NAVIGANT
CONSULTING

FINAL 2008 Energy Trust of Oregon

Production Efficiency Impact Evaluation

Presented to

Energy Trust of Oregon

September 3, 2010

Presented by

Navigant Consulting
1375 Walnut Street, Suite 200
Boulder, CO 80302
phone 303.728.2500
fax 303.728.2501
www.navigantconsulting.com

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Section 1. Executive Summary

Energy Trust of Oregon's (Energy Trust) Production Efficiency (PE) program offers energy efficiency services for industrial processes of all kinds, including manufacturing, agricultural, and water/wastewater treatment. The PE program provides funding for studies to identify energy-saving opportunities and financial incentives to help businesses implement them. Navigant Consulting conducted an impact evaluation of the 2008 PE program, which included two components:

1.) Site-level analysis, including field verification and equipment logging, of 24 large sites with custom energy efficiency projects to verify program impacts; and
2.) A review of 17 project files and the savings calculators for the Small Industrial Initiative (SII).

1.1 Program Impacts

As seen in Table 1-1, the impact evaluation yielded an end-use program realization rate of 86% and corresponding gross savings of 67,735,063 kWh.

Table 1-1. Impact Summary of the 2008 PE Program

Indices of Program Savings Value	Value
Working Estimate of 2008 Program Savings	78,687,954 kWh
Realization Rate	86%
Gross Savings Estimate	67,735,063 kWh
Demand Savings Estimate	8,659 kW

The working estimate of savings includes 3,234,335 kWh installed through the SII. The PE program delivered gas savings of 17,555 therms from eight projects implemented at six participant sites. Because of the relatively small scope of these gas projects, the impact evaluation of the 2008 PE program did not include gas measures.

Interviews with PE program participants yielded a free-ridership estimate of 23% and a net-to-gross ratio of 77%. Table 1-2 shows the final 2008 PE program net savings estimates amounted to 51,971,014 kWh, or 66% of 2008 program working savings.

Table 1-2. Free-Ridership Summary of the 2008 PE Program

Indices of Program Savings Value	Value
Gross Savings Estimate	67,735,063 kWh
Net-to-Gross Ratio	77%
Net Savings Estimate	51,971,014 kWh
Net Savings as a Percentage of Working Savings	66%

1.2 SII Review

Navigant Consulting found the SII Prescriptive Savings Calculators to accurately estimate savings accrued from energy efficient upgrades of pumps, motors, air compressors, etc. The prescriptive input assumptions (e.g., loading factors, motor efficiencies, etc.) used in each calculator correlate with industry standards and are representative of "average" operating or installation conditions.

1.3 Recommendations

Recommendation 1: Pursuant to the Plant Closure Study (Recommendation Four of the 2007 PE Program Impact Evaluation), define and project future savings estimates at the program level.

Though more prevalent in the 2007 PE Program, the 2008 PE Program had a number of sites that suffered from reduced savings as a result of unforeseen closures. A Plant Closure Study will more accurately characterize the impact of these production changes on realized savings.

In addition to the economic malaise, modified production schedules and capacity led to changes in system configurations which were not incorporated into original study findings. This often resulted in realized savings that differed significantly from original projected savings, despite the measure being correctly installed.

Recommendation 2: Conduct follow-up measurement and verification (M&V) on projects that were not fully implemented. Consider providing incentives and/or engineering support for the commissioning of these projects to capture the unrealized energy savings.

The partial implementation of measures at three sites resulted in low project realization rates. In these cases, there is opportunity for the site to achieve additional energy savings and improve the project realization rates by completing these projects in the future. Some site contacts indicated to the Navigant Consulting engineer that follow-up projects were being considered. Energy Trust should attempt to verify subsequent project activities and document the energy savings.

In the case of one site, providing an incentive or engineering support for the commissioning of the project would have identified and corrected initial system failures and ensured that the project measures were performing as expected, thereby improving the project's realization rate.

Recommendation 3: Use consistent end-use classifications for the various pumping measure applications.

Pumping projects evaluated for the 2008 PE program fell into several categories: pumping as a part of water treatment (sites 14 and 15), irrigation water pumping (sties 11 and 12), process water or other liquid pumping (sites 16 and 25), and vacuum pumping (site 13). The Navigant Consulting team recommends the water pumping measures be categorized into one of two end-use classifications, Pumping and Irrigation Pumping, and that vacuum pumping measures be classified as Process.

Energy Trust of Oregon
851 SW Sixth Avenue, Suite 1200
Portland, Oregon 97204

Telephone: 1.866.368.7878
Facsimile: 503.546.6862
energytrust.org

MEMO

Date: October 1, 2010
To: Board of Directors
From: Philipp Degens, Evaluation Manager
Kim Crossman , Sr. Industrial Sector Manager
Subject: Staff Response to the 2008 Impact Evaluation of the Production Efficiency Program

The Production Efficiency (PE) program is now in its eighth year of operation. The evaluation covers the first year in which Energy Trust staff was responsible for the program management.

The PE team of Energy Trust staff and PDCs continue to do a good job in accurately estimating energy savings from projects. The overall realization rate of reported in the study of 86% included many projects that were adversely impacted by the downturn in the economy. Taking economic effects out of the estimate would have brought the realization rate to over 90%. The simple methods used to adjust for economic effects continue to be viewed as appropriate.

Two factors alluded to in the report will require adjustment of the reported 86% realization rate. The first is the use of a three year moving average of end use specific realization rates to estimate savings of sites that did not receive a site visit. This 3 year moving average was calculated in the report but not used in the final calculation of the realization rate. This method was discussed at length with the Energy Trust Board Evaluation Committee, and adopted for use in future evaluations. Use of the moving average will increase the average overall 2008 program realization rate to 88%.

The second factor is that Site 22 actually completed its project a few months after the evaluation site visit was performed. A subsequent site visit was performed and resulted in an estimated realization rate of 176%. As the measure was installed two years after the savings were claimed the savings were de-rated by 20% (2 years of the 10 year expected project lifetime). Inclusion of these savings brings the overall program year savings realization rate to just under 91%. Inclusion of these savings follows the study recommendation of tracking larger projects and was discussed during Evaluation Committee meetings.

The PE program is changing in that more savings are coming from smaller projects. This change will impact future evaluations requiring a larger sample of site visits to obtain accurate estimates.

Section 2. Introduction

Energy Trust of Oregon's (Energy Trust) Production Efficiency (PE) program offers energy efficiency services for industrial processes of all kinds – including manufacturing, agricultural and water/wastewater treatment. The program provides funding for studies to identify energy-saving opportunities and financial incentives to help businesses implement them.

Navigant Consulting, Inc. (Navigant Consulting), formerly Summit Blue Consulting, was selected to conduct two evaluation reports, spanning two program years, of the PE program. The first report, delivered in August 2009 and revised in October 2009, included an impact evaluation of the 2007 program and a process evaluation of the 2008 PE program. This volume is the second report which contains the results of an impact evaluation of the 2008 PE program.

2.1 Program Background

Energy Trust began operation in March 2002, charged by the Oregon Public Utility Commission with investing funds collected from Oregon's utility rate payers in cost-effective energy conservation. Energy Trust develops and manages outreach programs through which eligible Oregon residents and businesses receive cash and service incentives for saving energy.

This began with the passing of Senate Bill 1149 in 1999, a restructuring law which required Oregon's two largest investor-owned utilities, Portland General Electric and PacifiCorp, to collect a three percent public purpose charge from ratepayers to fund energy savings programs. Northwest Natural Gas began voluntary participation in Energy Trust program a year later and Cascade Natural Gas began participation in 2006.

The PE Program was established by Energy Trust in March 2003 to implement energy efficiency measures in Oregon's industrial organizations. Through the PE Program, eligible participants are provided financial and service incentives to improve the electric and natural gas efficiencies of their industrial and agricultural equipment, systems and processes in new and existing businesses.

The stated program goals are to achieve:

- A significant increase in industrial electric efficiency activity
- Low-cost savings
- Broad participation

2.2 *Prior PE Program Evaluations*

The current evaluation follows four previous evaluations of the PE Program. The prior studies were a process evaluation conducted at the end of the program's first six months of operation,[1] a second process evaluation and impact evaluability assessment completed at the end of 2005,[2] and a third process and second impact evaluation conducted to assess the 2006 program,[3] and a fourth process evaluation (the first of Navigant Consulting's two reports) on the 2008 program and third impact evaluation on the 2007 program.[4]

2.3 *Evaluation Goals*

The purpose of this evaluations is to inform Energy Trust and program stakeholders of the effectiveness of the PE Program, how the PE Program can be improved, and energy savings impacts of the program. The specific goal of the evaluation is to develop reliable estimates of program and measure specific electric savings for 2008.

2.4 *Organization of Report*

This introductory chapter gives background on the program and frames the results of this evaluation. The report has three additional sections:

Section 2: Program Background

Section 3: Impact Evaluation

The following appendices are included at the end of this report:

A: Free-Ridership and Spillover

B: Site-Level Energy Savings Evaluation Summaries

C: Site-Specific Measurement and Verification Plan

D: Ex-Post Adjusted Estimates by Industry (NAICS)

[1] Research Into Action, Production Efficiency Program End-of-First-Year Progress Evaluation, June 22, 2004.
[2] Research Into Action, Production Efficiency Program: Process Evaluation and Impact Evaluability Assessment, December 30, 2005.
[3] Research Into Action, 2006 Production Efficiency Program: Process and Impact Evaluation, August 12, 2008.
[4] Summit Blue Consulting, Production Efficiency Program Evaluation Report, August 14, 2009 revised October 6, 2009.

Section 3. Participation Summary

The PE program achieved electric working savings of 78,687,954 kWh across 354 participant sites and 405 projects. This working estimate of savings includes 3,234,335 kWh installed through the Small Industrial Initiative (SII).

The PE program also realized gas working savings of 17,555 therms from eight projects at six participant sites. Table 3-1 breaks out these energy savings values, and incentives paid, by program track.

Table 3-1. PE Program Working Savings by Program Track

Program Track	Working Savings (KWh)	% of Total kWh	Working Savings (Therms)	% of Total Therms	Incentive	% of Total Incentive
Custom	46,934,510	60%	5,087	29%	3,868,067	50%
Lighting	13,312,346	17%	0	0%	986,792	13%
Production Efficiency	12,102,296	15%	6,713	38%	2,046,654	27%
Small Industrial Initiative	3,234,335	4%	1,473	8%	440,689	6%
Participant Initiated	1,752,009	2%	0	0%	222,974	3%
Prescriptive	1,348,982	2%	4,282	24%	120,696	2%
Green Rewind	3,476	0%	0	0%	672	0%
Kaizen Blitz	0	0%	0	0%	33,640	0%
Total	**78,687,954**	**100%**	**17,555**	**100%**	**7,720,184**	**100%**

Table 3-1 also calculates the percentage of working savings (kWh and therms) and incentive per track relative to the total savings and incentive. The custom track produced energy savings efficiently with 60 percent of the total electric savings realized for only 50 percent of the total incentives paid.

In addition to the installed projects summarized in Table 3-1, 94 Technical Analysis Studies (TAS) studies were completed in 2008.

Section 4. Impact Analysis

4.1 Impact Summary

The 2008 PE program working estimate of savings totaled 78,687,954 kWh across 354 participant sites. Within this participant universe, 24 sites were selected through the evaluation sample and comprised 40,962,113 kWh, or 52% of working savings. Impact evaluation results were calculated at the end-use and industry[5] levels, yielding a realization rate of 86% and 82%,[6] respectively. Demand savings were calculated at the program level using Energy Trust's Cost-Effectiveness calculator.[7] Table 4-1 provides a summary of program performance.

Table 4-1. Impact Summary of the 2008 Production Efficiency Program

Indices of Program Savings Value	Value
Working Estimate of 2008 Program Savings	78,687,954 kWh
Realization Rate	86%
Gross Savings Estimate	67,735,063 kWh
Demand Savings Estimate	8,659 kW
Net-to-Gross Ratio	77%
Net Savings Estimate	51,971,014 kWh
Net Savings as a Percentage of Working Savings	66%

Project level net-to-gross ratios were developed through comprehensive interviews with the participants in the impact evaluation sample. Navigant Consulting used Energy Trust's approach to calculate a program level net-to-gross ratio by averaging the project level net-To-gross ratios and applying this un-weighted factor to all other participant sites in the PY 2008 PE program.

Appendix A provides additional information on the models that were developed to estimate free-ridership, which accounted for:

1.) Budget: Whether participant budgets could accommodate the project;

2.) Influence: How influential participants believed the program and its services were in the decision to install the incentivized measures; and

[5] North American Industry Classification System codes (NAICS)

[6] Appendix D: 2008 PE Program Savings by NAICS Code

[7] The Pacific Northwest industrial load shapes from the C-E Calculator (ETO C-E Calculator Production Efficiency_021408.xls) were applied to estimate demand savings for the PE Program. In the absence of more detailed plant information, the operative load shapes used were Industrial Shift 1, 2, and 3.

3.) Intention: Participants' (retrospectively) stated intentions in the absence of program intervention.

It should be noted that a subset of participants reported taking actions that constituted program spillover, generating both electricity and natural gas savings. However, the analysis of spillover savings was outside the scope of this study's research objectives.[8]

4.2 Impact Evaluation Methodology

The impact evaluation of Energy Trust's 2008 PE program was designed to address several key research questions, including:

- Were measures installed as reported in the project application files?
- Were working savings estimates consistent with evaluation verified savings?
- What percentage of verified savings was attributable to free-ridership?

Evaluation, Measurement & Verification (EM&V) strategies varied across end-use categories and site-level characteristics. The resources used to verify working savings estimates included:

- *Program Tracking Records* – A thorough review of available program participant data across all installed projects. This included identifying program specific measures installed, date of measure installations, availability of pre-installation data, and an understanding of unique participant operating characteristics.
    - Baseline assumptions (i.e., pre-existing conditions) were reviewed and, to the extent possible, verified for each project in the impact evaluation sample.
- *Project Level Engineering Calculations* – An engineering review of assumptions and methodologies was used to estimate measure-level energy savings. Findings were compared against on-site measure performance parameters and informed supplemental data collection needs.
- *On-Site Measurement & Verification (M&V)* – On-site M&V efforts included the verification of measure installations, collection of key energy performance variables, and confirmation of assumptions used to develop working saving estimates. Recorded parameters included:
    - Measure presence and appropriate installation. If a measure was missing, determine if it was installed and/or removal date and reason.

[8] Appendix A provides a list of equipment that respondents to the spillover survey implied had been installed.

- Key energy performance variables of installed measures that typically fall into three categories:
  - Quantity of installed measures,
  - Capacity (e.g., amperage, wattage, tons) of installed measures, and
  - Efficiency of installed measures.
- Key facility performance data, such as daily schedules, seasonal variations in schedules, occupancy, and control strategies.
- A limited set of behavior and demographic data.
- Spot measurements, run-time hour monitoring, and end-use interval metering of a sample of installed measures to confirm pre-/post- installation performance characteristics. The rationale for different data collection strategies is provided below:
  - Spot Measurements – Spot measurements were the first and simplest level of on-site performance measurement and included one-time instantaneous measurements of technology, system, or environmental factors including temperature, volts, amperes, true power, power factor, light levels, etc. As a general guide, these measurements were used to quantify single operating parameters that did not vary significantly over time and were intended to provide a snap-shot in time of measure performance.
  - Run-Time Hour Data Logging – Run-time hour monitoring represented the second level of performance measurement and was used to record run-time profiles over a given time period or operating hour totals. Run-time hour monitoring was particularly useful for estimating long–term energy consumption from short-term measurements, particularly for technologies which exhibited constant performance characteristics.
  - Interval Metering – Interval metering was the most comprehensive level of on-site performance measurement and involved real-time monitoring of the energy use of specific end-uses over a specified time period. This generally involved recording true energy use or "proxy" values such as voltage and amperes from which energy used was computed. Interval metering was primarily used to measure post-installation energy use of variable performance measures (e.g., variable speed drive compressors).

- *Billing/Metered Data* – Where available, billing data was collected and used to benchmark working savings estimates for measures that represented a substantial portion of site energy use.

- *Secondary Literature* – Resources included program documentation (e.g., Energy Trust work papers, implementation contractor tools) and representative studies (e.g., DEER,[9] ASHRAE[10]).

M&V protocols adopted for the impact evaluation were consistent with the International Performance Measurement and Verification Protocols (IPMVP).[11] Table 4-2 presents a listing of the IPMVP protocols, the nature of the performance characteristics of the measures to which measurement and verification (M&V) options were applied, and an overview of the data requirements to support each option.

[9] Database for Energy Efficient Resources, (DEER)

[10] American Society of Heating, Refrigerating and Air Conditioning Engineers, ASHRAE Standard, ANSI/ASHRAE/IESNA Standard 90.1-2004

[11] http://www.evo-world.org/

Table 4-2. IPMVP Options and Data Requirements

IPMVP M&V Option	Measure Performance Characteristics	Data Requirements
Option A: Engineering calculations using spot or short-term measurements, and/or historical data.	Constant performance	• Verified installation • Nameplate or stipulated performance parameters • Spot measurements • Run-time hour measurements
Option B: Engineering calculations using metered data.	Constant or variable performance	• Verified installation • Nameplate or stipulated performance parameters • End-use metered data
Option C: Analysis of utility meter (or sub-meter) data using techniques from simple comparison to multivariate regression analysis.	Variable performance	• Verified installation • Utility metered or end-use metered data • Engineering estimate of savings input to SAE model
Option D: Calibrated energy simulation/modeling; calibrated with hourly or monthly utility billing data and/or end-use metering.	Variable performance	• Verified installation • Spot measurements, run-time hour monitoring, and/or end-use metering to prepare inputs to models • Utility billing records, end-use metering, or other indices to calibrate models

Evaluation findings were used to adjust measure installation counts, performance variables, input assumptions, and realized savings at the end-use category and industrial sector levels. Net savings were also estimated and details on the Net-to-Gross methodology are provided in Appendix A.

Sampling Approach

The impact evaluation sample was drawn from the population of non-SII projects within the 2008 PE program participant universe. This includes projects in the custom, participant initiated, prescriptive motors, production efficiency, and lighting program tracks. A stratified sampling methodology with a 90% confidence and 15% precision goal was used to ensure that evaluation findings were representative of overall program performance. Strata based on expected energy savings were defined by:

1.) Ordering all custom projects according to their respective working savings;

2.) Specifying a set of certainty sites to be included in the evaluation sample – that is, the 10 project sites with the greatest working savings in 2008 were included;

3.) Randomly select an additional 14 sites to bring the total number of sites to 24.

Projects within the sample were then adjusted to under sample end uses that are well understood and have with low variation in expected performance. Sample adjustments included:

- Removed and selected replacement sites for any project that included only lighting or prescriptive motors; and
- Removed and replaced one project site that only operated two months out of the year.

The final impact evaluation sample is provided in Table 4-3. Figure 4-1 provides perspective on the impact evaluation sample verifiable savings relative to the participant universe of PY 2008.

Figure 4-1. Comparison of Sample Verifiable Savings to 2008 Participant Universe

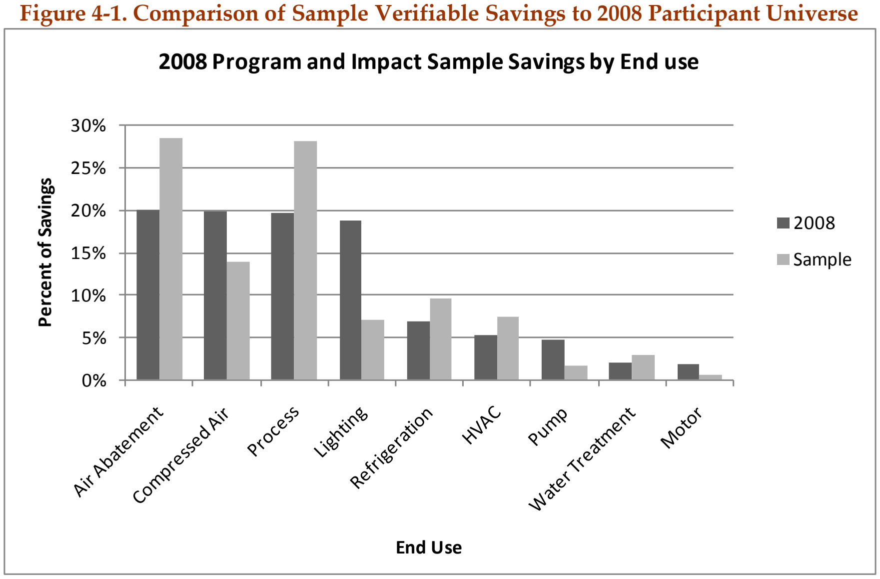
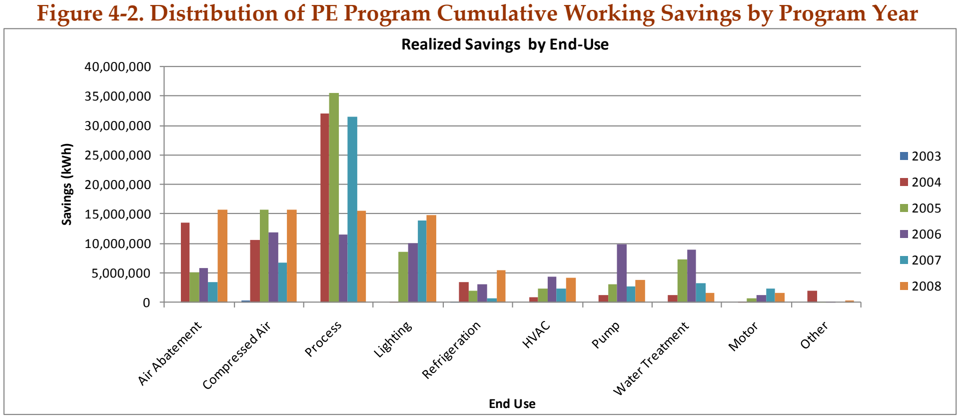


Figure 4-2 working savings by program year, dating back to 2003. Aside from process measures in PY 2008, the distribution of working savings by end-use category has remained fairly consistent throughout the history of the PE program and supports the final impact evaluation sample.

Figure 4-2. Distribution of PE Program Cumulative Working Savings by Program Year



Evaluation Site Visits

The evaluation team completed on-site EM&V activities for the 24 projects chosen in the impact evaluation sample. The majority of the site visits were conducted between September of 2009 and April 2010, however site 12's site visit was conducted in April of 2009 because of their seasonal operations. The following subsections provide an overview of project-specific evaluation findings and the challenges encountered throughout the evaluation process.

Data Gathering and Evaluation Approach

Prior to scheduling on-site evaluation activities with participant staff, the evaluation team thoroughly reviewed all project level documentation to develop an understanding of project characteristics. An evaluation plan[12] was developed for each site and approved by senior engineering staff prior to deployment. This plan served to:

1.) Identify base and installed measures included in the final evaluation sample.

2.) Identify performance influencing parameters and assumptions used to develop project-level working savings estimates.

3.) Outline an M&V approach that included:

   a. Quantity and type of measurement equipment to be used on-site.

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[12] All site-specific evaluation plans used the template provided in Appendix C: Site-Specific Measurement and Verification Plan.

b. A prioritization of evaluation supporting data collection parameters.

c. Key variables and uncertainties to be resolved with participant staff.

Throughout this process, Navigant Consulting remained cognizant of each site's unique operating characteristics, sensitivity of program installed equipment, and availability of participant staff to support M&V activities. The final evaluation strategy used to characterize project and measure level impacts made the most of available resources. Table 4-3 details the final evaluation approach used to develop gross savings estimates at the measure and project levels. Detailed site evaluation reports have also been developed and are included in Appendix B.

