Impact Evaluation of 2005 Custom HVAC Installations

Part I

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Executive Summary

Introduction

The purpose of this study was to evaluate the energy savings achieved by fifteen Custom HVAC measures installed in 2005. Savings are quantified by total annual energy use reduction, summer and winter peak diversified demand impact, and the percentage of energy savings occurring during peak periods.

Description of Evaluation Methodology

National Grid USA Service Company (National Grid, or the Company) contracted with DMI to evaluate the savings of ten of the fifteen Custom HVAC applications.

Before the Site Visit

For each application being evaluated, DMI received a copy of the application package and any additional information available from National Grid. DMI reviewed the application and attached documentation to develop an understanding of the measure and of the tracking analyst's savings calculation. As directed by the National Grid study manager, the evaluation plan followed the tracking analyst's methodology unless the methodology was determined to be flawed or impractical to duplicate.

DMI devised an evaluation plan for each application, each of which included a measure description, any sources of energy savings or penalties, the estimation approach used in the tracking analysis, the proposed methodology of the evaluator, and how/why the two analyses may differ. Each plan also included an interview questionnaire, a list of observations to make at the site, and a metering plan.

The National Grid study manager reviewed and commented on each evaluation plan, and these comments were incorporated accordingly. Once a site's evaluation plan was approved, DMI contacted the customer's National Grid account manager to inform them that the initial evaluation site visit was being scheduled. In some cases, DMI requested that the account manager introduce DMI to the customer as representatives of National Grid and to describe the evaluation process.

At the Site

DMI visited all sites included in this study and observed the installed measures in their current operational state. Customers were interviewed regarding current operations, hours of use, and the base or pre-retrofit condition and sequences of operation.

DMI recorded power measurements where called for by the evaluation plan, noting production variables such as production rate, operating speed, pressure, and/or flow rate.

DMI reviewed and collected customer data such as hours of use, operators' log sheets, controls computer electronic data, and other available data pertinent to the specific application.

Additional information and improved understanding of the installations typically occurred during the site visits. Possible changes to the proposed evaluation methodology described in the evaluation plan were discussed with the study manager prior to making alterations.

Data Analysis

DMI used site and metered data to develop estimates of annual energy savings, the percentage of savings occurring during peak hours, and summer and winter super peak diversified demand savings. National Grid guidelines detailed in the Attachments to the Scope of Work were used to determine these parameters.

DMI utilized Microsoft's Excel 2003 as the principal calculation tool in the evaluation analyses. Weather data provided by the National Climatic Data Center's Engineering Weather Data CD, 2000 Interactive Edition, and actual weather data from the National Oceanographic and Atmospheric Agency (NOAA) website was used in the analyses where energy use was affected by outdoor weather conditions. For all sites where such data was available, 15-minute interval customer load data was obtained from National Grid to assist in the determination of facility operating characteristics.

Equipment performance was quantified through direct metering, site EMS trending, or the use of manufacturer's published performance data or selection software. The make and model of the installed equipment was used in installed case analyses while base case and pre-retrofit case equipment types were taken from the tracking analysis whenever available. Operating points and sequences were assumed to be the same as those in the tracking analysis unless there was direct proof that the original assumptions were no longer valid.

Presentation of Results

For each application reviewed, DMI submitted a draft evaluation report to the National Grid study manager for review and comment. The study manager discussed project findings with the DMI engineer who performed the evaluation study and requested clarifications within the calculations and report as necessary.

The objective of the site reports is to present not only the results for the four main study parameters, but also to explain why the realization ratios vary from the target of 100%. Reasons for discrepancies may be due to methodology issues in the tracking analysis, inaccurate assumptions used in the tracking analysis, or changes in site conditions or operating parameters. The structure of the site reports facilitates the segregation of these three main types of error.

The attached site reports follow the same general outline. An introductory section presents general findings and a table that compares tracking and evaluated parameters. The installation is described, followed by a description of the tracking analysis methodology. Remarks concerning the tracking methodology are made to support any differences between the tracking and evaluation approaches. The evaluation analysis approach is then described. Calculation assumptions and intermediate results are presented, with the final section devoted to a comparison of tracking and evaluation results. Whenever possible, the sources of discrepancies between tracking and evaluated results are described and the impacts are quantified. Supporting appendices include calculations and plots of metering data and other site data.

The reference numbers for sites included in Group 1 are used in the enumeration of report pages, figures, and tables. For example, page 3 of the report for Site No. 8 is listed as '8-3', and the third figure in the first appendix of that report is 'Figure 8A-3'.

