrepancies

Table 2 summarizes the savings realization rates and primary reasons for discrepancies between the tracking and evaluation estimates of annual energy savings. The site realization rates ranged from a low of 16% for Site 4 to a high of 211% for Site 6. Note that some of the ratios are "N/A" for the on-peak % and peak coincident demand reductions because the tracking estimates were zero for some of these values.

Aside from Site 6, most of the discrepancies were related to an overestimation of key operating parameters in the tracking analyses.

SITE ID	EI / D2	PROJECT DESCRIPTON & APPLICATION ID	RATIO EVALUATED / TRACKING						Primary Reason for Discrepancy
					Current Peak Coinc.		FCM Peak Coinc.		
			kWh/yr	On-Peak %	Sum. kW	Wint. kW	Sum. kW	Wint. kW	
1	EI	Ski Lodge, VFDs and Heating Controls Appl #: 501313	52%	112%	164%	56%	83%	49%	Tracking assumed baseline DAT for two RTUs to be constant 90F. Evaluation found that the DAT never exceeded 61F.
2	D2	University, Additional Cooling Loads Appl #: 505349	58%	116%	76%	N/A	75%	N/A	Evaluation found significantly lower cooling loads than predicted in the tracking estimate.
3	EI	Hospital, VFDs on AHUs Appl #: 507028	82%	104%	95%	40%	95%	44%	Evaluation estimated the total airflow for all fans to be 81%. Tracking estimated the total airflow for all fans to be 77%.
4	EI	School, EMS Schedules and Temperature Set Points Appl #: 511678	16%	141%	N/A	N/A	N/A	N/A	Some units had decreased post-retrofit cooling set points and increased post-retrofit hours of operation. Tracking overestimated the total cooling airflow.
5	EI	Office/Lab, Economizers Appl #: 515332	95%	166%	N/A	N/A	N/A	N/A	Tracking assumed fans at 26% OA, Evaluation found it to be 10% OA. Tracking humidity ratios not consistent with TMY2 weather data.
6	EI	Office/Lab, EMS Schedules Appl #: 515333	211%	N/A	N/A	N/A	N/A	N/A	Tracking unnecessarily adjusted the annual savings estimate by more than 50% to calibrate the TA model to billing data.

Table 2 - Site Discrepancies

Site 1

The evaluation estimate of annual energy savings was 48% lower than the tracking estimate for Site 1. The most significant reason for the decrease in savings was the reduced baseline and installed energy use of RTU-4 and RTU-5 compared to the tracking estimates for the MAU heating measure. The tracking savings overestimated the baseline and installed energy use by assuming a constant 90˚F discharge air temperature in the calculation for heating load. Monitoring data of the two heating units showed that the discharge air temperature (DAT) for RTU-5 was a constant 61˚F, and the DAT for RTU-4 varied between 32˚F and 59˚F. These two units provide the make-

up air to the kitchen from the exhaust fume hoods. These differences resulted in a reduction of savings equal to approximately 110,000 kWh per year. An additional 46,000 kWh was lost due to missing EMS schedules for the cabinet and unit heaters. All of the perimeter cabinet and unit heaters were supposed to have unoccupied schedules implemented, however the EMS showed that these units are operating in occupied mode during all hours, as in the pre-retrofit state.

Site 2

The energy and demand savings for Site 2 were calculated using eQuest building models calibrated to monitored data. Site 2 produced only 58% of the tracking savings. The primary cause of the reduced evaluation kWh savings is significantly lower total cooling loads in the math/physics building than the tracking analysis had predicted, especially during the spring and fall seasons when the cooling loads are predominantly internal heat gains from lighting and equipment. The cooling loads were lower than estimated in the tracking analysis due to significant reductions in the modeled usage, not the installed power densities, of lighting and equipment within the building, and the application of building shade to simulate existing trees around the building. This difference represented a reduction in annual energy savings of approximately 55,000 kWh. The tracking analysis also underestimated the pumping and auxiliary power of the central plant, overestimating its efficiency and thus total savings.