Table 4-3. 2008 PE Program Impact Evaluation Sampling Details

Site ID	End-Use Category	Evaluation Approach	Working Savings (kWh)	Percentage of Program Working Savings
1	Lighting	Lighting On/Off Logging	271,103	0.3%
2	Refrigeration	End-Use Metering	2,551,018	3.2%
3	Refrigeration	End-Use Metering	1,294,174	1.6%
	Lighting	Lighting On/Off Logging	584,447	0.7%
4	Process	End-Use Metering	531,432	0.7%
5	Process	End-Use Metering	3,234,671	4.1%
6	Compressed Air	End-Use Metering	188,728	0.2%
7	Compressed Air	End-Use Metering	1,345,989	1.7%
8	Compressed Air	End-Use Metering	126,022	0.2%
9	Compressed Air	End-Use Metering	765,941	1.0%
10	Compressed Air	End-Use Metering	124,252	0.2%
11	Pumping	End-Use Metering	96,582	0.1%
12	Pumping	End-Use Metering	200,918	0.3%
13	Pumping	End-Use Metering	296,438	0.4%
14	Water Treatment	End-Use Metering	17,870	0.0%
15	Water Treatment	End-Use Metering	1,180,854	1.5%
16	Pumping	End-Use Metering	80,462	0.1%
	Motors	Spot-Measurements	61,888	0.1%
17	Air Abatement	End-Use Metering	1,980,943	2.5%
	Motors	Spot-Measurements	109,165	0.1%
18	Lighting	Lighting On/Off Logging	275,654	0.4%
	Process	End-Use Metering	3,281,320	4.2%
	Compressed Air	End-Use Metering	585,077	0.7%

Site ID	End-Use Category	Evaluation Approach	Working Savings (kWh)	Percentage of Program Working Savings
	Motors	Spot-Measurements	3,486	0.0%
19	Air Abatement	End-Use Metering	8,214,268	10.4%
	Lighting	Lighting On/Off Logging	1,656,533	2.1%
	Motors	Spot-Measurements	36,110	0.0%
20	Compressed Air	End-Use Metering	442,659	0.6%
	Motors	Spot-Measurements	21,531	0.0%
21	Process	End-Use Metering	154,915	0.2%
	Compressed Air	End-Use Metering	960,164	1.2%
22	HVAC	End-Use Metering	1,364,304	1.7%
23	Process	End-Use Metering	3,646,117	4.6%
24	Air Abatement	End-Use Metering	1,200,507	1.5%
	Compressed Air	End-Use Metering	998,446	1.3%
	HVAC	End-Use Metering	1,621,959	2.1%
	Lighting	Lighting On/Off Logging	1,083,759	1.4%
	Process	End-Use Metering	372,407	0.5%
Site Total			***40,962,113***	***52.1%***

4.3 *Impact Evaluation Results*

The collected data and evaluation analyses were used to develop realized gross savings for each unique end-use measure (e.g., lighting, motors, HVAC, etc.) and industry (e.g., wood products, utilities, etc.) represented within the impact evaluation sample. Gross savings, relative to working savings, were aggregated to form end-use measure and industry level realization rates across the complete 2008 PE program participant universe:

$$Program\ Realization\ Rate = \frac{\sum_i^N \left(\frac{kWh_{verified,i}}{kWh_{working,i}} \right) x kWh_{Program,i}}{kWh_{Program}}$$

Where:

1.) $kWh_{verified,i}$ = Verified savings for end-use or industry *i* in the impact evaluation sample

2.) $kWh_{working,i}$ $kWh_{working,i}$ = Working savings for end-use or industry *i* in the impact evaluation sample

3.) $kWh_{Program,i}$ kWh_{Total} = Total 2008 PE program working savings for end-use or industry *i*

4.) $kWh_{Program}$ = Total 2008 PE program working savings

Ex-Post Adjusted Estimates by End Use

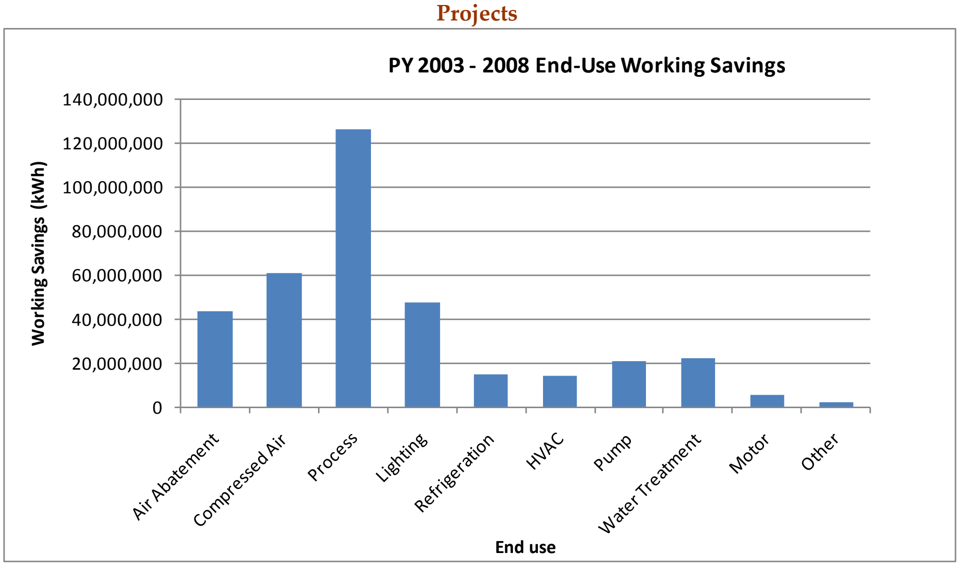
Table 4-4 provides gross realized savings and realization rates across each unique end-use measure category within the 2008 PE program. Similarly, ex-post estimates by industry type (NAICS) are provided in Appendix G.

Table 4-4. 2008 PE Program Savings by End-Use Category

	Program Site Count	Evaluation Sample Project Count	Total Program Working Savings (kWh)	Evaluation Sample Working Savings (kWh)	Percentage of Total Program Working Savings	Percentage of Evaluation Sample Working Savings	Evaluation Sample Verified Savings (kWh)	End Use Category Realization Rate	Evaluated Program Working Savings (kWh)
Air Abatement	8	6	15,786,014	11,395,718	20%	28%	9,910,764	87%	13,728,969
Compressed Air	69	9	15,642,032	5,537,278	20%	14%	5,881,897	106%	16,615,532
Process	20	8	15,491,330	11,220,862	20%	27%	7,462,021	67%	10,301,938
Lighting	123	6	14,835,509	3,871,496	19%	9%	4,139,859	107%	15,863,872
Refrigeration	5	2	5,513,658	3,845,192	7%	9%	3,031,428	79%	4,346,794
HVAC	8	2	4,143,645	2,986,263	5%	7%	465,951	16%	646,539
Pump	27	4	3,807,332	674,400	5%	2%	462,443	69%	2,610,727
Water Treatment	2	2	1,648,224	1,198,724	2%	3%	1,326,333	111%	1,823,684
Motor	81	30	1,545,317	232,180	2%	1%	228,694	98%	1,522,115
Other	11	0	274,893	-	0%	0%	-	NA	274,893
Total	***354***	***69***	***78,687,954***	***40,962,113***	***-***	***-***	***32,909,390***	***86%***	***67,735,063***

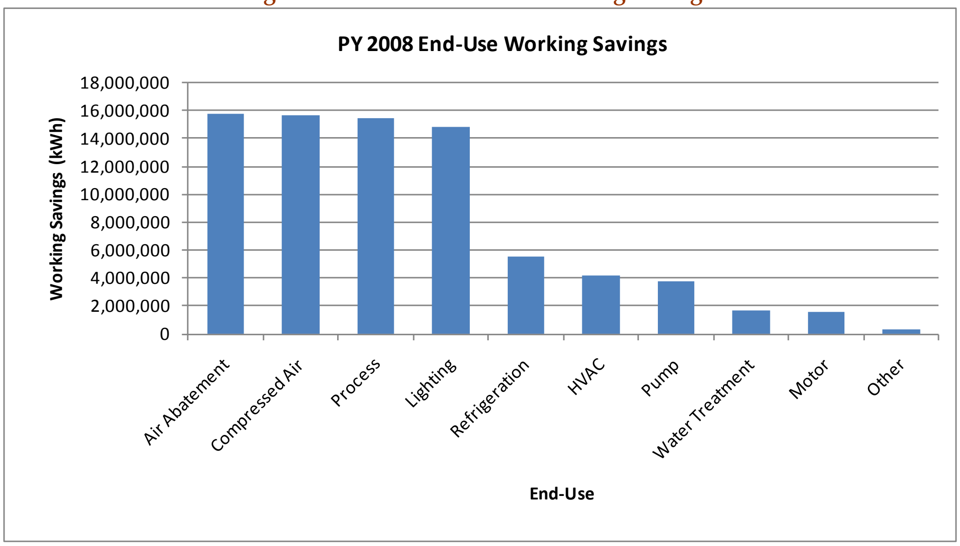
As illustrated in Figure 4-3, "Process" measures, including primary and secondary process, have historically accounted for the majority of program working and realized savings relative to other end-use measure categories. In 2008, however, process measures only accounted for 20% of working savings, largely due to the absence of a process-oriented Mega Project.

Figure 4-3. Cumulative End-Use Working Savings from PY 2003 – 2008, Excluding Mega Projects



Similarly, Figure 4-4 illustrates the distribution of end-use working savings in the PY 2008 PE program. Though process measures were not as prevalent, a majority of savings were attributed to air abatement, compressed air, process, and lighting measures. And as noted in Figure 4-3, this is consistent with the long term historical average of program savings.

Figure 4-4. PY 2008 End-Use Working Savings



Overview of Measure Performance

The Navigant Consulting team adopted a collaborative evaluation approach. Team members shared insight, experiences, and engineering methods throughout the impact evaluation process which served to standardize evaluation practices and allowed for patterns in measure-level performance to be identified. What follows is a high level discussion of each end-use category evaluated in the PY 2008 PE program.

Air Abatement Measures

Energy Trust's 2008 PE program included eight projects that implemented air abatement measures comprising 20% of program savings. Six of these were included in the impact evaluation sample, totaling 28% of sample working savings. These projects included both abatement of air emissions and filtering of internal air. A combination of direct measurements of power and current and available static pressure data were used to calculate energy use for these projects. And while a number of sites experienced reduced demand due to the current economic malaise, the realization rates for these measures were not greatly affected due to their comprehensive nature, operating on air in large parts of each facility. Realization rates were fairly consistent and ranged from 88.5% to 104% for the six projects in the evaluation sample.

Compressed Air Measures

Compressed air projects included both replacement of air compressors and dryers, controls changes to that equipment, and piping reconfigurations to link previously separated compressed air systems. There were 69 compressed air projects included in the 2008 PE program, nine of which were included in the impact evaluation sample. Overall, compressed air projects comprised 20% of program working savings and 14% of the sample working savings.

The sampling distribution was not consistent with the program distribution of savings due to the fact that most compressed air projects have relatively modest savings. More specifically, it is the volume of compressed air projects that contributes to overall program savings and as such, it is difficult to weight them heavily enough with sample size limitations. However, evaluation experience has shown compressed air savings to be fairly consistent - within 10% for most projects, and the evaluation opted to focus on measures with more uncertainty in their savings estimates.

The evaluation team found that the compressed air projects matched the descriptions in the site reports well. Two exceptions, site 6 and site 18 saw changes in production capacity since the installation and verification process. In these cases, there were difficulties using baselines from previously measured data in the project files because the systems had been reconfigured, and loads had changed since the initial study. In addition, although some of the project files contained plots of metered data prior to the installation, it was difficult to obtain the raw data for baseline calculations at these sites.

Overall, compressed air measure realization rates were fairly high, with the exceptions of sites 6 and 18, ranging from 88% to 112%. Site 6 had a low realization rate of 63% because of the addition of a large new load at the location which resulted in re-enabling older air compressors which had been shut down as part of the project. It should be noted that under the original operating assumptions, site 6 would have realized 101% of the working savings estimate. Conversely, Site 18 had a realization rate of 155% because of increased savings at current *reduced* production rates. The overall realization rate for compressed air projects was 106%.

HVAC Measures

The 2008 PE program included eight HVAC projects representing 5% of program working savings. Both of the HVAC projects included in the impact evaluation sample were installed at electronics manufacturing facilities requiring large volumes of conditioned air to support their operations and constituted 7% of the sample's working savings. Site 24 included four HVAC projects and the project's low realization rate was due to the shutdown of some areas served by the replaced measures. Site 5 included an HVAC project that was shut down due to malfunction.

It is preferable to use long term billing or logged data to evaluate HVAC savings due to weather variability. This evaluation strategy was given priority when data logs were available from the facilities, and logged data was combined with on-site measurements to increase the engineering estimate of project savings. However, HVAC savings depend upon a myriad of factors including system efficiencies, interactive effects, and above all, weather patterns. Since much of the HVAC savings were based upon reduced heating and cooling loads associated with reduced air changes, and the system logs only provided airflow data, significant uncertainties were introduced into these calculations. The studies provided with the project applications generally did not adequately document their methodology of calculating these secondary HVAC savings, making verification difficult.

The realization rate for the two HVAC measures evaluated was calculated to be 16%. While this was due in part to facility closure, HVAC savings calculations provided in the program files were generally poorly documented and difficult to verify. It is highly recommended that program applications for HVAC measures be required to include details of the methodology used to calculate savings, not just tabulated results. This should improve the reliability of future savings estimates.

Lighting Measures

Because Energy Trust had extensive documentation and findings from previous lighting studies, along with standard wattage data, evaluation staff did not confirm power draw on pre-existing and retrofit fixtures during the on-site verifications. Instead, evaluation efforts focused on confirming that measure counts and retrofit model numbers correlated with the individual project applications. Only six lighting projects were included in the evaluation sample, although 123 received incentives in the 2008 PE program. The evaluation team justified the evaluation sampling due to the reliability of existing data, the consistency of past performance, and the quality of project documentation.

Lighting on/off loggers were deployed at one of the project sites that installed occupancy sensors to verify the reduction in lighting operating characteristics. In addition current loggers were used on the power feeds to lights at two of the sites to determine the operation of occupancy sensors. One of the projects had been shut down, resulting in no savings. Realization rates for this technology exceeded 100% at two of the sites because the verified reduction in operating hours exceeded the program application assumption of 25%.

The overall realization rate for lighting projects included in the sample was 107% despite the fact that one of the projects had been shut down. However, since that project constituted only 7% of the sample savings it did not strongly affect the overall 2008 PE program realization rate.

Motor Measures

Energy Trust provided prescriptive rebates for NEMA premium efficiency motors purchased by participants of the 2008 PE program. The evaluation process for this technology included an interview with site personnel to determine the deployment status of incentivized motors. With only one exception, all verified motors were found to be installed and operating as intended. In the one case, the participant ordered motors to replace ones taken from spares. As such, only some of the motors rebated were installed at the time of inspection.

Process Measures

Process savings comprised approximately 20% of the 2008 program working savings, but represented 27% of the sample working savings. Because of the high degree of uncertainty in savings for this type of measure it was considered an evaluation priority. Overall, there were 20 process measures in the 2008 PE program, eight of which were included in the impact evaluation sample. On-site verification efforts confirmed that process improvements had been implemented as noted in the project application files. However, in two cases, the projects had since been removed or shut down due to changes in economic conditions.

Verification of process measures consisted of a combination of several techniques:

1.) Visual inspection of equipment and operation.
2.) Onsite measurement and logging of equipment power.
3.) Use of facility data logs for both equipment power and production levels.
4.) Use of equipment specifications to determine operation under varying conditions.

Overall the realization rate for process measures was only 67%, however this was primarily driven by the complete removal of one of the seven projects. Realization rates on three of the remaining projects ranged from 94% to 100%. Two of the projects affected each other and were consequently evaluated together, resulting in a combined realization rate of 89%. The final project had a realization of 87%. The reduced realization rate in that case was also due in part to additional, extraneous changes on the affected systems.

Pumping Measures

The 2008 PE program included 35 pumping projects, comprising 5% of program working savings. The impact evaluation sample included four pumping projects. Two of the pump measures were installed on irrigation systems while the remaining two were installed at manufacturing facilities. Collectively, the four projects comprised 2% of the sample working savings. The relatively modest representation of pumping measures in the evaluation sample was driven by the small scale of most pumping projects. On-site metering, billing data, and production or irrigation records were used to analyze savings for these measures.

All four projects were confirmed to be installed and operating as expected. However, all but one of the projects yielded realization rates, ranging from 14% to 58%. The remaining project, at site 13, was a vacuum pump project that realized 94% of the project working savings and was not deemed to be representative of typical pumping projects. Similarly, the lowest realization rate of 14% at site 16 involved the installation of a VFD on a drying fan and was improperly classified as a pumping project. Site 16's low realization rate was attributed to a reduced production schedule; savings would have increased moderately to 39% of project working savings under full production. The remaining two irrigation water pumping projects had realization rates of 57% and 58% and were operating at normal capacity. Navigant emphasizes that because of annual variations in, and the unusual configuration of pumps with only one VFD, that there are substantial uncertainties in the savings for this site. The underwhelming realization rates were primarily attributed to two factors:

1.) At site 11 the VFD pump could not act as trim, but instead adjusted to the head pressure developed by the constant speed pump, resulting in minimal savings when both units were operating.
2.) At site 12 incorrect motor efficiencies were assumed in the initial study that bolstered savings estimates.

The overall realization rate of 69% for the pumping end-use category may be slightly high, since the two irrigation water pumping projects, which comprise the bulk of pumping projects, had an overall realization rate of only 58%. Overall, the Navigant Consulting team recommends more thorough documentation for pumping technologies.

Refrigeration Measures

Five refrigeration measures comprised 7% of program savings in the 2008 PE program. Two of these were projects included in the evaluation sample representing 9% of the sample working savings. This constituted a significant increase from the 2007 PE program which incentivized only one refrigeration measure. The two projects included in the sample were both large refrigerated warehouses with substantial claimed savings of 1.3 and 2.6M kWh/year, respectively.

There was a significant discrepancy in realization rates between the two evaluated sites; one of the projects yielded a realization rate of 90% while the other realized only 57% of the project working savings. The lower realization rate was attributed to the under-utilization of the installed equipment. More specifically, the warehouse was designed to accommodate future expansion and the refrigeration system was substantially oversized for the current conditions. Since this was a new facility, it was not possible to utilize billing data to determine savings and on-site measurements and end-use metering were used to inform the evaluation. These data were combined with weather data to estimate annual savings at each site.

The overall realization rate for refrigeration end-use measures was 79%. It is recommended that expected utilization levels be carefully reviewed for projects implemented at new facilities to ensure that expected savings are accrued.

Water Treatment Measures

A total of five water treatment measures were included in the 2008 PE program, constituting 1.6M kWh/year of savings but only 2% of program savings. Both projects included in the impact evaluation sample and represented 3% of the sample working savings. The projects involved installing variable frequency drives on water pumps and both were operating at normal capacity during the evaluation.

These measures were evaluated using a combination of on-site metering, pump specifications, and billing data. Site 14 had a low realization rate of 47% due to operational conditions which were not accounted for in the initial study. Conversely, site 15 performed as expected and yielded a realization rate of 112%. Due to the fact that site 15 was substantially larger than site 2, the overall realization rate for water treatment end-use measures was 111%.

These projects are representative of pumping measures at water treatment sites, but are not likely to be representative of the process related water treatment measures evaluated under the 2007 PE program. As such, the Navigant Consulting Team recommends classifying such projects in the pumping category in the future to distinguish them from process related measures.

Baseline Adjustments

Energy Trust's baseline[13] guidelines currently state a preference for measured baselines. However, calculated baselines are deemed acceptable in simple cases or where measurement is not practical due to capacity increases, equipment removal, or the presence of medium and high voltage systems. Theoretical baselines use industry standards for new construction or

[13] Baseline Assumptions -Final rev 3.2.doc

equipment and a combination of the discussed methods is used where appropriate. Energy Trust's guidelines also require any assumptions to be clearly stated and the methodology summarized.

In some cases the baselines stated on the applications showed some discrepancies. Technical studies did not always directly relate to the savings claimed on applications and, in some cases, were completely absent from application files. Furthermore, in some cases there are printed plots of vendor measured baselines but the logged data is not available. The lack of availability is, in some cases, simply due to the length of time since the initial study was performed and the choice of paper records by Energy Trust. In other cases, however, vendor performed studies were considered proprietary if the customer did not fund the analysis and the logs were not provided for this analysis.

Navigant Consulting reviewed applications for baseline conditions and adjusted baselines using several criteria. Where pre-installation measured data was available and the system usage had not significantly changed since the time of its measurement, Navigant Consulting used this data to confirm baselines given in the project files. Where pre-installation measurements were not available or applicable, Navigant Consulting used specifications of baseline equipment to calculate usage. In a number of cases motors listed on prescriptive applications were verified to be installed and operating, but no calculations were performed on these projects. Lighting projects were also generally prescriptive in nature and standard wattages were used for calculations. Occupancy logging was performed at some locations with sensors to determine the reduction in operational hours.

Production data was collected from sites whose projects claimed production dependent savings. When possible this data included both pre- and post-installation figures. The pre-installation values were used along with pre-installation equipment information to calculate per-production unit energy use. This was then used to estimate how much energy would have been used to produce the current amount of product and this value was used as a baseline.

Compressed air systems' current power usage was logged and the compressor curves or CAGI data was used to calculate air consumption from power usage. If initial baseline data was available and the system had not changed appreciably, this was used as the baseline. If there had been changes in use since the initial baseline was measured, or if the system had been completely reconfigured or was new, the air usage was used to estimate usage with the previous or an equivalent standard efficiency system using compressor data for that system. Control strategies were taken in to account in the calculations.

Projects involving both fans and pumps included air abatement, water, and HVAC projects, among others. These projects were generally treated in a similar manner to compressed air. If pre-installation logged data was available and applicable, it was used to confirm or adjust the baseline provided in the application. Where this was not the case, fan and pump curves were used to estimate the capacity of the current system from power logging. This was then used along with specifications for the pre-installation system to calculate a baseline usage. In several cases, production slowdowns had significantly impacted the current usage and the baseline had to be adjusted for current conditions.

Water treatment plant projects included pumping, aeration, and controls upgrades. In several cases billing data was used to calculate savings. This was done only where the project savings comprised a significant portion of the facility usage and could clearly be discerned on the bill. In these cases, at least one pre- and one post-installation year of billing data was used to estimate savings. The baseline usage was adjusted for any weather dependencies using bin data for the area. Where billing analysis was not appropriate and the individual equipment could be reliably logged, a combination of measured data and facility monitoring data was used to create a baseline as with other project types.

Economic Factors

Throughout the evaluation process, the Navigant Consulting technical staff distinguished between reduced energy consumption achieved through improved controls and efficient measure installations, relative to a decrease in production throughput as a result of economic influencers.

Though there were fewer sites affected by the economy malaise in the 2008 PE program, evaluation staff accounted for savings from a reduction in site production activities using the following approach:

1.) If the site was closed, then achieved savings were considered null.
2.) If the changes in production levels were semi-permanent, then the savings were prorated and two sets of realization rates were calculated – the current realization with a modified baseline to account for the reduction in operating hours, and the theoretical realization rate under normal operating conditions. The final site level realization rate was then calculated to be the average of the two realization rates.
3.) If the changes in production levels were short term, then the realization rate was calculated using the site's normal operating characteristics.

This approach ensured that savings were appropriately allocated to program activities, independent of external conditions. Table 4-5 provides a tabular illustration of project and program level realization rates by current economy, full capacity, and average production schedules. Even though the overall program realization rates only shifted by approximately 1%, the realization rates within particular projects varied considerably (e.g., site 16). In the future, if larger sites representing a substantial portion of program working savings are affected by economic factors, we would expect larger deviations in achieved realization rates.