Description of Sample Projects

Sites 1 through 8 are Design 2000*plus* applications, while Sites 9 and 10 are Energy Initiative applications. Brief descriptions of each project are presented below:

Site 1 installed a groundwater-source heat pump system for heating and cooling rather than gas-fired boilers and split-system condensing units

Site 2 installed variable speed drives on two 40-hp hot water pumps

Site 3 implemented chilled water and condenser water reset sequences for a large chilled water plant

Site 4 installed computer room units having glycol economizer capability rather than standard units that would require compressors to operate throughout the year

Site 5 installed two 200-ton high-efficiency chillers for year-round operation

Site 6 installed water-side free cooling for the installation covered in Site 5.

Site 7 installed a high-efficiency rooftop unit to provide humidity control at a supermarket

Site 8 implemented comparative enthalpy economizer and static pressure reset controls on eight rooftop units at a calling center

Site 9 replaced DX cooling sections in three air handling units with chilled water coils served by a central chilled water plant

Site 10 implemented controls to turn off HVAC equipment during unoccupied hours

Results

Annual energy savings as evaluated varied from 120% (Site 10) to -225% (Site 1) of the tracking estimate. Tables 1 through 4 list the evaluation results and the tracking estimates for each application studied. The overall unweighted evaluated to tracking ratios for total energy, percent on-peak, and total diversified summer and winter demand are 76%, 103%, 36%, and 95%, respectively.

The percent of savings occurring during peak periods and the seasonal diversified demand reduction values were evaluated using the historical peak and super peak definitions that were used in the tracking analyses by National Grid vendors at the time these studies were completed. In the past, peak hours were 8 AM to 9 PM on weekdays with the exception of 9 standard holidays. Summer super peak periods were on peak days between 11 AM and 3 PM, while winter super peak hours were between 5 PM and 7 PM on peak days.

Table 1
Annual Energy Savings, kWh

Site	Application	Description	Tracking	Evaluated	Evaluated ÷ Tracking
1	D2 217838	Water-source Heat Pumps	5,401	(12,141)	-225%
2	D2 500325	VSDs on HW Pumps	130,348	67,834	52%
3	D2 502640	Chilled and Condenser Water Reset	49,496	1,274	3%
4	D2 506295	Computer Room Unit Dry Cooler	133,775	(21,659)	-16%
5	D2 506791	Water-cooled Chillers	1,041,481	1,071,259	103%
6	D2 506795	Waterside Economizer	193,954	215,631	111%
7	D2 507218	High-efficiency RTU	8,024	1,882	23%
8	D2 509020	Improved RTU Controls	368,641	155,052	42%
9	EI 119410	CHW Cooling, VSD on CHW Pump	116,462	18,784	16%
10	EI 509382	Unoccupied Setback Control	112,517	134,532	120%
		Total	2,160,099	1,632,449	76%
		Standard Deviation			99%

Table 2
Percent of Energy Savings On-peak

Site	Application	Description	Tracking	Evaluated	Evaluated ÷ Tracking
1	D2 217838	Water-source Heat Pumps	89%	44%	50%
2	D2 500325	VSDs on HW Pumps	43%	37%	86%
3	D2 502640	Chilled and Condenser Water Reset	28%	1%	4%
4	D2 506295	Computer Room Unit Dry Cooler	9%	47%	523%
5	D2 506791	Water-cooled Chillers	36%	37%	103%
6	D2 506795	Waterside Economizer	27%	30%	111%
7	D2 507218	High-efficiency RTU	75%	56%	75%
8	D2 509020	Improved RTU Controls	37%	37%	100%
9	EI 119410	CHW Cooling, VSD on CHW Pump	57%	49%	85%
10	EI 509382	Unoccupied Setback Control	0%	20%	N/A
		Total*	33%	34%	103%
		Standard Deviation			152%

*Total as weighted by estimated energy savings

Table 3
Summer SuperPeak Diversified Demand Reduction

Site	Application	Description	Tracking	Evaluated	Evaluated ÷ Tracking
1	D2 217838	Water-source Heat Pumps	7.4	(4.8)	-65%
2	D2 500325	VSDs on HW Pumps	16.0	7.5	47%
3	D2 502640	Chilled and Condenser Water Reset	8.9	(1.5)	-17%
4	D2 506295	Computer Room Unit Dry Cooler	0.0	(7.1)	N/A
5	D2 506791	Water-cooled Chillers	128.2	111.9	87%
6	D2 506795	Waterside Economizer	0.1	0.0	0%
7	D2 507218	High-efficiency RTU	7.0	1.0	15%
8	D2 509020	Improved RTU Controls	132.0	13.3	10%
9	EI 119410	CHW Cooling, VSD on CHW Pump	55.9	8.2	15%
10	EI 509382	Unoccupied Setback Control	0.0	0.0	N/A
		Total	355.6	128.5	36%
		Standard Deviation			44%