Site 3

Site 3 produced 82% of the tracking savings. The most significant reason for the decrease in savings was that some fans were found to be operating at significantly higher speeds than forecast by the tracking analysis. Based on monitoring data, the evaluation estimated that the annual average airflow for all fans was 81% of the total rated CFM, compared to 77% of the rated CFM in the tracking analysis. This resulted in a reduction in annual energy savings equal to approximately 53,000 kWh. One fan in particular represented over 80% of the total energy savings reduction of all fans. This unit was a 50-hp fan that serves the cafeteria and was observed to operate at 100% of the full load kW for the majority of the monitoring period. The increased operation of this unit alone was equal to approximately 44,000 kWh of the total reduction in savings.

Site 4

The evaluation estimate of annual energy savings for Site 4 was 84% lower than the tracking estimate of savings. There were three significant reasons for the decrease in savings. One was that seven of the rooftop units had their occupied cooling set point decrease instead of increase. Likewise, the unoccupied cooling set point for two units also decreased from 85°F to 70°F and from 80°F to 70°F. The total effect of all the changes to the cooling set points resulted in a decrease in saving of over 30,000 kWh. Second, the tracking analysis included all 96,500 CFM of air flow capacity in the cooling component of the analysis. However, this number represented the total CFM of all the units including the heating-only units. The evaluator found that the total flow for the 14 cooling units was 57,750 CFM. This error resulted in a decrease of annual energy savings of approximately 20,000 kWh. Lastly, half of the RTUs had their occupied schedules increase in hours from the pre-retrofit condition. This led to a reduction of annual energy savings of approximately 18,000 kWh.

Sites 5 and 6

Sites 5 and 6 represented ECM-3 and ECM-1, respectively, of a three measure project at one facility.

Site 5 produced 95% of the tracking savings. Although the evaluated savings were close to the tracking savings, there were several large discrepancies between the two analyses. The most significant of these resulted from the assumption used in the tracking analysis that all fans operated at 26% outside air prior to the implementation of the measure. The evaluation found that 10% outside air was the standard operating condition for all fans prior to this measure with the exception of four RTUs that had functioning dry bulb controlled economizers. The difference in outside air represented a reduction in annual energy savings of approximately 41,000 kWh.

Another key component to the difference in savings for Site 5 was the humidity ratios used in the tracking analysis. These values were not consistent with the TMY2 weather file that was used in the tracking analysis. Changes in the humidity ratio resulted in a reduction in annual energy savings of approximately 27,000 kWh. The savings reduction was so large because the humidity ratio is key component in determining the latent loads from the outside air. There were also several less significant factors that resulted in reduced energy savings such as the tracking assumption that the RTUs operated 24/7 rather than considering interactivity with the previous measures, ECM-1 and ECM-2, and assuming the fans only during occupied hours as determined in ECM-1 of this project.

Site 5 also produced a significant increase in savings resulting from calibrating the model to actual monitoring data, it was found that the cooling efficiency of the total cooling system was lower than the tracking estimate and the equipment load was higher. These two components resulted in an increase of savings of approximately 82,000 kWh as compared to the tracking estimate.

Site 6, which was the first ECM of the three, produced 211% of the tracking savings. The most significant reason for this increase in savings was the adjustments made by the tracking analysis on each component of the energy savings which underestimate the measure savings. The tracking analysis calculated annual energy savings for cooling, fan and humidification use and adjusted each by multiplying the annual savings estimate by 0.5. Likewise, the annual energy savings estimate for electric heat was multiplied by an adjustment factor of 0.3. According to the commissioning report in the project file, the HVAC model used to calculate annual savings was calibrated to match the monthly billing data for the facility. The evaluated savings are approximately 4% less than the unadjusted tracking savings.