Table 4-5. PY 2008 Economy-Adjusted Realization Rates

Site ID	End-Use Category	Working Savings (kWh)	Current Economy		Full Capacity		Average Production Levels	
			Verified Savings	Realization Rate	Verified Savings	Realization Rate	Verified Savings	Realization Rate
1	Lighting	271,103	263,648	97%	263,648	97%	263,648	97%
2	Refrigeration	2,551,018	2,288,415	90%	2,288,415	90%	2,288,415	90%
	Refrigeration	1,294,174	743,013	57%	743,013	57%	743,013	57%
3	Lighting	584,447	687,688	118%	687,688	118%	687,688	118%
4	Process	531,432	517,988	98%	517,988	97%	517,988	97%
5	Process	3,234,671	2,820,800	87%	2,820,800	87%	2,820,800	87%
6	Compressed Air	188,728	119,298	63%	119,298	63%	119,298	63%
7	Compressed Air	1,345,989	1,418,847	105%	1,418,847	105%	1,418,847	105%
8	Compressed Air	126,022	110,987	88%	110,987	88%	110,987	88%
9	Compressed Air	765,941	702,991	92%	702,991	92%	702,991	92%
10	Compressed Air	124,252	172,223	139%	172,223	139%	172,223	139%
11	Pumping	96,582	56,100	58%	56,100	58%	56,100	58%
12	Pumping	200,918	115,330	57%	115,330	57%	115,330	57%
13	Pumping	296,438	279,604	94%	279,604	94%	279,604	94%
14	Water Treatment	17,870	8,333	47%	8,333	47%	8,333	47%
15	Water Treatment	1,180,854	1,318,000	112%	1,318,000	112%	1,318,000	112%
	Pumping	80,462	11,409	14%	31,648	39%	21,529	27%
16	Motors	61,888	61,888	100%	61,888	100%	61,888	100%
	Air Abatement	1,980,943	1,431,280	72%	1,993,569	101%	1,712,425	86%
17	Motors	109,165	109,165	100%	109,165	100%	109,165	100%
	Lighting	275,654	-	0%	-	0%	-	0%
	Process	3,281,320	-	0%	-	0%	-	0%
18	Compressed Air	585,077	906,000	155%	468,200	80%	687,100	117%

Site ID	End-Use Category	Working Savings (kWh)	Current Economy		Full Capacity		Average Production Levels	
			Verified Savings	Realization Rate	Verified Savings	Realization Rate	Verified Savings	Realization Rate
	Motors	3,486	-	0%	-	0%	-	0%
	Air Abatement	8,214,268	7,270,785	89%	7,270,785	89%	7,270,785	89%
	Lighting	1,656,533	2,125,463	128%	2,125,463	128%	2,125,463	128%
19	Motors	36,110	36,110	100%	36,110	100%	36,110	100%
	Compressed Air	442,659	485,992	110%	485,992	110%	485,992	110%
20	Motors	21,531	21,531	100%	21,531	100%	21,531	100%
	Process	154,915	146,364	94%	146,364	94%	146,364	94%
21	Compressed Air	960,164	842,529	88%	842,529	88%	842,529	88%
22	HVAC	1,364,304	-	0%	-	0%	-	0%
23	Process	3,646,117	3,646,000	100%	3,646,000	100%	3,646,000	100%
	Air Abatement	1,200,507	1,208,699	101%	1,208,699	101%	1,208,699	101%
	Compressed Air	998,446	1,123,030	112%	1,123,030	112%	1,123,030	112%
	HVAC	1,621,959	465,951	29%	465,951	29%	465,951	29%
	Lighting	1,083,759	1,063,060	98%	1,063,060	98%	1,063,060	98%
24	Process	372,407	330,869	89%	330,869	89%	330,869	89%
Site Total		***40,962,113***	***32,909,390***	***80%***	***33,054,118***	***81%***	***32,981,754***	***81%***

It should be noted that site 19 and site 21 were also affected by the economic downturn. However, due to a lack of information regarding baseline production levels, savings could not be prorated and the realization rates for these projects were left unchanged.

Site 6 was unique in that production capacity actually increased at the site for auxiliary processes. However, the change in capacity was not due to a change in the economy, and the realization rate was not adjusted.

To help assess the PE program's effectiveness at estimating project energy savings without the influence of economic conditions which are out of Energy Trust's control, Table 4-6 recalculates the realization rates presented in Table 4-5 by removing the four sites that were closed or had other operational changes that influenced the project realization rates. Without these sites the realization rate at average production levels increases ten percent to 91%. Navigant Consulting recommends future evaluation efforts to remain cognizant of differences between the working savings assumptions and *ex-post* operating conditions.

Table 4-6. PY 2008 Realization Rates with Economy-Adjusted Sites Removed

Site ID	End-Use Category	Working Savings (kWh)	Current Economy		Full Capacity		Average Production Levels	
			Verified Savings	Realization Rate	Verified Savings	Realization Rate	Verified Savings	Realization Rate
1	Lighting	271,103	263,648	97%	263,648	97%	263,648	97%
2	Refrigeration	2,551,018	2,288,415	90%	2,288,415	90%	2,288,415	90%
	Refrigeration	1,294,174	743,013	57%	743,013	57%	743,013	57%
3	Lighting	584,447	687,688	118%	687,688	118%	687,688	118%
4	Process	531,432	517,988	98%	517,988	97%	517,988	97%
5	Process	3,234,671	2,820,800	87%	2,820,800	87%	2,820,800	87%
6	Compressed Air	188,728	119,298	63%	119,298	63%	119,298	63%
7	Compressed Air	1,345,989	1,418,847	105%	1,418,847	105%	1,418,847	105%
8	Compressed Air	126,022	110,987	88%	110,987	88%	110,987	88%
9	Compressed Air	765,941	702,991	92%	702,991	92%	702,991	92%
10	Compressed Air	124,252	172,223	139%	172,223	139%	172,223	139%
11	Pumping	96,582	56,100	58%	56,100	58%	56,100	58%
12	Pumping	200,918	115,330	57%	115,330	57%	115,330	57%
13	Pumping	296,438	279,604	94%	279,604	94%	279,604	94%
14	Water Treatment	17,870	8,333	47%	8,333	47%	8,333	47%
15	Water Treatment	1,180,854	1,318,000	112%	1,318,000	112%	1,318,000	112%
	Air Abatement	8,214,268	7,270,785	89%	7,270,785	89%	7,270,785	89%
	Lighting	1,656,533	2,125,463	128%	2,125,463	128%	2,125,463	128%
19	Motors	36,110	36,110	100%	36,110	100%	36,110	100%
	Compressed Air	442,659	485,992	110%	485,992	110%	485,992	110%
20	Motors	21,531	21,531	100%	21,531	100%	21,531	100%
	Process	154,915	146,364	94%	146,364	94%	146,364	94%
21	Compressed Air	960,164	842,529	88%	842,529	88%	842,529	88%

Site ID	End-Use Category	Working Savings (kWh)	Current Economy		Full Capacity		Average Production Levels	
			Verified Savings	Realization Rate	Verified Savings	Realization Rate	Verified Savings	Realization Rate
23	Process	3,646,117	3,646,000	100%	3,646,000	100%	3,646,000	100%
	Air Abatement	1,200,507	1,208,699	101%	1,208,699	101%	1,208,699	101%
	Compressed Air	998,446	1,123,030	112%	1,123,030	112%	1,123,030	112%
	HVAC	1,621,959	465,951	29%	465,951	29%	465,951	29%
	Lighting	1,083,759	1,063,060	98%	1,063,060	98%	1,063,060	98%
24	Process	372,407	330,869	89%	330,869	89%	330,869	89%
Site Total		***33,219,814***	***30,389,648***	***91%***	***30,389,648***	***91%***	***30,389,648***	***91%***

Three-Year Average Realization Rates

Although the sampling strategy is designed to produce unbiased estimates of realization rates in each program year, many factors can result in year-to-year variations. In this section Navigant Consulting calculates a three-year average realization rate by end use. Averaging end use realization rates over a three-year period provides a larger sample on which to base the realization rates.

There are two valid options to determine average realization rates, either by weighting each project by savings, or using a straight unweighted average. The former method allows for the greater program level effects of larger projects. The latter treats each project as equally important to the overall realization rate. This method assumes that any variation in realization rate is not affected by the size of the project. Each method provides a different perspective on end use and program realization rates.

In calculating the annual realization rate for 2008 in Table 4-4, Navigant Consulting used a weighted average to allow for the greater affects of larger projects. Athree-year average across program years 2006, 2007 and 2008 is presented in Table 4-7. To calculate this, Navigant Consulting calculated an unweighted average by summing the realization rates of each project within the end use category and dividing by the number of projects within the end use category. The weighted three-year average is calculated by weighting the end use realization rate for each program year by the *number of projects* within each end use for that year. It should also be noted that, in some cases, projects at a single site were divided into multiple phases and these have been treated as a single project if they were performed in the same year. This is because disaggregating savings at an individual site for related measures (e.g. lighting in two adjacent areas or two upgrades of the same compressed air system) is often not possible. It should also be noted that the mega project (site 27) was not included in the 2007 averages.

Table 4-7. Three-Year Average Realization Rate by End Use

End Use	2006	2007	2008	Weighted 3-Year Average
Air Abatement	108%	90%	87%	99%
Compressed Air	135%	97%	106%	118%
HVAC	92%	100%	14%	71%
Lighting	91%	117%	88%	101%
Motors	None	89%	80%	83%
Process	92%	63%	78%	76%
Pumping	72%	41%	56%	61%
Refrigeration	93%	None	73%	86%
Water Treatment	103%	18%	79%	87%
Total projects	63	31	39	133

There was some variation in the end use category groupings between 2006 and 2007/2008 due to changes in evaluation methodology and program administration. The following items are of particular note:

- Waste water and fresh water categories used in 2006 were combined into water treatment;
- The pneumatic conveyance category in 2006 is classified as air abatement;
- Pumping category includes the end use categories "hydraulics" which was only sampled in 2006 and "irrigation pumping" only found in the 2008 sample; and
- The Process fan category is now part of Process.

It should also be noted that the 2006 evaluation assigned a realization rate of 100% to some projects with minimal data for evaluation purposes. In addition, economic conditions contributed to unusually low realization rates on many of the projects in 2007.

4.4 SII Technical Review

The Small Industrial Initiative (SII) is a component of the PE program designed to round out the larger PE program by offering participation opportunities to smaller industrial plants and helping the vendor supply network to incorporate energy efficiency into their sales and services. The SII track is different than the mainstream, or “custom,” PE program in two ways. First, the SII operates through a network of vendors who sell Energy Conservation Measures (ECMs) instead of the PDC working directly with the end use customer. Second, the SII rebates are “semi-calculated” in that they require a limited number of inputs in order to calculate the energy savings and rebate.

In 2008, 127 projects representing 3,234,335 in working kWh savings were completed through the SII. The top two end uses within the SII were compressed air projects with 30 sites representing 1,216,946 kWh in working savings (or 38% of SII working savings) and agricultural pumping projects with 24 sites representing 993,867 kWh of working savings (or 31% of the total SII working savings). Navigant Consulting conducted a technical review of the SII calculators used to estimate ECM energy savings and a review seven agricultural pumping and ten compressed air project files.

The Production Efficiency Program Implementation Manual identifies three quality assurance metrics for the SII:

1) Energy savings calculated by tightly controlled tools;
2) Repeatable simple processes; and
3) Proactive training and coaching of trade allies.

Reviewing the SII Prescriptive Savings Calculators is consistent with these quality assurance metrics and will enable Energy Trust to improve the accuracy of participant savings estimates in future program cycles.

SII Calculator Review

Whereas custom measures have more variability between installations, are more complex, and are less frequently implemented; prescriptive measures possess characteristics for which energy and demand savings can more readily be generalized and benefit from economies of scale.

The SII relies on the calculation of prescriptive savings primarily through prescriptive input assumptions (PIAs) unique to the technology installed. However, if these assumptions are inaccurate, they may have a broad range of influence on perceived program performance.

Through a thorough review of prescriptive input assumptions, Navigant Consulting reviewed the accuracy of calculated measure savings and demand reductions, thereby ensuring that they are representative of average installation conditions within Energy Trust's service territory.

Navigant Consulting used a prioritized approach in reviewing prescriptive input assumptions that ensured measures with the largest impact on program performance were allocated the appropriate level of resources. As part of this effort, the project team also reviewed program level implementation records, evaluation reports,[14] and secondary literature where relevant.

Whenever possible, Navigant Consulting leveraged supporting project documentation to become familiar with the quantitative values used to determine savings or incentive levels, and to identify assumptions with the greatest level of uncertainty at the measure level. This allowed staff members to immediately focus research and data collection efforts on reducing these uncertainties in key assumptions, bolstering or filling data gaps in technology performance variables, and verifying key calculation factors. Impact evaluation findings were also compared against the prescriptive input assumptions for consistency, and outliers were flagged for further review.

Irrigation pump VFD V1.52

The Irrigation Pump VFD V1.52 calculator estimated energy savings for the installation of VFDs on existing irrigation pumps. The specific formula used to calculate savings is shown below:

$$\text{Annual kWh Savings} = \Delta\ [HRS_i \times HP_i \times 0.746 \div MOTOR_{Eff} \div VFD_{Eff}]$$

[14] Summit Blue Consulting, *Production Efficiency Program Evaluation Report*, Energy Trust of Oregon, Inc., October 6, 2009.

Where:

HRS_i = Annual Hours of Use for Base or Retrofit System i (User-Defined)
HP_i = Pump Horsepower for Base or Retrofit System i (User-Defined)
$MOTOR_{Eff}$ = Motor Efficiency (Prescriptive Input Assumption)
VFD_{Eff} = VFD Efficiency (Prescriptive Input Assumption)
0.746 = Conversion Factor (kW/HP)

It should be noted that HP_i is calculated through a quadratic regression model that accounts for user-input flow rates (GPM) and Control Pressures. Navigant Consulting found this relationship to adequately characterize the non-linear relationship between pump power and flow rate. Moreover, the savings equation accurately captures measure savings, assuming the correct prescriptive and user-defined input assumptions. The Irrigation Pump VFD V1.52 Calculator contained three prescriptive input assumptions used in the calculation of project energy savings:

Motor Efficiency: Motor efficiencies complied with the Department of Energy's General Purpose Motors Required Full-Load Nominal Efficiencies under the Energy Policy Act (EPact) effective October 24, 1997. The specific efficiencies are shown in Table 4-8.

Table 4-8. Pump Motor Efficiency Assumptions

Pump (HP)	Motor (Efficiency)
5	87.50%
7.5	89.50%
10	89.50%
15	91.00%
20	91.00%
25	92.40%
30	92.40%
40	93.00%
50	93.00%
60	93.60%
75	94.10%
100	94.50%
125	94.50%

VFD Efficiency: The VFD efficiency was assumed to be 95%. This is consistent with industry standards, as well as the efficiency used in the PE Project Impact Evaluations.

Relationship between Pump Speed and Power: Fluid Dynamic Laws prove that pump power (in theoretical systems with no static head) varies with the cube of pump speed, as shown below:

$P1 / P2 = (Q_1 / Q_2)^3$

Where:

P_i = *Pump Power (Watts)*

Q_i = *Pump Volume Flow Capacity (GPM)*

The cubed relationship is representative of ideal situations and it is industry accepted practice to adjust this factor to a value between 2.1 and 2.9 to reflect system inefficiencies.[15] This adjustment is also consistent with the 2008 PE Project Impact Evaluations.

Navigant Consulting found the Irrigation Pump VFD V1.52 Calculator to be mathematically astute. Uncertainty in measure savings is primarily attributed to user-defined inputs that are unique to each project. Ensuring the accuracy of these inputs (e.g., annual hours of operation, flow rate, head (psig)) through application requirements will greatly contribute to the accuracy of program savings estimates.

Irrigation System Change Out (Single Duty Point) V1.51

The Irrigation System Change Out (Single Duty Point) V1.51 Calculator estimates energy savings for single-point duty irrigation system upgrades, including new water delivery methods and new pumps and pump motors. The specific formula used to calculate savings is shown below:

$$\text{Annual kWh Savings} = \Delta\ [AREA \times INCHES \times PRESSURE_i \times 2.31 \times 0.746) / (SYSTEM_{Eff} \times 27{,}154.3 \times 3960 \times 60 \times PUMP_{Eff\,i} \times MOTOR_{Eff\,i})$$

Where:

AREA = Total Area (acres) of Irrigated Land (User-Defined)

INCHES = Net inches of water delivered the Irrigated Land (User-Defined)

$SYSTEM_{Eff\,i}$= *Efficiency of Irrigation System for Base or Retrofit System i (User-Defined)*

$PRESSURE_i$ = *Operating Pressure (psig) for Base or Retrofit System i (User-Defined)*

$PUMP_{Eff\,i}$ = *Pump Efficiency at operating Flow and Pressure for Base or Retrofit System i (User-Defined)*

$MOTOR_{Eff}$ = *Motor Efficiency (Prescriptive Input Assumption)*

27,154.3 = Conversion Factor (acre-inch/gallon)

2.31 = Conversion Factor (ft/PSI)

0.746 = Conversion Factor (kW/HP)

3960 = Conversion Factor (gpm ft/HP)

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[15] US Department of Energy, Energy Efficiency and Renewable Energy. *Improving Pumping System Performance: A Sourcebook for Industry. 2006*

60 = Conversion Factor (Min/Hour)

Navigant Consulting found the savings equation to accurately capture measure savings, assuming the correct prescriptive and user-defined input assumptions. The calculator contained two prescriptive input assumptions used in the calculation of project energy savings:

Motor Efficiency: Motor efficiencies complied with the Department of Energy's General Purpose Motors Required Full-Load Nominal Efficiencies under the Energy Policy Act (EPact) effective October 24, 1997. The specific efficiencies are shown in Table 4-8.

System Irrigation Efficiency: Although the calculator does not prescriptively assume irrigation efficiency, it does suggest an efficiency range for the user. These ranges are shown in Table 4-9. While exact system efficiency is a function of multiple factors including weather, crop type and system geometry, the ranges provided are found to be in line with industry resources.[16,17]

Table 4-9. Irrigation System Efficiencies

Description	Typical Range
Big Gun Irrigation	50% to 60%
Hand Lines	50% to 60%
Hard Hose Traveler	50% to 60%
Overhead Sprinklers	70% to 80%
Linear System	75% to 85%
Center Pivot System	75% to 85%
Drip Irrigation System	85% to 95%

Overall, Navigant Consulting found the Irrigation System Change Out (Single Duty Point) V1.51 Calculator to correctly estimate system savings. Uncertainty in measure savings is primarily attributed to user-defined inputs that are unique to each project. Ensuring the accuracy of these inputs (e.g., irrigation volume, pump efficiency, flow rate, head (psig)) through application requirements will greatly contribute to the accuracy of program savings estimates.

It should be noted that this tool does not account from additional savings that may be recognized through installation of VFDs on pumping systems. Additionally, several minor spelling errors were found in the calculator. Navigant Consulting recommends having a copy editor review the calculators to identify and resolve these minor errors.

[16] United States Department of Agriculture, National Resource Conservation Service *National Engineering Handbook: Irrigation Guide*, 1997
[17] Washington State Department of Ecology *Water Resources Program Guide 1210*, 2005 http://www.ecy.wa.gov/programs/wr/rules/images/pdf/guid1210.pdf

Comprehensive Irrigation Tool V1.51

The Comprehensive Irrigation Tool V1.51 Calculator is used to calculate energy savings for the installation of new pump motors and VFDs on existing irrigation pumps. The tool may be used in cases where the original motor had a VFD. The calculator utilizes the same formulas and algorithms as the Irrigation Pump VFD V1.52 Calculator discussed in above. The specific formula used to calculate savings is shown below:

$$\text{Annual kWh Savings} = \Delta\ [HRS_i \times HP_i \times 0.746 \div MOTOR_{Eff\,i} \div VFD_{Eff\,i}]$$

Where:
HRS_i = *Annual Hours of Use for Base or Retrofit System i (User-Defined)*
HP_i = *Pump Horsepower for Base or Retrofit System i (User-Defined)*
$MOTOR_{Eff\,i}$ = *Motor Efficiency for Base or Retrofit System i (Prescriptive Input Assumption)*
$VFD_{Eff\,i}$ = *VFD Efficiency for Base or Retrofit System i (Prescriptive Input Assumption)*
0.746 = Conversion Factor (kW/HP)

It should be noted that HP_i is calculated through a quadratic regression model that accounts for user-input flow rates (GPM) and Control Pressures. Navigant Consulting found this relationship to adequately characterize the non-linear relationship between pump power and flow rate. Moreover, the savings equation accurately captures measure savings, assuming the correct prescriptive and user-defined input assumptions. The Irrigation Pump Calculator contained three prescriptive input assumptions used in the calculation of project energy savings:

Motor Efficiency: Motor efficiencies complied with the Department of Energy's General Purpose Motors Required Full-Load Nominal Efficiencies under the Energy Policy Act (EPact) effective October 24, 1997. The specific efficiencies are shown in Table 4-8 above.

VFD Efficiency: The VFD efficiency was assumed to be 95%. This is consistent with industry standards, as well as the efficiency used in the PE Project Impact Evaluations.

Relationship between Pump Speed and Power: Fluid Dynamic Laws prove that pump power (in theoretical systems with no static head) varies with the cube of pump speed, as shown below:

$$P1 / P2 = (Q_1 / Q_2)^3$$

Where:
P_i = *Pump Power (Watts)*
Q_i = *Pump Volume Flow Capacity (GPM)*

The cubed relationship is representative of ideal situations and it is industry accepted practice to adjust this factor to a value between 2.1 and 2.9 to reflect system inefficiencies.[18] This adjustment is also consistent with the 2008 PE Project Impact Evaluations.

Navigant Consulting found the Comprehensive Irrigation Tool V1.51 Calculator to be mathematically astute. Uncertainty in measure savings is primarily attributed to user-defined inputs that are unique to each project. Ensuring the accuracy of these inputs (e.g., annual hours of operation, flow rate, head (psig)) through application requirements will greatly contribute to the accuracy of program savings estimates.

Air Compressor (1 machine to 1) V1.5

The Air Compressor (1 machine to 1) V1.5 Calculator is used to calculate energy savings for the 1:1 replacement of less efficient air compressors. The specific formula used to calculate savings is shown below:

$$Annual\ kWh\ Savings = \Delta\ [POWER_i * \sum^{l} \{(LOADING_{factor\ il} + PENALTY_{il})*(1+ (PSI_{rated\ i} - PSI_{system}))/250)* HRS_{il}\}]$$

Where:

$POWER_i$ = *Rated power for compressor i in kW*

$LOADING_{factor\ il}$ = *Loading factor for Base or Retrofit System i at load l (Prescriptive input assumption)*

$PENALTY_{il}$ = *Power penalty (Prescriptive input assumption)*

$PSI_{rated\ i}$ = *Rated presser for Base or Retrofit system I (User-Defined)*

PSI_{system} = *Pressure of the system (User Defined)*

HRS_{il} = *Annual Hours of Use for Base or Retrofit System i at Load l (User-Defined)*

250 = Conversion factor pressure reduction to energy savings (Prescriptive input assumption)

$POWER_i = HP_i * .746 * 1.1 / (MOTOR_{eff})$

Where:

HPi = *Horse Power of Base or Retrofit System i (User-Defined)*

$MOTOR_{Eff}$ = *Motor Efficiency (Prescriptive Input Assumption)*

0.746 = Conversion Factor (kW/HP)

1.1 = Maximum motor service factor (Prescriptive Input Assumption)

Navigant Consulting has found the savings equation to accurately capture measure savings, assuming the correct prescriptive and user-defined input assumptions. The Air Compressor (1

[18] US Department of Energy, Energy Efficiency and Renewable Energy. *Improving Pumping System Performance: A Sourcebook for Industry. 2006*

machine to 1) V1.5 Calculator contained five prescriptive input assumptions used in the calculation of project energy savings:

Loading Factor: The loading factor corrects for compressors' lower efficiency when lightly loaded, and the non-linear relationship between loading and power. This is only relevant to VFD and inlet modulation compressors. Loading factor is calculated according to the following equations:

$$LOADING_{factor\ i} = PARTLOAD_{il} * C_x + C_{0x}$$

Where:

$PARTLOAD_{il}$ = Percentage loading for system i at given interval l (User-Defined)

C_i= Scaling coefficient for Partload l, based on Table 4-10~~Table 4-10~~

C_{0i}= Scaling coefficient not for Partload l based Table 4-10~~Table 4-10~~

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Results of the loading factor equation and the scalar values match well with industry standard performance expectations.[19]

Table 4-10. Scaling Factors for Air Compressor Loading

Part Load	below 50%		above 50%	
Control type	C_x	C_{0x}	C_{0x}	C_x
Inlet modulation	0.68	0.32	0.68	0.32
On/Off (recips)	0.00	1.00	0.00	1.00
Load/Unload	0.30	0.70	0.30	0.70
VFD	0.15	0.70	0.00	1.00
Modulation with unloading	0.30	0.89	0.68	0.32

Power Penalty: The power penalty is a correction to the loading factor and influences savings when the receiver is not sized effectively. It is only calculated for load/unload and inlet modulation compressors and is a function of the part load and the receiver ratio, which are both user-defined. The prescriptive assumptions provided by Table 4-11 correlate with industry standards and literature.[20]

[19] The Compressed Air Challenge, US Department of Energy, *Fundamentals of Compressed Air Systems*, 2004

[20] Ibid.