Table 4
Winter SuperPeak Diversified Demand Reduction

Site	Application	Description	Tracking	Evaluated	Evaluated ÷ Tracking
1	D2 217838	Water-source Heat Pumps	0.0	0.0	N/A
2	D2 500325	VSDs on HW Pumps	15.5	7.8	50%
3	D2 502640	Chilled and Condenser Water Reset	0.8	0.1	13%
4	D2 506295	Computer Room Unit Dry Cooler	30.7	2.9	9%
5	D2 506791	Water-cooled Chillers	121.9	125.0	103%
6	D2 506795	Waterside Economizer	66.6	59.0	89%
7	D2 507218	High-efficiency RTU	0.0	0.0	N/A
8	D2 509020	Improved RTU Controls	2.7	11.1	410%
9	EI 119410	CHW Cooling, VSD on CHW Pump	(0.7)	(0.5)	66%
10	EI 509382	Unoccupied Setback Control	0.0	20.6	N/A
		Total	237.5	226.0	95%
		Standard Deviation			139%

National Grid has been in the process of changing the definitions of peak and seasonal super peak periods. Tables 5 through 7 on the following pages present the impact of these changes on the evaluated results. The peak period definition was expanded to include the hours between 6 AM and 10 PM. The number of standard holidays remains the same. The summer and winter super peak periods were changed to cover the worst case demand periods on the entire grid. The summer super peak definition is now the hottest hour in June, July or August on weekdays from 3 PM to 5 PM, while the new winter super peak period is the coldest hour in January on weekdays from 5 PM to 7 PM.

Table 5
Percent of Energy Savings On-peak - New Definitions

Site	Application	Description	Evaluation	Revised	Revised ÷ Evaluation
1	D2 217838	Water-source Heat Pumps	44%	52%	118%
2	D2 500325	VSDs on HW Pumps	37%	46%	123%
3	D2 502640	Chilled and Condenser Water Reset	1%	22%	3757%
4	D2 506295	Computer Room Unit Dry Cooler	47%	53%	113%
5	D2 506791	Water-cooled Chillers	37%	46%	124%
6	D2 506795	Waterside Economizer	30%	39%	131%
7	D2 507218	High-efficiency RTU	56%	59%	105%
8	D2 509020	Improved RTU Controls	37%	47%	127%
9	EI 119410	CHW Cooling, VSD on CHW Pump	49%	54%	111%
10	EI 509382	Unoccupied Setback Control	20%	20%	102%
		Total*	35%	43%	124%
		Standard Deviation			1151%

*Total as weighted by estimated energy savings

Table 6
Summer SuperPeak Coincident Power Demand Reduction

Site	Application	Description	Evaluation	Revised	Revised ÷ Evaluation
1	D2 217838	Water-source Heat Pumps	(4.8)	(3.0)	63%
2	D2 500325	VSDs on HW Pumps	7.5	7.2	96%
3	D2 502640	Chilled and Condenser Water Reset	(1.5)	29.4	-2010%
4	D2 506295	Computer Room Unit Dry Cooler	(7.1)	(6.4)	91%
5	D2 506791	Water-cooled Chillers	111.9	110.0	98%
6	D2 506795	Waterside Economizer	0.0	0.0	N/A
7	D2 507218	High-efficiency RTU	1.0	4.7	452%
8	D2 509020	Improved RTU Controls	13.3	9.5	71%
9	EI 119410	CHW Cooling, VSD on CHW Pump	8.2	27.7	339%
10	EI 509382	Unoccupied Setback Control	0.0	0.0	N/A
		Total	128.6	179.0	139%
		Standard Deviation			785%

Table 7

Winter SuperPeak Coincident Power Demand Reduction

Site	Application	Description	Evaluation	Revised	Revised ÷ Evaluation
1	D2 217838	Water-source Heat Pumps	0.0	0.0	N/A
2	D2 500325	VSDs on HW Pumps	7.8	7.8	100%
3	D2 502640	Chilled and Condenser Water Reset	0.1	0.0	0%
4	D2 506295	Computer Room Unit Dry Cooler	2.9	6.0	208%
5	D2 506791	Water-cooled Chillers	125.0	125.0	100%
6	D2 506795	Waterside Economizer	59.0	59.0	100%
7	D2 507218	High-efficiency RTU	0.0	0.0	N/A
8	D2 509020	Improved RTU Controls	11.1	9.0	81%
9	EI 119410	CHW Cooling, VSD on CHW Pump	(0.5)	0.0	0%
10	EI 509382	Unoccupied Setback Control	20.6	24.7	120%
		Total	226.0	231.5	102%
		Standard Deviation			67%

Discussion of Results

Energy savings for eight of the ten sites were significantly different than the original estimates. Reasons for the discrepancies include: site made beneficial adjustments to the intended measures (Site 6), the site did not implement the proposed measures as intended per the MRDs (Sites 3 and 8), the installed equipment was not controlled to operate as intended (Sites 1, 3, and 9), the actual loads were found to be different than assumed for the tracking analysis (Site 7 and 9), equipment performance was different than estimated in the tracking analysis (Sites 1, 5, 6 and 9), the base case assumed in the tracking study was found to be invalid (Site 2), the tracking analysis did not account for all equipment that would be impacted by the measures being studied (Sites 1, 9, and 10), and the tracking analysis assumed operating conditions beyond the capacity of the proposed equipment (Site 4). Table 8 below lists the primary reasons for the discrepancies in annual energy savings estimates.