Conclusions

This evaluation shows that, aside from Site 6, these Custom HVAC projects as part of the Energy Initiative and Design 2000*plus* Programs are delivering less energy savings to National Grid customers than predicted by the tracking analyses. Several aggressive assumptions in the estimation of the tracking savings have resulted in a non-weighted realization rate of 64% for the five projects with reduced savings. Only when you include the savings estimate of Site 6 does the non-weighted realization rate go to 98%.

Equipment types and quantities were not an issue for this evaluation. Overall, the equipment that was installed as part of this program and the equipment being controlled by EMS resulting from the program were documented correctly. However, it was the operating parameters of this equipment that were generally overestimated in the tracking analyses.

In some cases, such as for Site 1, an incorrect TA assumption had a significant negative effect on savings. The TA estimated the discharge air temperature of two electric heating units to be 90°F. These units provide the make up air to the kitchen and it is unlikely that 90°F discharge air would be supplied to this type of space considering all the cooking equipment that is being used during the day. The monitoring data confirmed this by showing that the discharge air temperature of these units never exceeded 61°F. Though there are many assumptions that go into the estimation of the tracking savings, there are a few that have such a significant effect on the energy savings. It is recommended that assumptions such as these are given a closer look to determine their practicality.

Several of the sites evaluated in this project included measures related to EMS controls. In fact, five of the six projects utilized information taken from the EMS in the evaluation analysis, including schedules and temperature set points. For some of these sites, evaluators planned to utilize the EMS to trend relevant operating parameters. None of the sites visited were able to provide any significant trending data.

According to the TA report, Site 1 was supposed to provide trends of all the controlled equipment to ensure that the EMS was working properly as per the minimum requirements documents (MRD). However, evaluators determined that the capacity for trending at this site was very limited and that facility personnel did not know how to set up or retrieve trend data. This is an important component of any EMS installation so that energy savings can be monitored and maintained. It is recommended that for new EMS installations, customers and vendors should be required to provide all relevant trends to ensure that this feature is functioning properly. It is also recommended that facility personnel who will be working with the EMS should be given some type of training by the vendor so that they understand what the system is capable of. This will also help to avoid other issues that arise such as missing EMS schedules, which were also found at Site 1. In this case, the electric cabinet and unit heaters were to have unoccupied schedules implemented. However, evaluators found that the schedules were never entered for this equipment which resulted in zero savings. This would have been discovered had the EMS been set up to trend the operation of these units.

Another recommendation related to EMS measures is to verify all schedules and set points via the post-installation inspection. Site 4 saw a large decrease in savings because some of the post-retrofit operating schedules included more operating hours than the pre-retrofit schedules. In addition, some temperature set points in both the cooling and heating modes were adjusted between the pre- and post-retrofit to negatively affect savings. Evaluators were able to record the operating schedule and temperature set points for each RTU and HVU involved in this measure. A comparison between these settings and the pre-retrofit settings would show if the measure is operating in general as intended at the post-inspection.

For savings estimates that involve measure interactions, the program implementers should make sure that all installed measures have their savings calculated taking those interactions into account. This will ensure that savings from any of the measures installed are not being double counted or underestimated. Each measure should be presented in series with the installed case of the first measure representing the base case of the second measure and so on. The evaluators can then replicate that specific order of savings calculation which will properly factor in the interactions the same way as the original estimate does. This occurred in Sites 5 and 6 which represented ECM-3 and ECM-1, respectively, of three measures installed at the same site. ECM-1 was proposed to implement schedules that would shut off fans during the unoccupied period. ECM-3 was the economizer measure that followed ECM-1, but calculated energy use for all hours including unoccupied periods.

Evaluators utilized all of the monitoring data that was installed during this project either directly in the analyses or indirectly to verify assumptions. There are some instances where additional temperature loggers would have been helpful to verify occupied and unoccupied temperature set points. Though this was not required because of the primary use of power loggers on the HVAC equipment, temperature loggers in select spaces would help to verify the temperature and occupancy settings from EMS schedules. There were some instances where the power monitoring data revealed operation that was different than what was expected from the TA report. In some of these cases, additional temperature monitoring would have helped to explain these discrepancies.