Table 4-11. Power Penalty Assumptions for Inlet Modulation and Load/Unload Compressors

Part Load		20%	30%	40%	50%	60%	70%	80%	90%	100%
Receiver Ratio (gal/cfm)	0	10.0%	11.0%	11.0%	9.5%	8.0%	6.5%	4.5%	2.0%	0.0%
	1	10.0%	11.0%	11.0%	9.5%	8.0%	6.5%	4.5%	2.0%	0.0%
	2	6.5%	7.3%	7.5%	6.8%	5.8%	4.8%	3.5%	1.5%	0.0%
	3	3.0%	3.5%	4.0%	4.0%	3.5%	3.0%	2.5%	1.0%	0.0%
	4	2.3%	2.8%	3.0%	3.0%	2.8%	2.3%	2.0%	1.0%	0.0%
	5	1.5%	2.0%	2.0%	2.0%	2.0%	1.5%	1.5%	1.0%	0.0%
	6	1.5%	2.0%	2.0%	2.0%	2.0%	1.5%	1.5%	1.0%	0.0%
	7	1.0%	1.5%	1.5%	1.5%	1.5%	1.0%	1.0%	0.5%	0.0%
	8	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	0.5%	0.0%
	9	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.0%	0.0%
	10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Motor Efficiency: Motor efficiencies complied with the Department of Energy's General Purpose Motors Required Full-Load Nominal Efficiencies under the Energy Policy Act (EPact) effective October 24, 1997. The specific efficiencies are shown in Table 4-8.

Motor Service Factor: A motor service factor of 1.1 is assumed for all systems. This value is consistent with industry standards and prior evaluation experience.

Pressure Reduction Factor: Energy savings from pressure reduction are calculated as:

$$Pressure\ factor = 1 + (PSI_{rated\ i} - PSI_{system}))/250$$

The equation yields 0.4% in savings for each 1 psi reduction in pressure. This assumed pressure reduction is conservative as the industry nominal reduction is 0.5% savings for each 1 psi.[21]

Navigant Consulting found the Air Compressor (1 machine to 1) V1.5 Calculator to be mathematically astute. Uncertainty in measure savings is primarily attributed to user-defined inputs that are unique to each project. Ensuring the accuracy of these inputs (e.g., annual hours of operation, rated and system pressure and loading conditions) through application requirements will greatly contribute to the accuracy of program savings estimates.

Particular attention should be paid to loading conditions as these are often quantitatively unknown to users. Moreover, periods of monitoring may be necessary to obtain accurate loading operating points and hours at those points.

Air Compressor (2 machine to 1) V1.5

[21] The Compressed Air Challenge, US Department of Energy, *Advanced Fundamentals of Compressed Air Systems*, 1999

The Air Compressor (2 machine to 1) V1.5 Calculator is used to calculate energy savings for the 2:1 replacement of less efficient air compressors. The specific formula used to calculate savings is shown below:

Annual kWh Savings $= \Delta\ [POWER_i * \sum^{l} \{(LOADING_{factor\ il} + PENALTY_{il}) * (1 + (PSI_{rated\ i} - PSI_{system}))/250) * HRS_{il}\}]$

Where:

$POWER_i$ = *Rated power for compressor i in kW*

$LOADING_{factor\ il}$ = *Loading factor for Base or Retrofit System i at load l (Prescriptive input assumption)*

$PENALTY_{il}$ = *Power penalty (Prescriptive input assumption)*

$PSI_{rated\ i}$ = *Rated presser for Base or Retrofit system I (User-Defined)*

PSI_{system} = *Pressure of the system (User Defined)*

HRS_{il} = *Annual Hours of Use for Base or Retrofit System i at Load l (User-Defined)*

250 = Conversion factor pressure reduction to energy savings (Prescriptive input assumption)

$POWER_i = HP_i * .746 * 1.1 / (MOTOR_{eff})$

Where:

HPi = Horse Power of Base or Retrofit System i (User-Defined)

$MOTOR_{Eff}$ = *Motor Efficiency (Prescriptive Input Assumption)*

0.746 = Conversion Factor (kW/HP)

1.1 = Maximum motor service factor (Prescriptive Input Assumption)

Navigant Consulting has found the savings equation to accurately capture measure savings, assuming the correct prescriptive and user-defined input assumptions. The Air Compressor (2 machine to 1) V1.5 Calculator contained five prescriptive input assumptions used in the calculation of project energy savings:

Loading Factor: The loading factor in the 2 machine to 1 machine calculator serves two purposes. First, the loading factor accounts for the time that each machine is operating. It assumes that the primary compressor is machine #1 and that the full system load is produced by this machine at loads less than its rated air flow. At loads above the rated airflow of machine #1, machine #1 operates at 100% loading and machine #2 operates at the difference between the system airflow and machine #1's airflow.

At loads below the capacity of machine #1:

$PARTLOAD_{\#1l} = DEMAND/CAPACITY_{\#1}$

$PARTLOAD_{\#2L} = 0$

At loads above the capacity of machine #1:

$PARTLOAD_{\#1l} = 100\%$

$PARTLOAD_{\#2L} = (DEMAND - CAPACITY_{\#1})/CAPACITY_{\#2}$

Where:

$DEMAND = \% \ FLOW \ / \ (CAPACITY_{\#1} + CAPACITY_{\#2})$
$CAPACITY_{\#1}$ = *Rated air flow of machine #1 (User-Defined)*
$CAPACITY_{\#2}$ = *Rated air flow of machine #2 (User-Defined)*
%FLOW = Operating points of system I (User-Defined)

Second, it corrects for compressors' lower efficiency when lightly loaded, and the non-linear relationship between loading and power. This is only relevant to VFD and inlet modulation compressors. Loading factor is calculated according to the equation below:

$LOADING_{factor\ mi} = PARTLOAD_{ml} * C_x + C_{0x}$

Where:

$PARTLOAD_{ml}$ = *Percentage loading for the machine m at given interval l (User-Defined)*
C_i= *Scaling coefficient for Partload l, based on Table 4-10~~Table 4-10~~*
C_{0i}= *Scaling coefficient not for Partload l based on Table 4-10~~Table 4-10~~*

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Results of the loading factor equation and the scalar values match well with industry standard performance expectations.[22]

Power Penalty: The power penalty is a correction to the loading factor and influences savings when the receiver is not sized effectively. It is only calculated for load/unload and inlet modulation compressors and is a function of the part load and the receiver ratio, which are both user-defined. The prescriptive assumptions, provided by Table 4-11, correspond well to industry standards and literature.[23]

Motor Efficiency: Motor efficiencies complied with the Department of Energy's General Purpose Motors Required Full-Load Nominal Efficiencies under the Energy Policy Act (EPact) effective October 24, 1997. The specific efficiencies are shown in Table 4-8.

Motor Service Factor: A motor service factor of 1.1 is assumed for all systems. This value is consistent with industry standards and prior evaluation experience.

Pressure Reduction Factor: Energy savings from pressure reduction are calculated as:

$Pressure\ factor = 1 + (PSI_{rated\ i} - PSI_{system}))/250$

[22] The Compressed Air Challenge, US Department of Energy, *Fundamentals of Compressed Air Systems*, 2004
[23] Ibid.

The equation yields 0.4% in savings for each 1 psi reduction in pressure. This assumed pressure reduction is conservative as the industry nominal reduction is 0.5% savings for each 1 psi.[24]

Navigant Consulting found the Air Compressor (2 machine to 1) V1.5 Calculator to be mathematically astute. Uncertainty in measure savings is primarily attributed to user-defined inputs that are unique to each project. Ensuring the accuracy of these inputs (e.g., annual hours of operation, rated and system pressure and loading conditions) through application requirements will greatly contribute to the accuracy of program savings estimates.

Particular attention should be paid to loading conditions as these are often quantitatively unknown to users. Periods of monitoring may be necessary to obtain accurate loading operating points and hours at those points.

The calculator assumes that machine #1 operates as the main compressor and machine #2 operates as a trim, only turning on when demand is higher than the capacity of machine #1. The calculator instructions do not direct the user that the main compressor must always be defined as machine #1 and the trim must be defined as machine #2. Navigant Consulting recommends clarification to the calculator instructions to the calculator to avoid potential mistakes.

Regional Tool Mar 9

The Regional Tool Mar 9 Calculator is identical to the Air Compressor (1 machine to 1) V1.5 Calculator and is used to calculate energy savings for the 1:1 replacement of less efficient air compressors. As such the same input assumptions and feedback apply to this calculator as well.

SII Project File Review

Navigant Consulting also reviewed invoices of SII projects that claimed savings through the prescriptive calculators reviewed. Overall, the projects used the calculators correctly and the evaluation team's only comment related to the incentive payment on a project using the Irrigation Pump VFD V1.52 Calculator.

More specifically, this project involved the installation of a 60 HP irrigation pump VFD. The incentive was paid on custom incentive rates for an annual energy savings estimate of 75,517 kWh.

Initial project costs were estimated to be $13,000, but the final incentive was calculated using the revised project invoice of $9,972.08. Costs were disaggregated into four components:

1.) Material Costs: $8,653

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[24] The Compressed Air Challenge, US Department of Energy, *Advanced Fundamentals of Compressed Air Systems*, 1999

2.) Labor: $740
3.) Permit: $162
4.) Installation of Lights for Fuel Pumps: $417

The installation of lights for fuel pumps may have been outside the scope of the project and lengthened the perceived pre- and post-incentive payback years. In the interest of making the program appear more financially attractive, Energy Trust may consider restricting project costs to encompass project-specific material and labor only.

4.5 Conclusions and Recommendations

Program Impacts

The impact evaluation yielded an end-use program realization rate of 86% and corresponding gross savings of 67,280,112 kWh.

Table 4-12. Impact Summary of the 2008 PE Program

Indices of Program Savings Value	Value
Working Estimate of 2008 Program Savings	78,687,954 kWh
Realization Rate	86%
Gross Savings Estimate	67,735,063 kWh
Demand Savings Estimate	8,659 kW

The working estimate of savings includes 3,234,335 kWh installed through the Small Industrial Initiative (SII). The PE program delivered gas savings of 17,555 therms from eight projects implemented at six participant sites.

Interviews with PE program participants yielded a free-ridership estimate of 23% and a net-to-gross ratio of 77%. The final 2008 PE program net savings estimates amounted to 51,621,926 kWh, or 66% of 2008 program working savings.

Table 4-13. Free-Ridership Summary of the 2008 PE Program

Indices of Program Savings Value	Value
Net-to-Gross Ratio	77%
Net Savings Estimate	51,971,014 kWh
Net Savings as a Percentage of Working Savings	66%

SII Calculator Review

Navigant Consulting found the SII Prescriptive Savings Calculators to accurately estimate savings accrued from energy efficient upgrades of pumps, motors, air compressors, etc. The prescriptive input assumptions (e.g., loading factors, motor efficiencies, etc.) used in each calculator correlate with industry standards and are representative of “average” operating or installation conditions.

Recommendations

Throughout the impact evaluation process, the Navigant Consulting team collectively documented evaluation observations, assessed program feedback obtained through discussions with program participants and staff, and exhaustively reviewed available program records. This information has been used to develop a set of recommendations that will improve future program implementation efforts while enhancing the accuracy of impact evaluation findings.

The following recommendations for Energy Trust’s 2008 PE program remain cognizant of the previous program recommendations made for 2007 PE program and aim to explain how the adoption of prior recommendations influenced current program findings and improvement opportunities.

Recommendation 1: Pursuant to the Plant Closure Study (Recommendation Four of the 2007 PE Program Impact Evaluation), define and project future savings estimates at the program level.

As noted in section 3*.3.3 Economic Factors*, the Navigant Consulting team distinguished between reduced consumption achieved through improved controls and efficient measure installations, relative to a decrease in production throughput as a result of economic influencers. Though more prevalent in the 2007 PE program, the 2008 PE program also had a number of sites that suffered from reduced savings as a result of unforeseen closures. A Plant Closure Study will more accurately characterize the impact of these production changes on realized savings.

In the 2008 PE program, project site 17 installed three new baghouses in compliance with new federal maximum achievable control technology (MACT) regulations. The corresponding realization rate for the low dust collection system ranged from 72% - 101% due to reductions in plant demand during the impact evaluation effort. When the facility returns to 7,800 hours of operation per year the annual savings will increase to 1,993,569 kWh, a 101% realization rate.

In addition to the economic malaise, modified production schedules and capacity led to changes in system configurations which were not incorporated into original study findings. This often resulted in realized savings that differed significantly from original projected savings, despite the EEM being correctly installed. As an example, project site 6 installed a new 100 HP, variable speed drive screw compressor designed to replace the existing three pre-installation compressors. The new VFD compressor was expected to adjust its speed to match compressor output to system demand. Energy savings were expected to accrue from the new compressor’s ability to follow the variable flows closely with variable kW consumption. However, the post-installation demand required an increase in production capacity and both the pre- and post-installation compressors operated in unison. The Navigant Consulting Team calculated savings for both the expected and realized system configurations:

1.) Configuration 1: Replace the three baseline air compressors with one 100 HP, VFD compressor as originally planned. In this scenario, the baseline energy consumption values from the initial assessment report were accepted and manufacturer performance curves for the 100 HP, VFD compressor were used to estimate the annual energy consumption for the replacement compressor under similar air demand conditions. The difference between the base and retrofit annual energy consumption represented the project level savings for this scenario.
2.) Configuration 2: Extrapolate the end-use metered results for the 100 HP, VFD compressor, along with the existing three baseline compressors to estimate annual post installation energy consumption under the current operational conditions. In the absence of a definitive baseline, Navigant Consulting assumed that site 6 would have otherwise installed an equivalent non-VFD compressor with modulated airflow. Drawing upon manufacturers' performance curves, the difference in annual energy consumption between the VSD and non-VSD air compressor configurations was taken to be the project level savings for this scenario.

Although the expected configuration (#1) achieved a 107% realization rate, the actual system configuration (#2) only achieved a 63% realization rate. This was due to the fact that the second configuration utilized a theoretical baseline with a non-VFD equivalent compressor with the same CFM requirements. Although the realized project savings are low, it is not particularly useful to compare the realized savings to the projected savings because they assume different configurations and future project savings may revert back to 107% pending plant demand needs. Defining and projecting future savings for projects with adjusted production schedules will further explain discrepancies between estimated and achieved savings.

Recommendation 2: Conduct follow up M&V on projects that were not fully implemented. Consider providing incentives and/or engineering support for the commissioning of these projects to capture the unrealized energy savings.

The partial implementation of measures at three sites resulted in low project realization rates. In these cases, there is opportunity for the site to achieve additional energy savings, and improve the project realization rates, by completing these projects in the future. Some site contacts indicated to the Navigant Consulting engineer that follow up projects were being considered. Energy Trust should attempt to verify subsequent project activities and document the energy savings.

Specific 2008 PE projects to monitor are:

1.) Site 22: At this site, condenser water reset was disabled after initial implementation due to a failure to limit the reset under certain conditions, resulting in a zero percent realization rate for this site. Facilities staff hired since the prior attempt to implement this measure indicated that they were going to investigate the measure again during 2010. If the controls are re-enabled and the realization rate was found to be 100 percent, the potential additional energy savings is 1,364,304 kWh. This additional energy savings would increase the program realization rate to 88.5 percent.
2.) Site 24: Software problems caused EEM 2, cooling water temperature reset and cooling tower operation adjustments, at site 24 to be promptly discontinued, resulting in a zero percent realization rate for this measure. The facility still intends to restart this measure once the software glitch is repaired. If the realization rate were found to be 100 percent, the additional energy savings would bring the overall program realization rate to 87.5 percent.
3.) Site 14: In the original ATAC study, sequencing of the pumps was recommended along with the VFD installation. Although the 2008 PE incentive and energy savings was based solely in the VFD installation, additional energy savings may be realized if the pumps are properly sequenced in the future. The evaluation team is not able to estimate the additional energy savings from the pump sequencing.

In the case of site 22 providing an incentive or engineering support for the commissioning of the project would have identified and corrected initial system failures and ensured that the project measures were performing as expected, thereby improving the project's realization rate.

Recommendation 3: Use consistent end use classifications for the various pumping measure applications.

Pumping projects evaluated for the 2008 PE program fell into several categories: pumping as a part of water treatment (sites 14 and 15), irrigation water pumping (sties 11 and 12), process water or other liquid pumping (sites 16 and 25), and vacuum pumping (site 13). The Navigant Consulting Team recommends the water pumping measures be categorized into one of two end use classifications, Pumping and Irrigation Pumping, and that vacuum pumping measures be classified as Process.

The Pumping end use would include all liquid pumping at industrial and water treatment facilities. Industrial process pumping is usually for water and has similar characteristics to water treatment pumping. These two categories have more in common than either does with process changes in other categories and could be classified together.

Contrastingly, vacuum pumping is a completely different process from the pumping of water. As such, it is better classified as a custom process project than as generic Pumping.

Irrigation water pumping is seasonal and has very different operational characteristics from categories and should be treated separately for realization rates as well as expected savings.

Recommendation 4: Make minor clarifications to SII calculators

The two recommendations offered by Navigant Consulting are:

1.) Clarify operating assumptions for more complex replacements: As an example, the Air Compressor (2 machine to 1) V1.5 Calculator assumes that machine #1 operates as the main compressor while machine #2 operates as a trim, only providing air when demand is higher than the fully capacity of machine #1. However, the calculator does not clearly define the relationship between the two machines and it may be easy for users to inadvertently assign the main compressor at their facility to machine #2. Providing clear instructions on how to use the calculator will greatly reduce the potential for erroneous outputs.
2.) Consider having copy editor review tool: As an example, Navigant Consulting found a number of spelling errors in the Irrigation System Change Out (Single Duty Point) V1.51 Calculator. Though seemingly minor, correcting for these errors in the future will greatly improve the perceived quality of the SII Prescriptive Savings Calculators.

Appendix A: Free-Ridership and Spillover

Overview

For evaluation of Energy Trust Production Efficiency program, Navigant Consulting worked with the Energy Trust evaluation staff to refine a set of survey questions and a model for estimating free-ridership at the program level based on:

- **Budget:** Whether participants' budgets could accommodate the project;
- **Influence:** How influential participants believe the program and its services were in the decision to install the project; and
- **Intention:** Their (retrospectively) stated intentions in the absence of the program.

The free-ridership estimation method used for Production Efficiency is detailed in this appendix and is based on a memo prepared by Phil Degens and Sarah Castor of Energy Trust, dated June 4, 2008, entitled *Energy Trust Free-Ridership Methodology*.

Background

The California Evaluation Framework states:

> "Free-riders are project participants who would have installed the same energy efficiency measures if there had been no program. How free-ridership is handled is a critical component of making the evaluations cost effective and accurate. Uncertainty surrounding free-ridership is a significant component of net energy and demand savings uncertainty."

Free-rider rates are also important inputs in program planning and redesign. Free-rider rates provide important information that signals when program changes should be made in such aspects as incentive levels, target markets, efficiency levels, eligibility requirements, or when the program should be terminated. This information helps programs evolve, retain their impacts, and remain relevant in the market.

Methods for calculating and adjusting for free-ridership have changed over time. Estimation techniques vary from simple self reports to elaborate econometric decision models, as well as the use of comparison groups to adjust for, but not directly estimate, free-ridership. With self-reports, the initial, simple yes /no question of *Would you have done it without the program?* has evolved into a battery of questions that attempt to model the nuances of the decision-making process and extract the influence of the program. Multiple questions with a range of answers for each question require methods for weighting and scoring, as well as an algorithm to arrive at a final estimate of free-ridership.

Energy Trust has utilized an assortment of different methods to estimate free-ridership using participant self-reports. These methods have been shown to have a various weaknesses and biases. Suggested approaches developed in other parts of the country to address these shortcomings have tended to increase data collection requirements.

To address both shortcomings and increased data requirements, Energy Trust staff has developed a method for calculating free-ridership that is simple, transparent, and unbiased. A goal in developing this method was the ability to apply it to all programs and their markets. An added goal was the ability to obtain the self-reported results through a reduced set of survey questions. These questions can be incorporated in a short program feedback survey administered online or on paper at the time of participation. The timing of the survey, as well as its brevity, should increase participant response rates. In addition, having the survey administered at the time of participation may yield more accurate information, since the program is still fresh in the respondent's mind and the chances are greater that the person most directly involved in the project is the survey respondent.

Survey Questions

Table A-1 presents the survey questions used and the abbreviated label for the question shown in subsequent tables for the PE Custom Participants.

Table A-1. Survey Questions Related to Free-Ridership and Corresponding Chart Abbreviations

QUESTION ASKED	CHART ABBREVIATION
Had your firm not been able to get an Energy Trust incentive for the installation, how would your plans have changed, if at all? *(Specific alternatives queried, plus "anything else?")*	Intention
How influential was the technical study in planning for this <measure> installation? *(11-point scale)*	Influence: Study
How influential was the Production Efficiency Incentive in planning for this <measure> installation? *(11-point scale)*	Influence: Incentive
How influential was the Production Efficiency Program in planning for this <measure> installation? *(11-point scale)*	Influence: Program
At that time, could your budget have accommodated the full cost of the equipment installation without the incentive? *(Yes/No/Don't Know)*	Budget

The PE Small Participant methodology substituted the influence of the vendor for the influence of the technical study as studies were not conducted for the Small Participants.

Methodology

As a starting point for developing the methodology, Energy Trust evaluation staff has used the belief that the key question to be answered is whether the participant was influenced by the program. This is relatively easy to determine if only a few yes/no questions are asked and answers are consistent (e.g., "The program had no influence" and "I would have taken the action if the program had not existed," or "The program had a critical influence on my decision" and "The action would not have taken place without the program"). If a more nuanced approach is used, such as allowing for degrees of influence, providing a "don't know" option or increasing the number and scope of the questions, the calculation becomes more difficult and requires a set of rules and algorithm.

The set of rules and algorithm that Energy Trust has developed use as their basis the *Laplace Criterion*. The *Laplace Criterion* states that "in the absence of any prior knowledge, we must assume that the events have equal probability," assuming, of course, that the events are mutually exclusive and collectively exhaustive.[25] This means that if it is not absolutely clear if the program had an influence on the participant's action or decision, equal odds are given to the outcome that the program had an influence and the outcome that the program did not have an influence. In these cases, the probability of the program having influence is 50% and the probability of it NOT having an influence is 50%. In other words, the participant has a 50% chance of being a free-rider.

The 50% free-rider outcome is only an outcome in a subset of the cases, as both influence and participant intent in the absence of the program might have a range of possible answers. To address all possible outcomes, a set of assumptions was developed that create the framework for calculating unbiased free-rider scores.

- Assumption 1: Respondent is truthful.
    - **Implication 1:** Consistent responses have easily calculated free-rider rates of 0% and 100%.
    - **Implication 2:** Participants that provide inconsistent or contradictory responses are viewed as having answered questions truthfully. With no additional information, both answers are given equal validity.

[25] The *Laplace Criterion* is based on *Bernoulli's Principle of Insufficient Reason* which states that if we are ignorant of the ways an event can occur (and therefore have no reason to believe that one way will occur preferentially compared to another), the event will occur equally likely in any way. Keynes referred to the principle as the principle of indifference, formulating it as follows: "If there is no known reason for predicating of our subject one rather than another of several alternatives, then relatively to such knowledge the assertions of each of these alternatives have an equal probability."