Table 8
Summary of Annual Energy Savings Discrepancies

Site	Application	Evaluation ÷ Tracking	Primary Reason for Discrepancy of Savings Estimate
1	D2 217838	-225%	Well pump control problems result in much greater cooling season energy use, the tracking analysis did not account for building-side pumping requirements; base case cooling system performance was assumed to be worse than State Energy Code requirements.
2	D2 500325	52%	The base case assumption that the pumps would operate at the selection point throughout the year was found to be unrealistic, the installed case flowrates and pressure requirements are higher than originally estimated.
3	D2 502640	3%	Chilled water reset sequence was not implemented; condenser water reset sequence does not set back temperature as low as required in MRD.
4	D2 506295	-16%	The loss of savings is mostly due to the assumption that the dry cooler system would have allowed the refrigeration compressors to be turned off for 73% of the year; the evaluation found that the compressors operate throughout the year.
5	D2 506791	103%	The cooling load profile was found to be slightly different, cooling tower performance was better than originally estimated and the power demand of the condenser water pumps had been slightly overestimated, resulting in a slight increase in savings.
6	D2 506795	111%	The customer chose to allow free cooling to be entered at a warmer temperature than originally assumed thereby increasing the free cooling hours by more than 700 hours per year.
7	D2 507218	23%	The cooling load was found to be 24% of the tracking analysis estimate.
8	D2 509020	42%	The studied improvements were not installed per the MRD; drybulb economizer at an engagement temperature of 65°F was implemented rather than comparative enthalpy economizer; rather than static pressure reset, supply fans ae controlled at constant static pressure setpoints that are lower than the base case setpoint assumed in the study.

Table 8 Continued

Site	Application	Evaluation ÷ Tracking	Primary Reason for Discrepancy of Savings Estimate
9	EI 119410	16%	Cooling loads are lower than originally estimated, pre-retrofit equipment performance was better than originally estimated, three-way valves appear to have been installed in the secondary chilled water loop distribution system resulting in increased VSD operation throughout the cooling season, and a pump penalty was counted as a savings in the tracking analysis.
10	EI 509382	120%	The operating hours that the equipment was turned off were found to be greater than originally assumed and the controlled fans were found to draw more power.

Recommendations for Tracking Analysts

1. Tracking studies should clearly describe all system components that could potentially be impacted by the measures being studied. Omission of equipment in Sites 1, 9, and 10 impacted project realization.
2. Tracking studies should clearly describe how energy is going to be saved and under what conditions. A more thorough review of these details may have avoided the problems associated with Site 4.
3. Base case systems and controls should be based upon the most likely control sequences used in the field for similar applications. Savings for Site 2 were dependent upon a base case assumed control strategy that is not used in the field.
4. The basis for all assumptions that are used to support savings estimates should be clearly documented in the calculations supporting each application. The use of unsubstantiated cooling load assumptions at Site 7 did not allow the National Grid reviewer to determine whether the assumed annual loading was accurate.
5. Tracking analyses should include complete documentation of calculation methodologies including information regarding how base case systems were developed, copies of equipment performance data used, and basic assumptions that were used to apply the performance information to a particular project.

Recommendations for National Grid Technical Reviewers

6. Technical reviewers should be careful to confirm that simple analyses on par with ‘back of the envelope’ calculations utilize assumptions that include key factors that affect the diversity of run time and operating loads as well as variations in equipment performance.
7. Technical reviewers should require a written description of the installation, how the proposed measure saves energy, and the how the savings were estimated with each application for rebates.

8. Technical reviewers should check to make sure that the impacts on all equipment that may be affected by an installation are addressed (e.g. all hydronic pumping loads in ground source heat pump systems).
9. Technical reviewers should require adjustments to original energy studies if it is found during post-installation inspections and/or commissioning that the studied equipment was not actually installed.
10. For free-cooling applications, technical reviewers should pay particular attention to the required minimum chilled water or discharge air temperature and the claimed ambient condition that allows free cooling to be engaged. Temperature differentials across heat exchangers can range from 2°F for fluid-to-fluid heat exchangers up to 10°F or more for fluid-to-air heat exchangers.