- Assumption 2: Inconsistencies between stated program influence and stated intentions of what would have happened in absence of the program can be resolved. The 2008 Program evaluations will ask participants follow-up clarifying questions when contradictory answers are given.
- Assumption 3: Equal probabilities are given to inconsistent answers.
  - **Implication:** Event probabilities are additive, since the two possible events being considered are "project went through with program influence" and "project went through without program influence."
- Assumption 4: In cases where the answer is "don't know," all of the possible answers have equal probabilities of being true.
  - **Implication 1:** This will create a range of possible free-rider estimates for all participants that answer "don't know" for either the intent or influence questions but provided a valid answer for the other question.
  - **Implication 2:** If no information is available to any of the questions, the observation is not included in the analysis, as it is deemed equivalent to a participant that was not interviewed and thus not included in the analysis.

Assumption 2 might be considered by some as limiting in that it only focuses on the inconsistencies around the influence of the program and the stated intentions of how, if at all, the project would have changed in the absence of the program. Factors such as experience with the program, length of time the project was planned, or experience with energy efficiency are often factored into the free-rider estimation. However, they are not used to resolve inconsistent answers, as their relationship to the project in question is not clear and their inclusion in any weighting scheme or use in adjusting probabilities is not straightforward.

Participation in the program in the past is not sufficient to determine that the project under consideration would have gone through without the program's help, incentives, or studies. Past participation may have involved an end-use technology that has little relevance to the current project. On the other hand, past participation may have involved incentives and other type of program assistance that were needed to move the current project forward. Therefore, past program participation might be a good predictor of future participation, but cannot be considered a clear indicator of free-ridership. Even past experience with the same technology for which no incentive was received may not be a clear indicator that the participant is a free-rider. To make this assumption, the participant's economic conditions and investment criteria would need to remain unchanged, a reasonable assumption for only a short period of time. Over longer periods, economic conditions and investment criteria both change. Also, "comparable" equipment and technologies might not, in fact, be comparable and past experience with the program may not have been positive. For example, installation of additional VSDs through the program would be a sign of program success if the customer had poor experiences with VSDs in the past. Since past participation and past experience do not have a straightforward interpretation without further investigation, their use in calculating free-ridership is inappropriate.

Application

One of the ways that Navigant Consulting modified the Energy Trust methodology was to begin the process with stated intention rather than program influence. In Navigant Consulting's experience, most free ridership methods use stated intention as the bedrock of their free ridership score. This change will have little impact on the final free ridership estimate as state intention and influence are added together to create the unadjusted free ridership score. The 2008 PE Impact Evaluation provides another example of how flexible the Energy Trust scoring algorithm is.

Participant Intention in Absence of the Program

For stated changes in the project in absence of the program, there are three different levels of change:

1. No change in the program measure – would have installed identical measure
2. The program measure would have changed, but retained some energy efficiency features
3. No energy efficient equipment would have been installed

To determine the level of change, participants were asked how the project would have changed in absence of the program. A variety of answers could be given, from "No change," to "Change in scope," to "Postponing the project more than a year" to "Cancelled the project altogether." These answers were then allocated to one of the three options above. Changes that might have retained some of the energy-efficient features of the project were scored at the midpoint, as no reliable information on the efficiency level was available. Table A-2 provides the schema for scoring intent.

Table A-2. Free-Rider Scoring of Stated Intent in Absence of Program

STATED INTENT IN ABSENCE OF PROGRAM	FREE-RIDER SCORE	PROBABILITY ASSOCIATED WITH STATED INTENT	FREE-RIDER RATE ASSOCIATED WITH STATED INTENT
NO CHANGE IN PROJECT	1.00	50%	.50
CHANGE WITH SOME ENERGY EFFICIENCY RETAINED	0.50	50%	.25
SIGNIFICANT CHANGE WITH VIRTUALLY NO PROGRAM ENERGY EFFICIENCY RETAINED	0.00	50%	.0

Program Influence

As stated above, the second question to be answered is whether the program had an influence on the energy efficiency equipment installation. The algorithm is quite flexible and can include multiple program influences and allow for a range of answers for the participant's intent in absence of the program.

Participants rated program influence for three major factors:

4. Incentive
5. Technical Study/Vendor or Contractor
6. Program Assistance In General

The scoring algorithm was changed from a five-point scale influence scale to an eleven-point scale anchored only at the end points. Participants rated each influence on a 0 to 11-point scale, from "critical influence" (10) to "no influence" (0). The maximum value given for any of the three program factors is used as the indicator of program influence. This results in eleven scores that are equally distributed across a potential range from 0 to 10.

Table A-3 provides the schema for scoring program influence.

Table A-3. Free-Rider Scoring of Program Influence

PROGRAM INFLUENCE	FREE-RIDER SCORE	PROBABILITY ASSOCIATED WITH PROGRAM INFLUENCE	FREE-RIDER RATE ASSOCIATED WITH PROGRAM INFLUENCE
10-CRITICAL INFLUENCE	.0	50%	0.0%
9	.10	50%	5.5%
8	.20	50%	10.0%
7	.30	50%	15.5%
6	.40	50%	20.0%
5	.50	50%	25.0%
4	.60	50%	30.0%
3	.70	50%	35.0%
2	.80	50%	40.0%
1	.90	50%	45.0%
0 – NO INFLUENCE	1.00	50%	50.0%

Budget

Participants that reported they would have completed the project without the program were assumed to be free riders. However, participants that reported not having sufficient budget to undertake the specific project would not have been able to undertake the exact project with "no change." They perhaps would be able to undertake the project "partially" or not at all ("change"). Thus, participants that reported both "no change" and "no budget" were treated for the free-rider calculation as if they had reported "partial" change. So, in Table A-3 above, instead of a free-rider stated intent score of 0.50 (corresponding to "no change"), they were assigned a free-rider stated intent score of 0.25 (corresponding to "partial"). These adjustments are shown in the next section for the Production Efficiency participants.

Free Ridership Calculation

With the outcomes of being influenced or not being influenced by the program having equal probabilities, the free-rider rates associated with each outcome are additive. The equation below can be used to calculate the free-rider rate given participant responses and scores:

Free-rider rate =0.5*(program influence FR score) + 0.5*(stated intent FR score)

In cases where information is lacking (e.g., participant stated that they did not know if they were influenced), all of the outcomes associated with that question have equal probability of being true. This will result in the participant having a range for the free-rider rate. The range is estimated for all respondents with indeterminate answers by calculating the maximum and minimum values for each participant. The resulting high and low estimates will then delineate the range of free-ridership. To calculate a program level free ridership rate, each participant must have a specific free ridership score. For these program participants, the high and low estimates are averaged to calculate their score. This algorithm had little impact for the free ridership rates in this study as very few program participants were found in this category.

Table A-4 shows the different permutations of the free-rider rates that are calculated using the above algorithms.

Table A-4. Weights and Free-Rider Rates

STATED INTENT (FROM WHAT WAS DONE)	FR RATE: STATED INTENT	PROGRAM INFLUENCE	FR RATE PROGRAM INFLUENCE	PURE FREE RIDER RATE	BUDGET FACTOR ADJUSTMENT-	ADJ. FREE RIDER RATE
CHANGE	0	10	0.00	0	NOT APPLICABLE TO FREE RIDER CALCULATION	0%
CHANGE	0	9	0.05	5%		5%
CHANGE	0	8	0.10	10%		10%
CHANGE	0	7	0.15	15%		15%
CHANGE	0	6	0.20	20%		20%
CHANGE	0	5	0.25	25%		25%
CHANGE	0	4	0.30	30%		30%
CHANGE	0	3	0.35	35%		35%
CHANGE	0	2	0.40	40%		40%
CHANGE	0	1	0.45	45%		45%
CHANGE	0	0	0.50	50%		50%
PARTIAL	0.5	10	0.50	25%	NOT APPLICABLE TO FREE RIDER CALCULATION	25%
PARTIAL	0.5	9	0.55	30%		30%
PARTIAL	0.5	8	0.60	35%		35%
PARTIAL	0.5	7	0.65	40%		40%
PARTIAL	0.5	6	0.70	45%		45%
PARTIAL	0.5	5	0.75	50%		50%
PARTIAL	0.5	4	0.80	55%		55%
PARTIAL	0.5	3	0.85	60%		60%
PARTIAL	0.5	2	0.90	65%		65%
PARTIAL	0.5	1	0.95	70%		70%
PARTIAL	0.5	0	1.00	75%		75%
NO CHANGE	1	10	0.50	50%	IF THEY HAVE THE BUDGET, NO	50%
NO CHANGE	1	9	0.55	55%		55%
NO CHANGE	1	8	0.60	60%		60%

STATED INTENT (FROM WHAT WAS DONE)	FR RATE: STATED INTENT	PROGRAM INFLUENCE	FR RATE PROGRAM INFLUENCE	PURE FREE RIDER RATE	BUDGET FACTOR ADJUSTMENT-	ADJ. FREE RIDER RATE
NO CHANGE	1	7	0.65	65%	CHANGE IS	65%
NO CHANGE	1	6	0.70	70%		70%
NO CHANGE	1	5	0.75	75%	MADE. IF THEY HAVE NO BUDGET, MAKE THEM A PARTIAL FR (25% TO 75%)	75%
NO CHANGE	1	4	0.80	80%		80%
NO CHANGE	1	3	0.85	85%		85%
NO CHANGE	1	2	0.90	90%		90%
NO CHANGE	1	1	0.95	95%		95%
NO CHANGE	1	0	1.00	100%		100%
DK		10	0.00/.5	25%	NOT APPLICABLE TO FREE RIDER CALCULATION	25%
DK		9	0.05/.55	30%		30%
DK		8	0.10/.6	35%		35%
DK		7	0.15/.65	40%		40%
DK		6	0.20/.70	45%		45%
DK		5	0.25/.75	50%		50%
DK		4	0.30/.80	55%		55%
DK		3	0.35/.85	60%		60%
DK		2	0.40/.90	65%		65%
DK		1	0.45/.95	70%		70%
DK		0	0.50/1.0	75%		75%
CHANGE	0/.5	DK	0	25%	NOT APPLICABLE TO FREE RIDER CALCULATION	25%
PARTIAL	.25/.75	DK	0	50%		50%
NO CHANGE	0.5/1.0	DK	0	75%		75%
DK	NA	DK	NA	NA		NA

Production Efficiency Free-Rider Results

Table A-5 presents the results on a case-by-case basis for the surveyed Production Efficiency participants.

Table A-5. Free-Rider Case Assignment for Production Efficiency

STATED INTENT (FROM WHAT WAS DONE)	PROGRAM INFLUENCE	BUDGET FACTOR ADJUSTMENT-	ADJ. FREE RIDER RATE	2007 CUSTOM PARTICIPANTS (FIRST MEASURE ONLY)	2008 SMALL PARTICIPANTS	2008 CUSTOM PARTICIPANTS
CHANGE	10	NOT APPLICABLE TO FREE RIDER CALCULATION	0%	5	8	6
CHANGE	9		5%	1	2	7
CHANGE	8		10%	1	5	1
CHANGE	7		15%	0	2	0
CHANGE	6		20%	0	1	0
CHANGE	5		25%	0	1	0
CHANGE	4		30%	0	0	0
CHANGE	3		35%	0	0	0
CHANGE	2		40%	0	0	1
CHANGE	1		45%	0	0	0
CHANGE	0		50%	0	0	0
PARTIAL	10	NOT APPLICABLE TO FREE RIDER CALCULATION	25%	6	9	4
PARTIAL	9		30%	3	8	8
PARTIAL	8		35%	1	8	5
PARTIAL	7		40%	0	3	3
PARTIAL	6		45%	0	3	1
PARTIAL	5		50%	0	1	0
PARTIAL	4		55%	0	0	0
PARTIAL	3		60%	0	0	0
PARTIAL	2		65%	0	0	0
PARTIAL	1		70%	0	0	0
PARTIAL	0		75%	0	0	0
NO CHANGE	10		50%	2	3	1
NO CHANGE	9		55%	1	1	2
NO CHANGE	8		60%	1	3	0

STATED INTENT (FROM WHAT WAS DONE)	PROGRAM INFLUENCE	BUDGET FACTOR ADJUSTMENT-	ADJ. FREE RIDER RATE	2007 CUSTOM PARTICIPANTS (FIRST MEASURE ONLY)	2008 SMALL PARTICIPANTS	2008 CUSTOM PARTICIPANTS
NO CHANGE	7	IF THEY HAVE THE BUDGET, NO CHANGE IS MADE. IF THEY HAVE NO BUDGET, MAKE THEM A PARTIAL FR	65%	0	3	0
NO CHANGE	6		70%	0	1	0
NO CHANGE	5		75%	0	0	1
NO CHANGE	4		80%	0	0	0
NO CHANGE	3		85%	0	1	0
NO CHANGE	2		90%	0	0	0
NO CHANGE	1		95%	0	0	0
NO CHANGE	0		100%	0	1	0
DK	10	NOT APPLICABLE TO FREE RIDER CALCULATION	25%	1	0	0
DK	9		30%	0	0	0
DK	8		35%	0	0	0
DK	7		40%	0	1	0
DK	6		45%	0	0	0
DK	5		50%	0	1	0
DK	4		55%	0	1	0
DK	3		60%	0	0	0
DK	2		65%	0	0	0
DK	1		70%	0	0	0
DK	0		75%	0	0	0
CHANGE	DK	NOT APPLICABLE TO FREE RIDER CALCULATION	25%	0	0	0
PARTIAL	DK		50%	0	0	0
NO CHANGE	DK		75%	0	0	0
DK	DK			0	0	0
TOTAL OF COMPLETED SURVEYS				22	67	40

To determine the estimated free-rider rate for the Production Efficiency programs, the gross savings of each participant was multiplied by the measure-specific free-rider rate to calculate net savings. Summing gross and net savings across all participants and then dividing total net savings by total gross savings produces the savings weighted free ridership rate. The unweighted free-rider rate is a simple average of the measure-specific free-rider rates across the sample.

Table A-6. Production Efficiency Program Free Ridership Rates

	FREE RIDERSHIP	NET-OF-FREERIDER RATE
2007 CUSTOM PARTICIPANTS – WEIGHTED	.275	.725
2007 CUSTOM PARTICIPANTS – UNWEIGHTED	.281	.719
2008 CUSTOM PARTICIPANTS – WEIGHTED	.25	.75
2008 SMALL PARTICIPANTS - WEIGHTED	.24	.76

Spillover

Spillover Method

Participants were asked if they had installed any energy-efficient equipment for which they did not apply for an incentive. Spillover rates varied by participant type. Over 50% of Custom participants reported installing energy efficient equipment compared to only 25% of Small participants.

We asked these participants to rate the influence of the program on their decision to install the equipment, using an eleven-point influence scale ranging from "No influence" to "Critical influence." These preliminary results suggest that the program may assume more importance as time passes. The 2008 program participants rated the influence of the program around a "5" rating on the influence scale compared to a rating of "7.00" from 2007 participants.

Table A-7. Spillover and Impact of the Program on Decision to Install Energy Efficient Equipment

	SPILLOVER RATES	IMPACT OF PROGRAM
2007 ENERGY TRUST CUSTOM PARTICIPANTS	57.1	7.00
2008 ENERGY TRUST CUSTOM PARTCIPANTS	65.0	4.88
2008 SMALL PARTICIPANTS	25.4	5.76

Spillover Results

Table A-8 identifies the efficient equipment participants reported installing without an incentive by program and program year. Lighting, motors, variable speed drives, pumps, and compressed air systems were the most reported equipment installed without an incentive. Many of the projects described were custom applications that may or may not have qualified for a program incentive.

Respondents were asked how influential the program was in their decision to install the energy efficient equipment without a rebate using a scale of 0 to 10 where 0 indicated low influence of the program and 10 indicated high influence of the program. The 11-point scale was divided into a high (7-10), a medium (4-6) and a low (0-3) influence category. No strong relationship was found between the type of energy efficient equipment and the level of influence of the Energy Trust PE Program.

Table A-8. Spillover Equipment Installations

STATED EQUIPMENT INSTALLED WITHOUT AN INCENTIVE	LEVEL OF INFLUENCE
2007 CUSTOM PROGRAM	
Lighting, engineered air nozzles, premium efficiency motors	High
Lighting system, 5 ton AC unit VFD	High
Big milling machine	High
Spent in the last two years about $3m for thermal projects that did not receive an incentive. Typically lighting and process control modifications.	High
Lighting and motion sensors	High
Motors and stuff that would be an expense item. Individual replacement parts.	High
VSDs , Process control upgrade, motors, process changes to reduce energy	High

STATED EQUIPMENT INSTALLED WITHOUT AN INCENTIVE	LEVEL OF INFLUENCE
Downstream joint product system.	Medium
Updates to natural gas heaters. Installed low flow and water free toilets and urinals. Stopped air leaks.	Low
VFD drives for different pumps and pumps	Missing
Manufacturing plant. All kinds of equipment. Boiler system and dust collection system.	Missing
2008 CUSTOM PROGRAM	
Drives on boiler fan	High
Compressors, sanders	High
Lighting	High
VFD's	High
High-efficiency burn-out oven	High
Small VFD's	High
EE motors and lighting	High
Pump upgrades	High
Several premium efficiency motors and additional lighting projects.	High
Lighting sensors	High
High-efficiency motors	High
Lighting	High
Motors	Medium
Solar power panels for remote monitoring	Medium
VFD on 500HP motor	Medium
VFD's	Low
Premium motors	Low

STATED EQUIPMENT INSTALLED WITHOUT AN INCENTIVE	LEVEL OF INFLUENCE
Remote control for vacuum pumps	Low
Lighting	Low
Lighting	Low
Lighting and compressed air	Low
Dust collector	Low
Lighting and other minor jobs	Low
High efficiency motors	Low
Motors	Low
Premium efficiency motors	Low
2008 SII PROGRAM	
Same equipment	High
Took out one out of three light bulbs because this program got us started.	High
Electrical soft-starts. Like giant capacitors. Reduces power sags.	High
New motors- always replace with more energy efficient equipment	High
More lighting	High
Electric motors that had to be replaced and we went with an efficient model.	High
Lighting	High
Incorporated energy elements in our new building	High
Soft starter- variable speed drive for 50 hp motor	Medium
unsure - air conditioners, heaters	Medium
Idle timers on our trucks.	Medium
Motor - 150 hp	Medium
Installation, generators,	Medium

STATED EQUIPMENT INSTALLED WITHOUT AN INCENTIVE	LEVEL OF INFLUENCE
Motors	Medium
Low maintenance forklift battery, LED lights	Low
More lighting. T5 in just one area.	Low
Motors, controls, many things.	Low

Findings from Previous Evaluation

The current study addressed a number of ways to improve the free rider methodology that were identified in the previous study. They included a method for accounting for inconsistent answers, an expansion of the range of answers for the influence questions and providing measure-specific free ridership estimates. Each of these issues is discussed here.

Inconsistent Answers

Asking clarifying questions when inconsistent answers are given to free-rider questions has also been suggested as a way to arrive at a consistent result.

Navigant Consulting implemented a consistency check in the 2008 Custom Participant and 2008 Small Participant surveys when the free ridership intent questions and the influence questions did not agree with each other. There are three ways to use a consistency check.

1. If an inconsistency is found give the respondent an opportunity to correct it by modifying their earlier answers.

2. Use the consistency check in the algorithm – that is calculate a free rider rate then adjust it up or down if the consistency check shows inconsistent answers.

3. Use the consistency check to help indicate whether the final result is more likely to err on the high side or the low side.

In most cases, the inconsistency was detected when the customer reported they would have installed the energy efficient equipment at the same time and that the program had a significant influence on their decision. The inconsistency was pointed out to the customer and they were asked to explain their answers. Respondents were allowed to change their answer if they asked but they were not prompted to do so (option 1 above). Given the desire to maintain reasonable consistency with prior implementation of the free rider approach, option 3 was used.

For the Custom and Small Participants, most of those answering the consistency question gave answers that supported a low free rider rate. However, among those with the highest free rider rate and inconsistent answers, most of the answers to the open-ended consistency question were reasonably aligned with the free rider rate (that is the answer indicated that the measure would have been installed without the program). Although the consistency check tracked well to the free ridership scores using option 3, in future surveys, using the consistency check in the algorithm (option 2) is recommended.

Greater Range of Answers

Providing a greater range of possible answers, such as an 11-point influence scale or a percent efficiency reduction might provide a more realistic, continuous range of free-rider estimates, rather than the step-like found in the last evaluation.

Navigant Consulting implemented this change to all the surveys. For all influence questions, such as the following example, respondents were asked to provide a rating from "0 where 0 means no influence to 10 where 10 means a critical influence." In recent years, it has become a generally accepted standard in the industry that eleven point scales have some advantages over five point scales, especially for gauging customer satisfaction. An eleven point scale makes more intuitive sense to the respondent than a five point scale.

> **How influential was the Production Efficiency incentive in planning for the lighting improvements?**

Measure-Specific Free-Rider Rate Estimation

Energy Trust's approach has typically been to survey a sufficient number of participants that have installed each of the measures of interest. Instead of repeating the same questions for each type of equipment installed, the free-rider questions are asked once. In the future, Energy Trust anticipates that we will experiment with a variety of approaches to test what methods best capture measure-specific data.

All program participant surveys were changed to incorporate a specific measure of interest. For the 2007 survey of program participants, respondents were asked about two measures when they reported that different decisions making criteria were used. The 2008 Custom Survey and the 2008 SII Survey, project sites were randomly selected and measures were selected within the site with preference shown for measures with larger savings and non-lighting measures.

Appendix B: Site-Level Energy Savings Evaluation Summaries

4.6 Site 1

Site 1 consisted of a production facility for the manufacture of clothing. The site is approximately 150,000 square feet. The space is divided into an office area, a production floor and a warehouse space within a single building. All lighting renovations were completed prior to the building's occupation by the current tenant. The base system was not in use with the current operational characteristics.

Base System

In the warehouse areas, the original site lighting consisted of 113 high output 8-foot 2-lamp T-12 light fixtures. The production area base system was a combination of 86 8-foot 2-lamp T-12 light fixtures and 35 400 watt metal halide lights. The base system lights in this area are assumed turned off during closed hours. This assumption was made in the original savings estimates. However, it should be noted, that many similar warehouses make a different assumption. It is common practice to assume warehouse lights are not manually turned off and remain lit 24 hours per day.

Office areas had 4-foot 4-lamp and 2-lamp T12 lights as well as incandescent lights. Restrooms had incandescent lights.

The application indicated 5,134 hours of operation annually in all areas, corresponding to 19 hours per day Monday through Friday and 6 hours per day on Saturdays with holidays observed throughout the year. Facility personnel indicated that these hours are correct and that the lights are not manually turned on or off during the workday. These hours were used as a base case for both the estimated and calculated savings.

Project Measures

In the production and warehouse areas, previously existing high output T12 lights were removed and replaced with 4-lamp T8 fixtures on a nearly one-for-one basis. The previously existing metal halide lights were removed and not replaced. The production and warehouse fixtures were installed with occupancy sensors. For safety, 6 fixtures in the production area do not have sensors but remain on at all times. Estimated savings were based on Energy Trust of Oregon's lighting worksheet, which assumes occupancy sensors result in a 25% reduction in hours, yielding 3850.5 hours annually.

In office areas, 26 watt CFLs and 2-lamp 4-foot T8 lamps were installed in place of the incandescent and T12 fixtures.

In the restrooms, 26 watt CFLs and 2-lamp 4-foot T8 lamps were installed in place of the incandescent lights. Additionally, occupancy sensors were installed in restrooms. Estimated savings were based on Energy Trust of Oregon's lighting worksheet, which assumes occupancy sensors result in a 25% reduction in hours, yielding 3850.5 hours annually.

Measurement & Verification Methodology

During the site visit, NCI personnel counted the new light fixtures. Site personnel were interviewed to verify that the installation was a one-for-one replacement of previously existing fixtures, when reported. Measurement and Verification protocol IPMVP Methodology Option B was employed to determine the savings due to occupancy sensors. Onset HOBO on/off lighting data loggers were installed next to twelve randomly selected high bay fixtures for a period of four weeks. Data collected from lighting loggers indicates an actual reduction of 25% based on a 5,134 hour baseline.

Standard wattages used in the Energy Trust's lighting worksheets were used along with occupancy data to calculate energy use, baseline, and savings. These wattages are summarized in Table D- 1.

Table D- 1. Site 1 Lighting Fixture Wattages

Fixture	Standard Wattage
400W Metal Halide Fixture	461 W
2-Lamp 8' T12 HO Fixture	207 W
4-Lamp 4' T12 Fixture	144 W
4-Lamp 4' T12 Fixture	72 W
4-Lamp 4' T8 Fixture	108 W
2-Lamp 4' T8 Fixture	54 W
26 W CFL Hardwired Fixture	33 W

Evaluation Results

All of the fixtures listed on the application were confirmed at the site. The overall project at Site 1 realized 97% of expected kWh savings, as shown in Table D- 2.

Table D- 2. Site 1 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Lighting retrofit	244,691	238,256	97%
Occupancy sensors	26,212	25,392	97%
Total	**271,103**	**263,648**	**97%**

Minor differences between the estimated and verified savings were due to emergency lights being neglected from the original estimate as well as high wattage estimates for the removed 4-foot T12 lamps. The occupancy sensor study confirmed the original assumption of 25% savings was very close to reality. It was found that the occupancy sensors reduced lighting hours by 23% in the production area and by 25% in the warehouse area.

4.7 Site 2

Site 2 is a produce freezing facility and frozen food warehouse. The site received incentives for 7 energy efficiency measures (EEM) listed in Table D- 3. The facility has 4 refrigeration compressors with ammonia refrigerant. Two compressors are sized to serve the blast cells which operate at -35°F to quickly freeze fresh produce. Two compressors are sized to serve the freezer/frozen food warehouse. The blast cells mostly operate between July and September as fresh produce is brought in from the fields and orchards. The freezer/warehouse operates year-round to store product and as a transfer point for frozen products.

Table D- 3. Site 2 Project *Ex Ante* Savings

EEM ID	Measure	Project ID	kWh	Incentive	% Site Savings
EEM 1	Split Suction with Controls	0519	1,497,208	$ 15,298	59%
EEM 3	Compressor VFD Freezer (-20°F)	0519	70,785	$ 8,651	3%
EEM 4	Compressor VFD Blast (-35°F)	0519	21,213	$ 0	1%
EEM 5	Condenser Fan VFD	0519	48,380	$ 7,257	2%
EEM 6	Freezer (-20°F) Evaporator Fan VFD	0519	707,400	$ 31,274	28%
EEM 7	Blast (-35°F) Evaporator Fan VFD	0519	100,613	$ 12,207	4%
EEM 8	Fast Acting Doors	0519	105,419	$ 9,295	4%
	Total		**2,551,018**	**$ 83,982**	

The bulk of the project savings comes from two measures: EEM1 Split Suction Controls and EEM6 Evaporator fan motors. These measures are the focus of our evaluation analysis, though the installation of all measures was confirmed while on-site.

Base System

The project is new construction so there is no pre-installation data or system to analyze. The facility was built in 2008, and has operated through two harvest seasons. Two-shift operation occurs July through September when the blast cells are active to freeze fresh produce rapidly. During the remainder of the year the blast cells do not operate and the freezer portion of the facility maintains frozen produce and is a transfer warehouse for previously frozen produce.

In the baseline the refrigeration system consists of a single -35F suction system with 3 ammonia compressors, one condenser, 5 freezer evaporators and 3 blast cell evaporators. Two of the compressors would be able to handle most peak loads with the third providing redundancy and peaking capacity.

Project Measures

Each of the project measures are describe below.

EEM1: Split Suction with controls – This measure installs four smaller compressors and splits the refrigeration duties between the freezer (two 250 HP compressors) and blast cell (two 200 HP compressors) operations. An oversized condenser is also installed to reduce peak head pressures. In this configuration, improved blast cell operation can be implemented, and the freezer system can be operated at higher suction temperatures improving overall efficiency. The systems also remain linked so that one compressor can serve both functions simultaneously under appropriate load conditions. Also compressors from either system add redundancy to machines serving the other system. The EEM also includes more sophisticated controls to optimize the use of the installed equipment.

EEM3 and EEM4: Compressor VFDs for freezer and Blast Cell Lead Compressor – These measures improve the part load performance of the ammonia refrigeration compressors. In general a VFD modulated system approximates a linear response between power and load (stable kW/ton performance) down to 30% loading whereas a traditionally modulated system performance becomes significantly worse at low loads (about 50% power at 30% load). The VFD modulated machines will be the lead machines until full load and then they operated as the 'trim' machine with the constant speed compressor supplying base capacity in its efficient range.

EEM5: Condenser Fan VFD – This measure installs VFDs on condenser fans in place of on-off cycling of fans. Variable speed control creates more stable operation and saves energy due to affinity law relationships between condenser airflow and power.

EEM6 and EEM7: Evaporator Fan VFDs for Freezer and Blast Cell– These measures install VFDs on all evaporator fans in place of on-off cycling of fans. Variable speed control creates more stable operation and constant temperatures in the freezers and blast cells and saves energy due to affinity law relationships between evaporator airflow and power.

EEM8: Fast Acting Doors – Theses doors have a faster cycle time (9.2 seconds) than traditional bay doors (31 seconds). Reducing the time the bay doors are open decreases the external loads that must be met by the refrigeration system.

Measurement & Verification Methodology

During the site visit, Navigant Consulting personnel discussed the use and operation of the equipment with facility personnel to determine operational parameters of the systems. We visually inspected and verified that the project equipment was installed and operating. We discussed the automation systems and trend data capabilities and the history of stored data. We also took spot measurements of compressor, evaporator and condenser fan power and installed true RMS power data loggers on the same equipment to monitor operations over more than 2 weeks. Furthermore, the customer provided one full year of 15-minute interval trend data from the automation system for our analysis. These data were compared to operating assumptions in the Energy Analysis Report (EAR).

For the compressor measures, we reviewed the estimation methods used in the Energy Analysis Report and compared trend and logged data to that analysis. Our research occurred in January 2009 during the non-peak season when the blast cells were not operating and the freezer loads were among the lowest of the annual cycle. Inspection at this time allowed us to confirm operations during low loads when actual operation differed significantly from that assumed in the EAR.

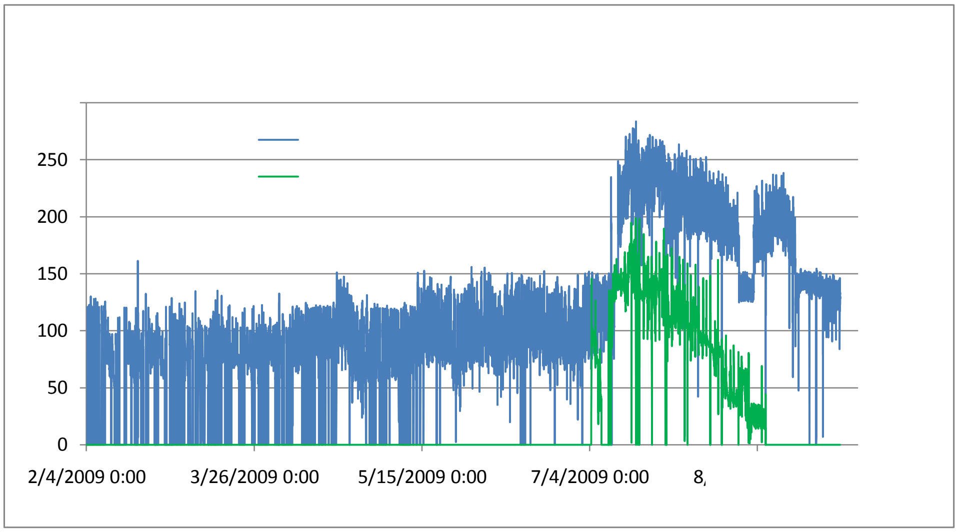
For the fan VFD measures we used measured and trended data to enhance engineering models that estimate power use at reduced loads.

Evaluation Results

The calculations included in the Energy Analysis Report (EAR) are rigorous and accurately constructed based on manufacturer performance data and hourly refrigeration models. Navigant Consulting reviewed these calculations and compared them to actual data collected by the automation system. Significant findings or differences that affect savings are noted below.

EEM1 –The EAR assumes at least one compressor runs at all times. In practice, the facility manager can and does turn off all compressors for periods of time. As a result the run hours for all compressors are less than predicted, especially when at low loads when savings would be higher. The Facility Manager reports that baseline equipment would have been operated in a similar fashion, with periods of no compressor operation; therefore, the savings are reduced for this measure. Figure D- 1 shows frequent compressor shutdown during cooler months.

Figure D- 1. Refrigeration Load (tons) for both -20˚F and -35˚F systems



EEM3 & EEM4 – The Compressor VFDs are performing as expected. The plant manager has changed the operations somewhat to run compressor #3 (250 HP blast cell service) more hours than planned. In doing so he minimizes the need to run a second machine when loads are generally low. This strategy results in fewer hours for compressor #2 and fewer overall operating hours as noted above, thus the measure savings is reduced from ex ante estimates. Furthermore, after the compressors have been off for a period they must operate at higher loads to recover. As a result there are fewer low-load hours when savings is the greatest, and measure savings is lower for EEM3 and EEM4.

Navigant Consulting notes that though the anticipated *measure* savings is lower for the first three measures, the plant manager is saving more energy *overall* by turning equipment off when loads permit. Lower measure savings reflect that he would have operated the facility in a similar fashion with or without the split suction lines or VFDs.

EEM5 – Due to low anticipated savings, Navigant Consulting performed less analysis for this measure. Condenser fan power generally tracks compressor power. Trend data show that the condenser fans do modulate and maintain target efficient head pressures on the systems, however due to reduced compressor run time, we estimate condenser fan VFD savings is proportionally lower.

EEM6 and EEM7 – Trend data show that evaporator fans stage and modulate as designed. In fact, the modulation range is greater than estimated in the EAR. EAR calculations assume that minimum freezer evaporator fan speeds are 50% of rated. In fact, the minimum speed is 40% and the fans operate many hours between 40% and 50%. Slower fan operation reduces energy use. Blast cell evaporator fan trends show operation as planned in the EAR (75% minimum). All fans are limited to 90% of full flow on the high end to improve savings.

EEM8 – Due to low anticipated savings, Navigant Consulting performed less analysis for this measure. Speed doors were observed, but the cycle times were not a brief as planned in the EAR. The cycles were increased somewhat (to about 12 seconds) to accommodate movement of product. Early problems with un-intentional triggers were addressed by re-aiming sensors.

Navigant Consulting shows ex ante and verified savings estimates in Table D- 4.

Table D- 4. Site 2 Estimated & Evaluated Savings

EEM ID	Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
EEM 1	Split Suction with Controls	1,497,208	1,249,322	83.4%
EEM 3	Compressor VFD Freezer (-20°F)	70,785	68,541	74.5%
EEM 4	Compressor VFD Blast Cell (-35°F)	21,213		
EEM 5	Condenser Fan VFD	48,380	40,370	83.4%
EEM 6	Freezer (-20°F) Evaporator Fan VFD	707,400	738,526	104.4%
EEM 7	Blast Cell (-35°F) Evaporator Fan VFD	100,613	100,613	100.0%
EEM 8	Fast Acting Doors	105,419	91,044	86.4%
	Total	**2,551,018**	**2,288,415**	**89.7%**

The plant manager does not report significant production variation due to the economy. Navigant Consulting does not recommend any savings adjustments due to the economic conditions over the past several years.

4.8 Site 3

Site 3 was a new 133,000 square foot warehouse with 94,000 square feet of refrigerated space. Refrigeration operation is continuous, 8,760 hours a year, with no shutdown periods, although employee occupancy is only typically 16 hours a day, seven days a week.

Base System

Multiple measures were implemented at this site: an efficient ammonia refrigeration system, VFDs on fan motors and high-bay T5 high-output lights with occupancy sensors. Since this is a new facility, the base system is the system that could be expected to be installed using standard practices without taking efficiency into account.

A large refrigeration system is required to cool much of the warehouse area and a cold dock. A liquid-injection, oil-cooled ammonia refrigeration compressor with a slide valve is available in the same capacity from the same manufacturer as the system that was installed and is used as the base case compressor. A single condenser fan on an evaporative condenser and twelve evaporator fans complete the refrigeration system. In the base case all of these fans would be constant speed units with mechanical time clocks on the evaporators and mechanical pressure switches controlling the condenser fan. There would be no zone specific evaporator cycling in the system.

The facility uses a large number of high bay lights. Similar facilities use a combination of 150 and 400 watt metal halide fixtures without occupancy sensors in such cases. Under these circumstances metal halide lights would be expected to remain on continuously, 8,760 hours per year.

Project Measures

The facility installed 278 T5HO fluorescent high bay fixtures with occupancy sensors on each unit in place of the HID fixtures.

An efficient thermosyphen oil-cooled ammonia compressor with a variable speed drive was installed as the primary refrigeration unit for the warehouse. Variable frequency drives were installed on the condenser fan and all twelve of the evaporator fans.

Measurement & Verification Methodology

During the site visit, Navigant personnel discussed the operation of the refrigeration and lighting equipment with facility personnel. Spot measurements of compressor and fan power were taken during the visit and current or power logging equipment was installed on the compressor, fans, and some of the lighting power feeds in the warehouse areas. The lighting current was logged to determine how much savings the occupancy sensors were providing. All of the loggers operated for a period of one month.

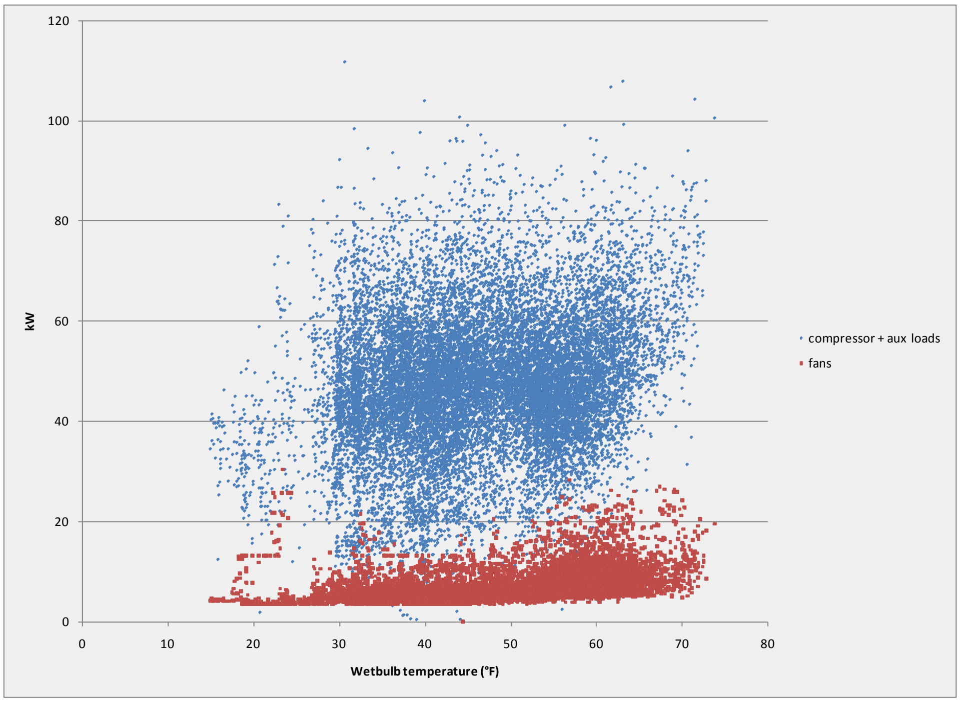
The loggers on the lighting power feeds monitored one-third of the lights in two of the three warehouse areas. The third warehouse area was very similar to the first and so the results were used for both areas. One of the loggers included a docking area which was expected to have significantly higher usage than the storage sections of the warehouse.

In addition to the devices installed by the evaluation team, the facility tracks power consumption for both the overall facility and most sub-areas, including offices and the warehouses. The compressor room, including all of the refrigeration equipment, is the only area not separately monitored, but energy use of the refrigeration system can be determined by subtracting the other areas from the facility total power use. Logs for instantaneous power usage, on a half hourly basis, were obtained for the year preceding the site visit, from December of 2008 to December of 2009. The facility also logs fan speeds and outside air temperature and humidity, and these data were obtained along with the power data. The compressor room loads include: the refrigeration compressors, condenser and evaporator fan variable frequency drives, and some auxiliary loads such as lighting.

Because both the compressor and fans were running significantly under-loaded during the site visit, the spot measurements of fan power cannot be reliably used to provide constants for the affinity law to estimate fan power based on trended speed data. Rather, Navigant Consulting estimated fan power using 30-minute speed data for each fan, rated horsepower, assumed 70% loading at full speed, 89% motor efficiency, 95% drive efficiency and a fan affinity law exponent of 2.5.

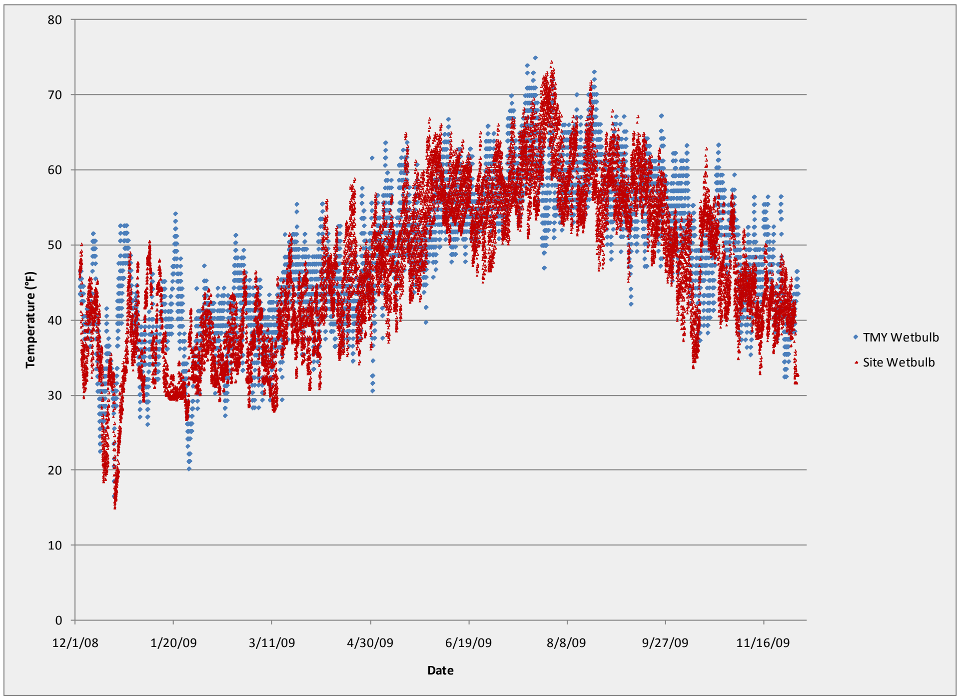
Navigant Consulting expected to see compressor and fan loads vary due to outdoor air conditions – temperature and humidity. As seen in Figure D- 2, the relationship between compressor and fan power and outdoor wetbulb temperature is fairly weak (Pearson coefficient $R^2<0.1$ for a linear relationship). Therefore, the annual data provided by the facility was determined to be more appropriate for analysis of compressor operation than extrapolating the monthly of data obtained during December and January with onsite logging. Although compressor and fan power increase with wetbulb temperature, there is no solid trend that can be reliably use to predict operation based solely upon outside conditions.

Figure D- 2. Site 3 Refrigeration Loads as Related to Wetbulb Temperature



If a stronger correlation with outdoor air conditions existed, measured data could be normalized to a typical meteorological year (TMY), for both a baseline and expected operation. The low correlation indicates that the warehouse is well insulated with minimal infiltration and that operational conditions have a greater affect on usage than weather. Nevertheless weather will have an effect and it is not reasonable to use overall average values for calculations. Because of the high degree of uncertainty in predicting usage based upon wetbulb or drybulb temperature, the actual trend data were used to characterize current refrigeration loads and refrigeration system power, and manufacturer's compressor data for operating setpoints equivalent to actual operation were used to predict operation of the baseline system for each time interval in the trend data set. The evaporator fans were assumed to be running full speed in the baseline condition if they were on during the measurements. If they were off, they were assumed to be off in the baseline as well. The condenser fan was assumed to require a fairly constant amount of use, so the overall airflow (based on fan speed) was used to calculate the equivalent full speed run-time for the year to provide a baseline. This method reliably estimates savings for the monitored year. In order to assert the monitored year savings is typical, we compared the measured year data to the typical meteorological year in Figure D- 3. Indeed, the range of temperatures and the variation are similar between the data sets, and so the use of measured data to determine savings is considered reasonable.

Figure D- 3. Site 3 Wetbulb Temperature and TMY Wetbulb Temperatures



Evaluation Results

The cold storage lights were found to operate only 40% of the time during the evaluation period. The dock area lights remained on more of the time, and 60% operation was estimated for luminaires based on data logger data. The dry storage warehouse lights remained on 93% of the time during the evaluation period, so only a maximum 10% reduction was used for these luminaries. Our 10% reduction reflects that the circuits monitored during the evaluation disproportionately included docking areas and the remaining areas would have slightly fewer operating hours. These measurements and estimates result in total annual lighting usage of 422,975 kWh. This estimate compares favorably with the trend metering data in warehouses and other non-office areas. The metering data showed a total use of 451,275 kWh during the year, which also includes some auxiliary loads such as computers and battery chargers in the areas. The evaluated lighting profile with the T5HO fixtures was compared with the baseline system predicted energy use, and Navigant determined total lighting savings of 687,688 kWh/year, 18% higher than the original estimate.

The variable speed drives on the evaporator fans were found to save 316,400 kWh/year, while the condenser VFD reduced usage by 14,387 kWh/year since it was assumed to be off much of the time in the base case due to historic low loading. Navigant Consulting calculated that the thermosyphen oil compressor with VFD saves 412,226 kWh/year. The combined refrigeration system savings is 743,013 kWh, or 57% of the predicted savings. The primary reason for the low refrigeration realization rate is that the system was designed oversized to allow for warehouse expansion, but currently is running only about 20% loaded on average. If the warehouse is eventually expanded the savings versus the baseline will increase.

Table D- 5. Site 3 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
T5HO High Bay Lights	584,447	687,688	118%
Ammonia Refrigeration	1,294,174	743,013	57%
Total	**1,878,621**	**1,430,701**	**76%**

4.9 Site 4

Site 4 is the transmitter for a television station. The site includes a vacuum-tube transmitter tower as well as supplementary equipment and electronics. It transmits continuously 24 hours a day, 365 days a year. The station needed to upgrade their transmitter to comply with the new digital television standard in 2008. The transmitter system includes two vacuum tubes, called transmitters, an exciter with two power feeds, and a fan-based cooling system.

Base System

The transmitter in place prior to this project was an analog transmitter and so is not treated as the base system. There are several digital transmitters available, and a standard IOT digital transmitter was used as the baseline. These units have been installed elsewhere for digital upgrades.

During the initial study electricity use at a 40 kW IOT transmitter at another television station was measured and compared to listed specifications. This unit listed power consumption between a typical usage of 129 and a maximum usage of 153 kW. The week of monitoring showed a tube used 66.3 kW. A transmitter uses two tubes, which would total 132.6 kW, 3% higher than the published typical usage. Based on this, the published data for typical usage is believed to be reasonable.

The manufacturer's rating for a 50 kW IOT transmitter, the equivalent of the transmitter at site 4, is a typical usage of 154 kW and a maximum usage of 181 kW. Based on the test of the 40 kW transmitter, the manufacturer's rating of 154 kW was taken as a baseline. This usage includes two tubes, but not the amplifier nor the cooling fans, which are basically the same for both transmitters.

Project Measures

The station installed a new 50 kW output digital transmitter. This MSDC unit has a rated typical power consumption of 93 kW and a maximum rated usage of 103 kW. The exciter and cooling equipment were basically the same as they would have been with the baseline transmitter, although some decrease in cooling needs was expected due to the reduced heat output from the lower power tubes.

Measurement & Verification Methodology

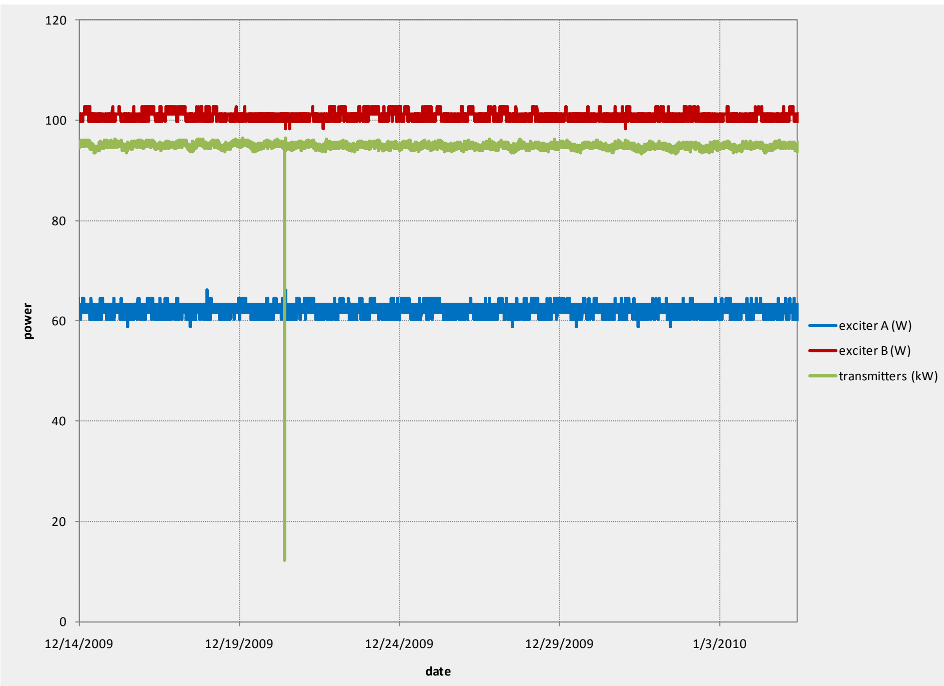
IPMVP option B was utilized at site 4. During the site visit Navigant Consulting measured the transmitter operation over a period of three weeks. Power use by the exciters were also measured and a spot measurement was taken of the cooling fans for the unit. The operation of the station was discussed with station personnel. As expected, the system operates continuously. A few hours a year of downtime for maintenance do not significantly impact system usage.

Evaluation Results

The average power consumption of the two transmitter tubes was found to be 94.9 kW over the logging period. This is slightly above the rated typical consumption of 93 kW. As shown in Figure D- 4, the transmitter's power consumption is steady over time. A brief drop in power of both transmitter tubes occurred at midnight on December 21st and corresponds to a maintenance period.

The two cooling fans used about 1.5 kW when on, however it was difficult to determine the runtime of these units as their usage would likely vary with weather and the logging period was too short to accurately gauge this. Based on observations during the site visit, the fan units appeared to be running around 50% of the time. Since the transmitters use 62% of the power of the baseline units, a similar decrease in cooling is expected. This would correspond to an additional savings of only 1.97 kWh annually, a negligible percentage of the overall usage.

Figure D- 4. Site 4 Transmitter and Exciter Power



The exciters use only 163 W, or 1,430 kWh per year. This is expected to be very close to the usage in the baseline system. As such any savings in either the cooling fans or exciters is within the margin of error of the evaluation. The exciters and cooling fans were not included in savings because of the difficulty of accurately assessing a baseline. However, these comprise significantly less than one percent of system power usage and would not affect the overall realization rate, within the margin of error of this calculation.

Table D- 6 shows the realization rate at site 4 is 97.5%. The steady running state of the transmitter allowed for an estimation which NCI found to be accurate.

Table D- 6. Site 4 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Efficient Digital	531,432	517,988	97.5%

Transmitter			
Total	**531,432**	**517,988**	**97.5%**

4.10 Site 5

Site 5 is a corporate office campus with a computer server farm. The site received incentives for an upgrade of server equipment that uses less energy directly (for the same computational and storage capacity) and also reduces cooling loads at the facility, thus having indirect energy impacts.

Table D- 7. Site 5 Project *Ex Ante* Savings

Measure	kWh	Status
Server upgrades	3,234,671	Operational
Total	**32234,671**	

Base System

The baseline equipment capacity for the server upgrade project is normalized on the unit, MIPS (Meaningful Indication of Performance per System). Three thousand one hundred and forty-eight (3148) old servers were replaced with 448 new IBM servers with equivalent total MIPS. The 1 for 7 server replacement ratio also frees up significant room in the server farm and reduces cooling loads for the equipment. The baseline equipment was a mix of machines from different manufacturers. The customer performed pre-installation spot measurement of existing equipment to determine baseline power consumption.

Project Measures

The replacement servers were IBM x3450 servers and HP BL460 servers. The replacement machines are similar in MIPS rating and differ insignificantly in tested power. Because of their significantly higher MIPS, each new server replaced 7existing machines. No other modifications were made at the facility at the time of this project. Since implementation more servers have been added increasing the overall server farm capacity.

Measurement & Verification Methodology

During the site visit, NCI personnel discussed the use and operation of the servers with facility personnel to determine operational parameters of the systems. We visually inspected and verified that the project equipment was installed and operating. We also performed spot measurements and installed amp data loggers on one server rack for 20 days. The rack contains 40 of the new servers plus one switch. The switch power draw is only 100W.

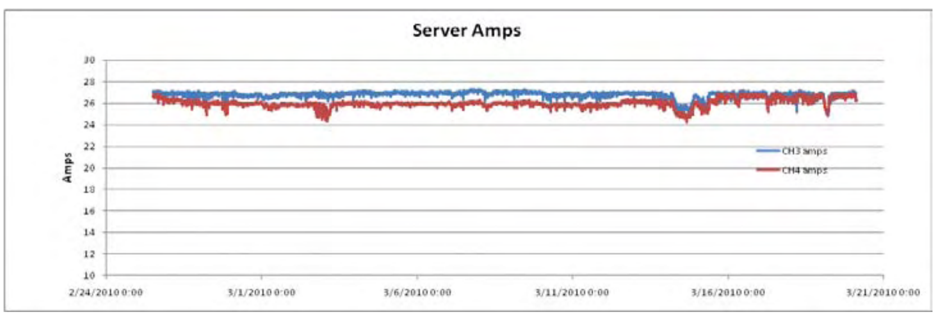
We also confirmed configuration and type of chilled water system that cools the server farm equipment year-round.

Evaluation Results

Facility personnel confirmed that the servers operate continuously 24/7. Since the time of the project additional equipment has been installed on-site with a net increase in system capacity. In general, server upgrades occur on a continual basis, as needed, and new equipment continues to deliver more MIPS / Watt.

NCI installed data loggers on 4 of 6 circuits serving a rack of 40 servers. The Amps on the trended circuits were consistent with spot measurements. Figure D- 5 shows the trend data for two data logger channels. As anticipated the current draw of this equipment is fairly constant with no discernable diurnal variation. The other monitored circuits are very similar.

Figure D- 5. Site 5 Server Rack Amps



After accounting for the switch, NCI estimated average server power was 442 Watts per server. This result is somewhat higher than the *ex ante* estimate; therefore, the verified savings is somewhat lower. The chiller water plant equipment is consistent with the overall 3.5 COP estimate for secondary energy savings from reduced system cooling.

Table D- 8 shows the savings results.

Table D- 8. Site 5 Estimated & Evaluated Savings

Measure	Estimated Savings	Verified Savings (kWh)	Realization Rate (%)

	(kWh)		
Server upgrades	3,234,671	2,820,800	87%

Navigant Consulting does not recommend any savings adjustments due to the economic conditions over the past several years.

4.11 Site 6

Project site 6 is a distributor and processor of metals. The site operates 24 hours a day, 365 days a year. The compressed air system operates continuously during these hours; however it runs at a lower capacity on the weekends.

Project site 6 installed a new 100 horsepower (HP), variable frequency drive (VFD) screw compressor that was intended to replace three older compressors totaling 100 HP.

Base System

Project site 6's pre-installation compressed air system consisted of three air compressors shown in Table D- 9.

Table D- 9. Pre-Installation Pump Summary

Compressor/Dryer Number	Make/Model	Rated ACFM/HP	Controls
1	Sullivan-I8I990M	160/40	Modulation
2	Sullivan-W044279	120/30	Modulation
3	Sullivan-S09750380	120/30	Modulation w/ Unload

Operation of compressors 1 and 2 was required at all times to meet the facility air demand, whereas compressor 3 was constantly running, but did not usually contribute to the compressed air output. The baseline assessment found that compressor 3 drew, on average, 10 kW of power; this value is much less than the 60% full load capacity value of the modulation compressor implying that it was unloaded. All three compressors operated at 115 psig.

Project Measures

Project site 6 installed a new 100 HP, variable speed drive screw compressor (Atlas Copco – GA75VSD-FF) designed to replace the existing three pre-installation compressors. The new VFD compressor was expected to adjust its speed to match compressor output to system demand. Energy savings were expected to accrue from the new compressor's ability to follow the variable flows closely with variable kW consumption.

The project was completed in December 2008.

Measurement & Verification Methodology

On-site verification activities were conducted on December 8, 2009 and consisted of the following activities:

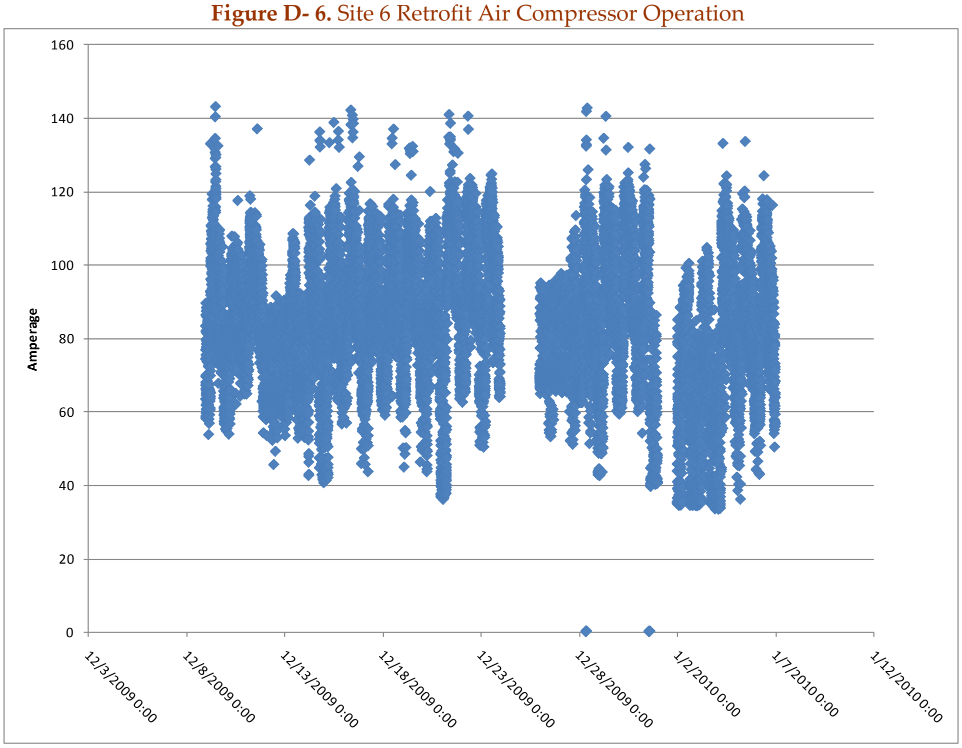
3.) A visual confirmation of the new 100 HP, variable speed air compressor.
4.) Spot measurements and current logger deployment on a census of the air compressors.
5.) Assessment of post-installation compressed air system operating characteristics.
6.) Confirmation of baseline equipment and operating patterns through discussions with facility personnel.

Discussions with project staff regarding system baseline consumption were consistent with the initial assessment and project verification reports. In the absence of primary energy consumption data for the baseline system, the evaluation team reviewed the power, pressure, and flow measurements collected over a one week period through the review's initial assessment. These results were deemed representative of the *expected* baseline system operation, and the annual energy consumption values were accepted for evaluation purposes (530,394 kWh/year).

However the post-installation operating conditions, including the compressed air system configuration at project site 6, differed significantly from the original projections. Specifically, site 6 chose to operate the both the baseline compressed air system and the 100 HP, variable speed air compressor in unison to support increased production. In light of this information, all four air compressors were metered for a 28 day period and the revised system annual energy consumption values were calculated by extrapolating the end-use metered results to an entire year's production schedule.

Figure D- 6 shows the logged demand profile for the retrofit air compressor.

Figure D- 6. Site 6 Retrofit Air Compressor Operation



Because of the change in compressed air needs at site 6, Navigant Consulting chose to calculate savings for two different system configurations:

7.) Configuration 1: Replace the three baseline air compressors with (1) 100 HP, VFD compressor as originally planned. In this scenario, the baseline energy consumption values from the initial assessment report were accepted and manufacturer performance curves for the 100 HP, VFD compressor were used to estimate the annual energy consumption for the replacement compressor under similar air demand conditions. The difference between the base and retrofit annual energy consumption represented the project level savings for this scenario.
8.)
9.) Configuration 2: Extrapolate the end-use metered results for the 100 HP, VFD compressor, along with the existing three baseline compressors to estimate annual post installation energy consumption under the current operational conditions. In the absence of a definitive baseline, Navigant Consulting assumed that site 6 would have otherwise installed an equivalent non-VFD compressor with modulated airflow.

Drawing upon manufacturers' performance curves, the difference in annual energy consumption between the VSD and non-VSD air compressor configurations was taken to be the project level savings for this scenario.

Evaluation Results

Consistent with the project verification report, the originally planned configuration (1) yielded a realization rate of 107%. Navigant Consulting finds no issue with this result as the operating conditions under this scenario are identical between the base and retrofit case.

The current configuration (2) yielded annual savings of 119,298 kWh. The realization rate of 63% is not particularly unexpected for this scenario as the original "estimated savings (kWh)" are not representative of the site operating conditions and final system configuration.

Table D- 10. Site 6 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Configuration 1: Replace baseline system with 100 HP, variable frequency drive (VFD) compressor	188,728	202,567	107%
Configuration 2: Install 100 HP, variable frequency drive (VFD) compressor instead of a non-VFD equivalent	188,728	119,298	63%

4.12 Site 7

Site 7 is a designer, developer, and manufacturer of semiconductors. The site operates 24 hours a day, 7 days a week, 365 days/year.

Site 7 installed a new 200 horsepower (HP), variable speed air compressor with a new blower purge desiccant dryer.

Base System

Site 7's existing compressed air system is characterized in Table D- 11:

Table D- 11. Pre-Installation Equipment Summary

Number	Equipment Type	Make/Model	Rated ACFM/HP	Controls
1	Compressor	Atlas Copco ZR4-67	1400/350	Load/Unload
2	Compressor	Sullair DW13	801/200	Constant Speed
3	Compressor	Sullair DW13	801/200	Constant Speed
4	Compressor	Sullair DW13	447/100	Constant Speed/Needs Repair
5	Dryer	Airtek TW 770	800/NA	Non-Heated
6	Dryer	Airtek TW 500	510/NA	Non-Heated
7	Dryer	Airtek TW 500	510/NA	Non-Heated
8	Dryer	Airtek TW 500	510/NA	Non-Heated

All of the compressors were oil free. The baseline analysis found that the Sullair machines did not function well in load/unload mode; air ends needed to be replaced or refurbished too often. They now purge excess air from the system to prevent compressor unloading.

It was estimated that 25% of the time compressors 2 and 3 ran fully loaded. The remaining 75% of the time compressor 1 ran fully loaded, with compressor 2 or 3 also fully loaded. Excess air was expelled from the system with a blow off valve that opened at 124 psi, and drained air until the pressure reached 121 psi, at which point the valve closed.

The existing four dryers operated all of the time. Moreover, three of the four dryers were not drying to the desired set point and required 15% of their rated capacity in air flow purge.

Project Measures

Site #7 installed a new 200 HP, variable speed air compressor in place of the failed 100 HP compressor, and a blower purge desiccant dryer. Under the new system configuration, one of the existing 200 HP compressors would serve as a base-load compressor with the VSD retrofit compressor as a trim. Similarly, the new blower purge dryer replaced the existing dryers that were not drying to the desired set point.

The new compressor was expected to reduce power consumption relative to the existing compressors by matching compressed air output to plant air requirements. This can be accomplished with VSD controls and without the blow-off. Similarly, the new blower purge desiccant dryer eliminated the additional baseline compressed air use, and replaced the system with a more efficient blower for dryer regeneration. This measure was expected to reduce the overall system flow.

The project was completed in December 2008.

Measurement & Verification Methodology

On-site verification activities were conducted on December 8, 2009 and included the following activities:

10.) A visual confirmation of the installation of the new 200 HP, variable speed air compressor and blower purge desiccant dryer.
11.) Spot measurements and current logger deployment on a census of air compressors and dryers.
12.) Assessment of post-installation compressed air system operating characteristics.
13.) Confirmation of baseline equipment and operating patterns.

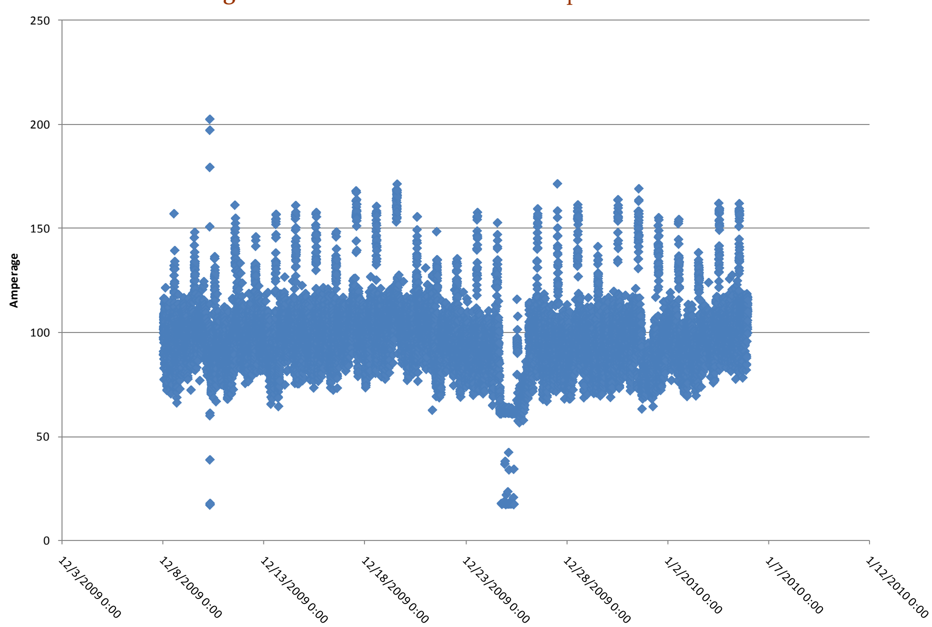
Discussions with project staff regarding system baseline consumption were consistent with the Compressed Air Energy Evaluation[26] and Project Verification Report[27]. In the absence of primary energy consumption data for the baseline configuration, the evaluation team reviewed the power, pressure, and flow measurements collected over two one-week periods of monitoring (October 22 through 29, 2007 and February 8 through 15, 2008) through the Compressed Air Energy Evaluation report's initial assessment. These results were deemed

[26] Compression Engineering Corporation, Compressed Air System Energy Assessment Report, November 2007
[27] PGE Customer Technical Services, Project Verification Report, February 2008

representative of the baseline system operating characteristics and provided the basis for increased system efficiency estimates from compressor and dryer retrofits.

The post-installation energy consumption values were calculated by extrapolating end-use metered results over a 28 day period (December 8th, 2009 through January 5th, 2010) to an entire year's production schedule. These findings were benchmarked against spot-measurements taken on-site during the inspection process to ensure accuracy. The manufacturer's compressor performance curves were procured to ensure measured performance was consistent with manufacturer expectations. Figure D- 7 provides the logged demand profile for the retrofit project:

Figure D- 7. Site #7 Retrofit Air Compressor Current



Project savings were derived by subtracting the annual retrofit compressor energy consumption from the baseline compressor system consumption. The compressed air operating schedule was unchanged in the base and retrofit cases, and the calculated annual savings are reflective of current conditions.

Evaluation Results

The installation of a new 200 HP, variable speed compressor, coupled with a new blower purge dessicant dryer compared favorably with the initial project assessment and project review files. The overall project yielded a realization rate of 105%

Table D- 12. Site 7 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Install 200 HP, Variable Speed Compressor & Blower Purge Desiccant	1,345,989	1,418,847	105%

Dryer			
Total	**1,345,989**	**1,418,847**	**105%**

4.13 Site 8

Site Description

Site 8 is a manufacturing facility specializing in fabrication and finishing of commercial and medical components. The site comprises several thousand square feet including office spaces, warehouses and manufacturing facilities.

The facility uses compressed air for a variety of uses including air tools, and valve controls. Prior to the retrofit, the site was experiencing demand issues with their compressed air system and required additional capacity. Measures for this site seek to improve compressed air efficiency and optimize at the new capacity through variable frequency drives (VFD) on a new air compressor motors as well as a VFD on the air compressor's cooling fan.

Project Description

Prior to the retrofit, the facility utilized one 60 HP air compressor and one 40 HP air compressor. These compressors were not able to supply the air required by the facility. During operational hours, they were operating at full capacity much of the time.

The project at Site 8 consisted of installing a new 100HP Quincy air compressor with a VFD, in place of the existing compressors. The old compressors were removed from the site. Additionally, a VFD was included on the new compressor's cooling fan.

Measurement & Verification Methodology

Measurement and Verification protocol IPMVP Option B was used to verify the improvements at Site 8. The 100HP VFD and was fitted with a WattNode power meter with MadgeTech pulse counter for a period of one week. The power supply to the cooling fan was inaccessible so the fan was not metered.

There was no ATAC study associated with this project, so no pre-installation power use could be verified. Additionally, the previously existing compressors were not available for inspection. The baseline case for the air compressor and fan assume same new equipment without the VFDs. This baseline methodology is the same as used in the brief technical review used to create the initial project estimates.

Savings for the VFD air compressor were calculated using logged power data and technical specifications provided by Roger's Machinery to derive a baseline power required for the same machine to produce the same volume of compressed air at a the given pressure without the VFD.

Because the cooling fan could not be metered, average fan VFD savings of 25% are assumed. These are the same savings that were used to calculate the original estimate.

Project Results

Logged data demonstrated the air compressors to be operating nearly fully loaded, in the range of 85-95% loaded, during 45% facilities operation hours, reducing the advantage of the VFD. Additionally, the site had changed their running air pressure from 100psi to 75psi. The realization rate for the air compressor is calculated to be 88% as seen in Table D- 13.

Realization for the fan is calculated at 100% because the method used for the estimate and verification was identical.

Table D- 13. Site 8 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
VFD Air Compressor	115,335	101,300	88%
VFD Fan	10,687	10,687	100%
Total	**126,022**	**110,987**	**88%**

Site personnel indicated that production at the facility has been slower than in previous years and is expected to continue at the current level. Since NCI used a baseline independent of previous operating conditions, this does not impact calculations but does account for the lower realization rate.

4.14 Site 9

Site Description

Site 9 is a food manufacturing facility. The site comprises several hundred thousand square feet including office spaces, warehouses and food processing facilities.

The facility uses compressed air for a variety of uses including air tools, conveyors, cleaning uses, and valve controls. Measures for this site seek to improve compressed air efficiency through variable frequency drives (VFD) on air compressor motors, a new air compressor and sequencing controls.

Project Description

Prior to the retrofit, the facility utilized three 100HP Quincy air compressors. Two of these compressors, called A3 and A4 are rated at 100 psi, while the third, called A2, is rated at 125psi. These compressors were controlled independently using inlet valve modulation to maintain an air compression system at 115 psi.

The Energy Trust project at Site 9 consisted of installing a new 150HP Quincy air compressor with a VFD, installing new compressor controls and stabilizing the system with a new 1,550 gallon air tank as well as miscellaneous piping and wiring improvements. The compressors are controlled such that compressor A2 provides a constant base load with the new VFD compressor acting as trim. When demand dictates, compressor A3 will act as additional trim. Compressor A4 serves as a backup. Additionally, system pressure was to be reduced to 105 psi from 125 psi.

Measurement & Verification Methodology

Measurement and Verification protocol IPMVP Option B was used to verify the impacts from the improvements at Site 9. The 150HP VFD compressor was fitted with a WattNode power meter with MadgeTech pulse counter. The three 100 HP compressors were fitted with current transducers and Hobo data loggers for a period of four weeks. Additionally site personnel were interviewed and the project was visually verified.

Site personnel indicated that production at the facility has been relatively constant over the past several years. The plant is currently running near capacity and is not expected to undergo production shifts in the foreseeable future. The ATAC study prepared prior to the retrofit includes detailed baseline analysis based on several weeks of power metering on all the compressors. These data reveal a baseline energy consumption of 1,939,882 kWh/year. This value is used as the baseline by NCI for impact evaluation.

Project Results

Logged data demonstrated the air compressors to be operating according to the prescribed control schedule. Compressor A2 ran as the base compressor. The VFD compressor acted as a trim as did compressor A3. However, compressor A3, ran at a higher average kW than expected in the ATAC study. It was logged to be running nearly as frequently as compressor A2. The VFD compressor ran at a lower average kW indicating that air needs were higher than estimated.

Additionally, it was found that the system was running at 109.6 psi rather than 105psi indicated in the initial ATAC study. Site personnel indicated that air pressure is set to be 106 psi according to their control system but frequently is in the range of 107 to 110psi.

Extrapolation of logged data revealed an estimated annual energy consumption of 1,236,970.83 kW/year. This is slightly more than estimated in the ATAC study. As shown in Table D- 14, the energy savings associated with the project is verified to be 92% of the estimated value. This realization indicated the ATAC study slightly underestimated air needs. This may be due to the system running at a higher pressure than expected or due to an underestimate of air demand.

Table D- 14. Site 9 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Air Compressors	765,941	702,991	92%
Total	**765,941**	**702,991**	**92%**

4.15 Site 10

Project site 10 is a corrugated box manufacturer. On average, the site operates two shifts per day from 7AM – 11PM, five days a week. The site may sometimes operate shifts on Saturdays depending on the workload.

The site installed a new 100 HP, variable frequency drive (VFD) controlled air compressor. The compressed air system is used both in the production and clean-up processes on the manufacturing floor.

Base System

Project site 10's existing compressed air system consisted of three air compressors and related equipment listed in Table D- 15:

Table D- 15. Pre-Installation Pump Summary

Compressor/Dryer Number	Make/Model	Rated ACFM/HP	Controls
1	QNWG-244-P/A	243/125/60	Modulation with Low Unload
2	QNWG-244-D/A	243/125/60	Modulation with Low Unload
3	QNW 40HP	164/25/40	Modulation with Low Unload
4	AD-400	400	Non-Cycling Dryer

In the base case, the system remained pressurized 19 hours per day, 5 days a week, with the potential for extended operating hours on Saturdays. The pressure drop between the compressor room and out in the plant averaged 5 psi. And the control system allowed header pressure to vary between 115 and 110 psig.

The facility controlled which compressors were in use with inlet modulation controls adjusting for demand. Each compressor responded to a pressure signal located internal to the compressor package. Typically, each compressor operated in hand mode as a base-loaded compressor using modulation control. Compressor 3 was a backup unit and rarely operated.

Compressor 3 was used as a backup and only operated when compressor 1 or 2 went down for maintenance.

Project Measures

Project site 10 installed a new 100 HP, Variable Frequency Drive (VFD) controlled air compressor. It was anticipated that the new VFD compressor would adjust its speed, matching compressor output to system demand. The existing fixed-speed compressors are 100% fully loaded, unloaded, or off, as directed by the system controls. The existing receiver tank provides minimal variation and low pressure drop on the supply side of the system. The existing non-cycling, refrigerated air dryer is currently being re-used.

Energy savings are expected from the new compressor's ability to follow the variable flows closely with variable power consumption. Similarly, energy consumption for the system is expected to be reduced because inefficient modulation controls are no longer used for normal operation.

The project was completed in August 2008.

Measurement & Verification Methodology

On-site verification activities were conducted on December 9, 2009 and comprised the following activities:

14.) A visual confirmation of the new 100 HP VFD controlled air compressor.
15.) Spot measurements and current logger deployment on a census of compressed air system components.
16.) Assessment of post-installation compressed air system operating characteristics.
17.) Confirmation of baseline equipment and operating patterns.

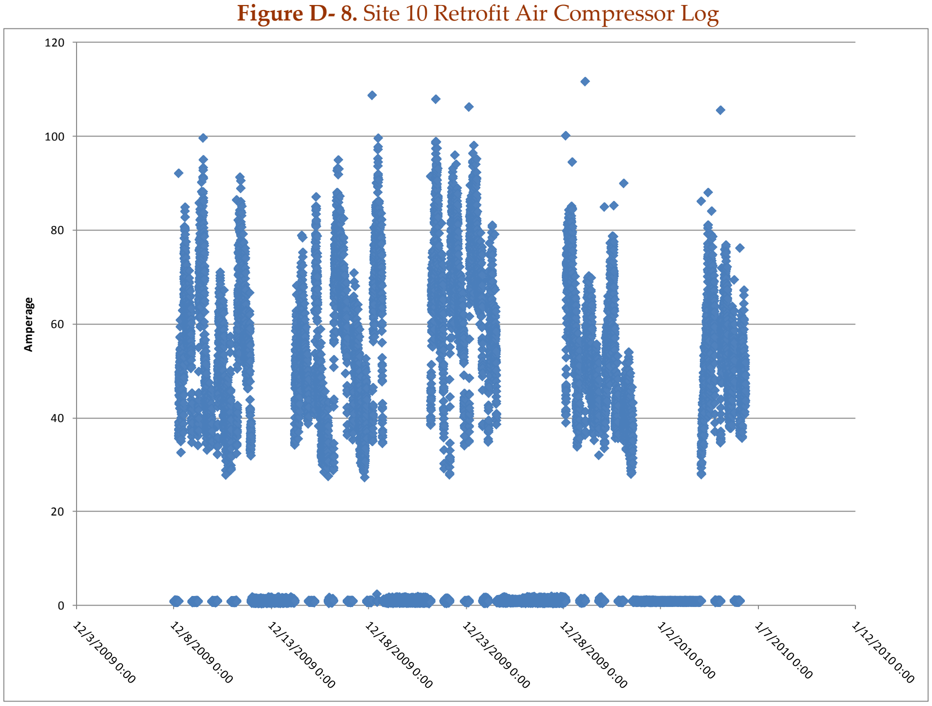
Discussions with project staff regarding system baseline consumption were consistent with the Compressed Air System Energy Assessment Report[28] and PGE Project Verification Report[29]. In the absence of primary energy consumption data for the baseline system, the evaluation team reviewed the power, pressure, and flow measurements collected over a 14 day period through the review's initial assessment. These results were deemed representative of the baseline system operation, and the annual baseline energy consumption values were accepted for evaluation purposes (394,522 kWh/year).

The post-installation energy consumption values were calculated by extrapolating end-use metered results over a 28 day period to an entire year's production schedule. These findings were benchmarked against spot-measurements taken on-site during the inspection process to ensure accuracy. Similarly, the manufacturer's compressor performance curves were procured

[28] Rogers Machinery Audit Group, Compressed Air System Energy Assessment Report, November 2007
[29] PGE Customer Technical Services, Project Verification Report, August 2008

to ensure measured performance was consistent with manufacturer expectations. Figure D- 8 provides the logged demand profile for the retrofit project:

Figure D- 8. Site 10 Retrofit Air Compressor Log



As noted earlier, the compressed air operating schedule was unchanged in the base and retrofit cases. Annual energy consumption was calculated by extrapolating the logged compressor findings across a full production year. Project savings were derived by subtracting the annual retrofit compressor energy consumption from the baseline compressor system consumption.

Evaluation Results

The installation of a new 100 HP, variable frequency drive (VFD) controlled air compressor achieved 172,223 kWh in savings, resulting in a project realization rate of 139%. Navigant Consulting is comfortable with the calculated savings exceeding expectations as the Compressed Air System Energy Assessment Report[30] reduced savings estimates to account for a safety factor. The additional savings may be attributed to normal fluctuations in the compressed air demands of the facility.

[30] Rogers Machinery Audit Group, Compressed Air System Energy Assessment Report, November 2007

Table D- 16. Site 10 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Install 100 HP Variable Frequency Drive (VFD) Air Compressor	124,252	172,223	139%
Total	124,252	172,223	**139%**

4.16 Site 11

Site 11 was a farm pump-house containing a 100 HP and a 125 HP pump. Operation varies annually based upon crops grown, weather, and water allocation. Typically irrigation takes place around six months a year, primarily between May and October.

Base System

The pump-house contains two constant speed irrigation pumps, one 100 HP and one 125 HP unit. Both pumps were used to irrigate crops, both individually and in tandem. Flow adjustments were made manually to the system, using pump staging and discharge valves, at the request of the growers.

Project Measure

The facility installed a VFD on the larger of the two the irrigation pumps at the site. A soft start, but no VFD, was installed on the 100 HP pump. This smaller pump was shut down by the controls when it was not needed, leaving only the variable speed 125 HP operating about half of the time. Flow adjustments were still made manually at the request of the growers. The estimated hours of operation in each mode are shown in Table D- 17.

Table D- 17. Site 11 Modes of Operation

Mode	Annual Hours
Full flow 100 HP and modulating 125 HP	2200
Modulating 125 HP pump alone	2200
Total	**4400**

Measurement & Verification Methodology

During the September site visit, Navigant Consulting personnel discussed the use and installation of the system with facility personnel. A spot measurement of power use was taken on the 125 HP pump, which was operating at full speed during the site visit. Monitoring equipment was installed on both pumps for a period of three weeks to determine power use. In addition, billing records and irrigation reports for the pumphouse were obtained to evaluate energy use in previous months.

Evaluation Results

During the monitoring period the 100 HP pump was not used. It was assumed that this would have been the case without the VFD as well. The loading profile on the 125 HP pump during the monitored period is shown in Table D- 18.

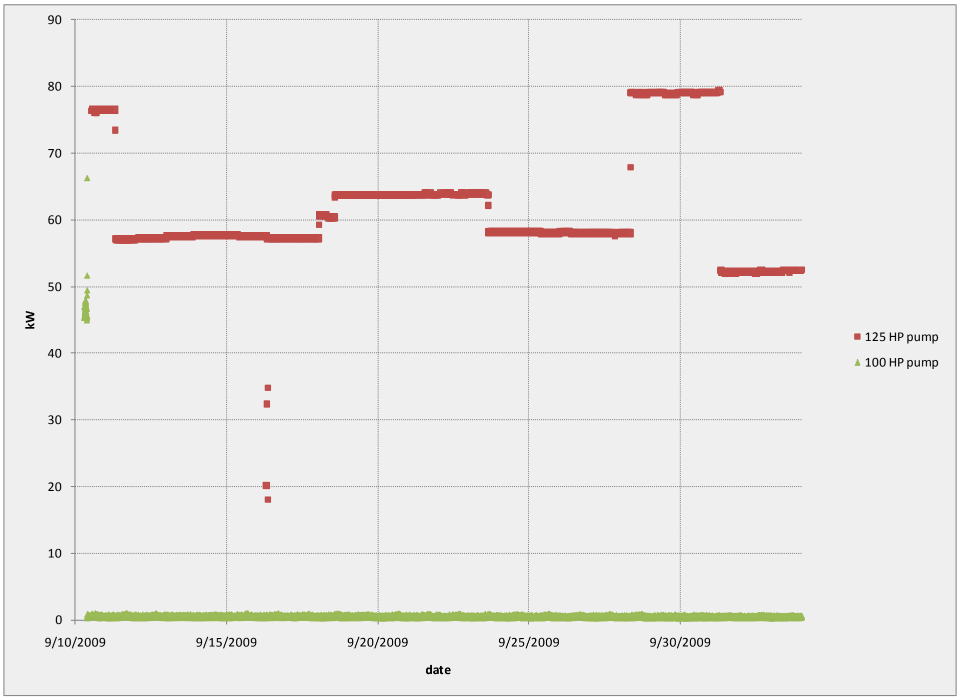
Table D- 18. Site 11 Monitored Pump Operation

Speed (flow) Range	Input Power	% of Monitored Time
100%	79 kW	15.8%
92%	63 kW	23.5%
89%	58 kW	47.9%
85%	52 kW	12.8%

This flow profile constituted around 195 million gallons (598 acre feet) of flow during the 572 hours of logging. The flow data for the site showed a total of 4,384 acre-feet of flow in 2008 and only 1,672 acre-feet in 2003 at the time of the initial study and used as the basis for *ex ante* estimates. Full water flow data for 2009 was not available at the time of the evaluation, but it appeared to be on track to use slightly more than in 2008, and significantly more than in 2003. Since usage depends on crop type, weather, and water allowances, it is not possible to estimate year to year usage accurately. The smaller pump had not been used during August and discussions with personnel indicated that operation had been similar to logged data recently. Based on this, usage for the month would have been around 753 acre-feet using 45,826 kWh, 15% less than the 53,600 kWh from billing data, indicating a slightly higher percentage of time at full pumping. Figure D- 9 shows the logged power data.[31]

[31] The brief spike at the beginning for the 100 HP pump is due to launching the equipment prior to installation and does not indicate operation of the pump.

Figure D- 9. Site 11 Pump Power



Based on the manufacturer's pumping curve and measured power, during the monitoring period the 125 HP pump used 35,237 kWh to pump approximately 195 million gallons, or 598 acre-feet, of water. This corresponds to 58.9 kWh/acre-foot during the monitoring period. Based on billing data and pumping records, in 2008 the pumphouse used 78.9 kWh/acre-foot overall. This can be broken down into 82.3 kWh/acre-foot during the period for which it is likely the 100 HP pump would not be in use under the new system and 76.7 kWh/acre-foot when it would be required. Overall pumping data was only available through July of 2009, but it appears likely that both pumps were in use for the majority of that time. The 2009 billing and data and pumping records correspond to an overall usage of 69.7 kWh/acre-foot, with both pumps operating for the vast majority of that time.

Based on billing data and pumping records, the 100 HP pump would be expected to run around half the time. During this time, the 125 HP pump would be running at reduced flow, but hydro-dynamic interaction between two pumps working at different speeds makes it difficult to calculate the power without measured data. An estimate based upon pump curves and affinity laws indicates savings around an average of 23 kW for the 125 HP pump operating at reduced speed with the 100 HP pump versus the two pumps throttled at full speed. It may be only a coincidence that this savings is similar to the average savings observed during the monitoring period with just the 125 HP pump. However, due to the many uncertainties in this calculation, this estimate is used only for comparison to the savings based on billing and water use data.

Based on billing information and discussions with personnel, the pumphouse operates around half the year, or about 4,380 hours per year. The available pumping records indicate that it would be necessary to use the 100 HP pump as well as the 150 HP variable speed unit for about half that time. Based on measured data combined with billing and pumping records, the facility could be expected to save approximately 23.4 kWh/acre-foot when flow is low enough to require only one pump and save 7 kWh/acre-foot when both pumps are in use. Based on pumping records, a typical year would use around 4,500 acre-feet of water, with around 2/3 of the flow using two pumps. This corresponds to 56,100 kWh/year of savings, a 58% realization rate.

Navigant emphasizes that because of annual variations in, and the unusual configuration of pumps with only one VFD, that there are substantial uncertainties in the savings for this site. However, based on billing records and measured data the savings appear to have been overestimated. The decrease in savings is primarily due to the fact that the VFD pump cannot simply act as trim, but must adjust to the head pressure developed by the constant speed pump, resulting in minimal savings when both units are operating.

Table D- 19. Site 11 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
VFD on Irrigation Pump	96,582	56,100	58%
Total	**96,582**	**56,100**	**58%**

4.17 Site 12

Site 12 is an agricultural site consisting of more than 5,000 acres. The facility grows a variety of vegetables. The irrigation system has two pump stations. Two sections of pipe following one of these pump stations were augmented with cement mortar lining to reduce internal friction and thereby reduce power consumption at the pumps.

Base System

The affected pump station consists of 4 pumps, each with a 150 HP premium efficiency motors controlled by a VFD, and supplies water to 3032 production acres.

The first distribution line from the booster station is a 4118 ft steel pipe with a diameter of 30 inches. Initial testing of that pipe yielded a Hazel-Williams coefficient of 89. This pipe leads to a distribution cluster where water is diverted to watering pipes and to a second distribution line. The second distribution line from is a 3410 ft steel pipe with diameter of 26 inches. Initial testing of that pipe yielded a Hazel-Williams coefficient of 65. This line leads to a distribution cluster were water is diverted to watering pipes and additional distribution clusters.

Project Measures

The first two distribution lines from the pump house were coated with cement mortar lining. Cement mortar lining provides a higher smoothness than aged steel, which leads to lower head loss due to friction.

The power savings estimates reported in the initial project study use the pump power equation and the Hazel-Williams equation of pressure loss due to pipe friction to estimate savings. The mortar lining installed has of Hazel-Williams coefficient 103.

The Hazel-Williams equation is

$$F = 0.2083 * (100*Flow/C)^{1.852} / d^{4.8655}$$

Where

F = Head loss due to friction (ft)
$Flow$ = Instantaneous flow in pipe (gpm)
C = Hazel-Williams coefficient
d = inside diameter of the pipe (in)

Since the Hazel-Williams coefficient (C) is in the denominator, increasing values reduce head loss due to friction (F). The pump power equation is

$$Power = (Flow * Head * 0.746)/(3960 * \mu_p * \mu_m)$$

Where

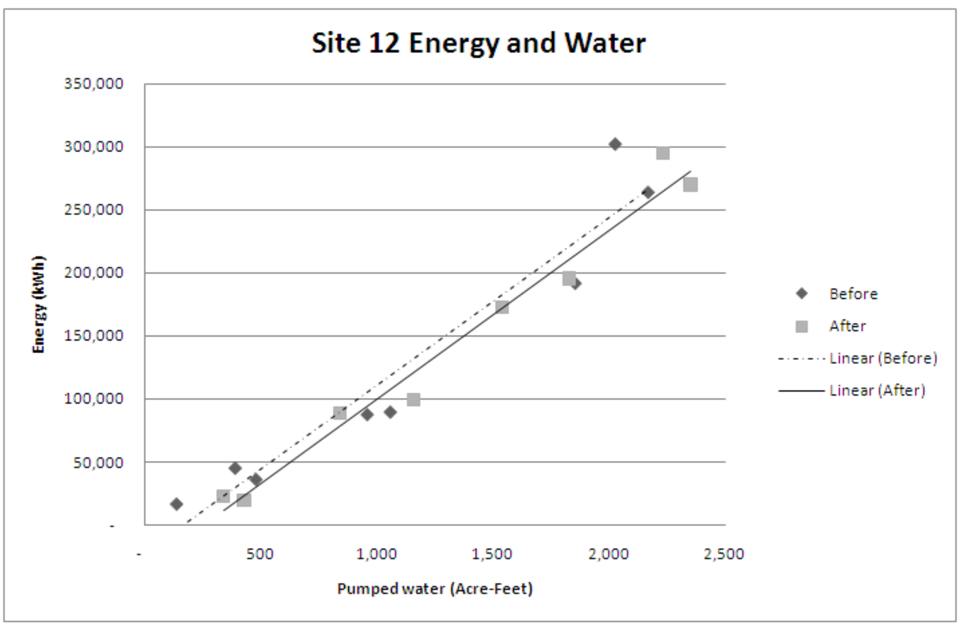
Power= *power draw (kW)*
Flow = Instantaneous flow in pipe (gpm)
Head = Total head loss (ft)
μ_p = *pump efficiency*
μ_m= *Motor efficiency*

Measurement & Verification Methodology

NCI personnel visited Site 12 in April 2009 and conducted spot measurements of the power usage on all the motors at the pump station. The cement mortar lining was not visible as it is on the interior of the pipes; however it is believed to have been applied in the two lines.

The Hazel-Williams friction equations and pump power equations were not used in the verification because NCI does not have a reliable method for measuring the current or baseline Hazel-Williams coefficients or instantaneous flows over the course of the year. Instead, billing analysis was used for verification. Energy usage for the years 2007 and 2008 were provided by the local utility and weekly watering information was provided by the site. These data, shown in Figure D- 10, demonstrate a linear relationship between water and energy use and a visible savings after the retrofit.

Figure D- 10. Site 12 Monthly energy and water usage before and after retrofit



The baseline energy consumption was calculated by finding that the average energy usage prior to the retrofit. This baseline energy was 92.4 kWh/Acre-Foot.

Savings were calculated according to the equation

$$Savings = \sum^{i=n} (Baseline\ energy * Water - Power)$$

Where

Savings = Annual energy savings (kWh/year)
n = months
Baseline Rate = 92.4 kWh/Acre-Foot
Water = monthly water use (Acre-Foot)
Energy = monthly energy use (kWh)

Evaluation Results

Savings due to the cement mortar lining were found to be 115,330 kWh/year, which was 57% of the estimated savings.

Table D- 20. Site 12 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Cement mortar lining	200,918	115,330	57.4%
Total	**200,918**	**115,330**	**57.4%**

Several factors may have led to this low realization. The initial estimate had been calculated using empirically measured pre-project flow and power data and pipe flow modeling. The modeling assumed a motor efficiency of 90%; however the motors are 95.4% efficient. Additionally, the study does not explicitly describe the VFD's affect on the system. It is unknown if the model accounted for power savings from the VFD during lower flow periods. If the VFD's affects were neglected, it would explain the high estimated savings. Additionally, it is common to see that adding an efficiency measure on top of another will cause a decrease in savings for each measure.

4.18 Site 13

Site 13 was a manufacturing plant for metal parts. The facility uses diffusion pumps to create high vacuum used in processing some of its products. The two diffusion pumps used on one furnace were replaced in 2008. Facility operation is 24 hours a day, seven days a week.

However, the diffusion pumps on the furnaces only operate 7,884 hours per year due to maintenance and system adjustments.

Base System

The furnaces at site 13 use positive displacement pumps to create a “low” vacuum from which the diffusion pump removes additional air. Diffusion pumps consist primarily of a heating element used to create fluid vapor which transports gas molecules out of the vacuum chamber using diffusion. These pumps have no moving parts and so have a significantly longer lifetime than positive displacement pumps. The older pumps are still in good working order, despite their age, because diffusion pumps have a long lifetime due to the lack of moving parts. Because of this, the base system would have been to keep the existing, older diffusion pumps on the vacuum chamber. This is still the case on a number of other furnaces in the facility.

Project Measure

The furnace vacuum chamber uses two diffusion pumps to maintain high vacuum in a furnace. These pumps were replaced. The roughing pumps used to create the base vacuum were not affected by this replacement, nor was the furnace itself. Consequently, only the diffusion pump power was taken into account in calculating project savings.

Measurement & Verification Methodology

During the site visit, NCI personnel discussed the use and installation of the pumps with facility personnel. A plant electrician took spot measurements of pump operation for the two new pumps and one old pump on a different system. Current measurement logging was installed for a period of three weeks to determine if the power usage of either the new or old style pumps varied over time and to verify that the operation was continuous.

Evaluation Results

The pumps were installed and operating as expected. Figure D- 11 shows the pump power usage for the two new pumps and one older unit on a different furnace. It is clear from the figure that the pump’s power draw does not vary significantly, so average values may be extrapolated over time. The old style pump averaged 23.3 kW, slightly higher than the 22.5 kW measured during the site visit. The new style pumps averaged slightly under 5.6 kW each, very close to the 5.4 and 5.6 kW measured during the site visit. This is a savings of 17.7 kW per pump. All of the pumps showed power factors of 0.99, which was expected since the primary component of a diffusion pump is a resistive element. Since the pumps operate 7,884 hours per year, this corresponds to a savings of 139,802 kWh per pump replaced, and 279,604 kWh for the project as seen in Figure D- 11.

Figure D- 11. Site 13 Pump Power

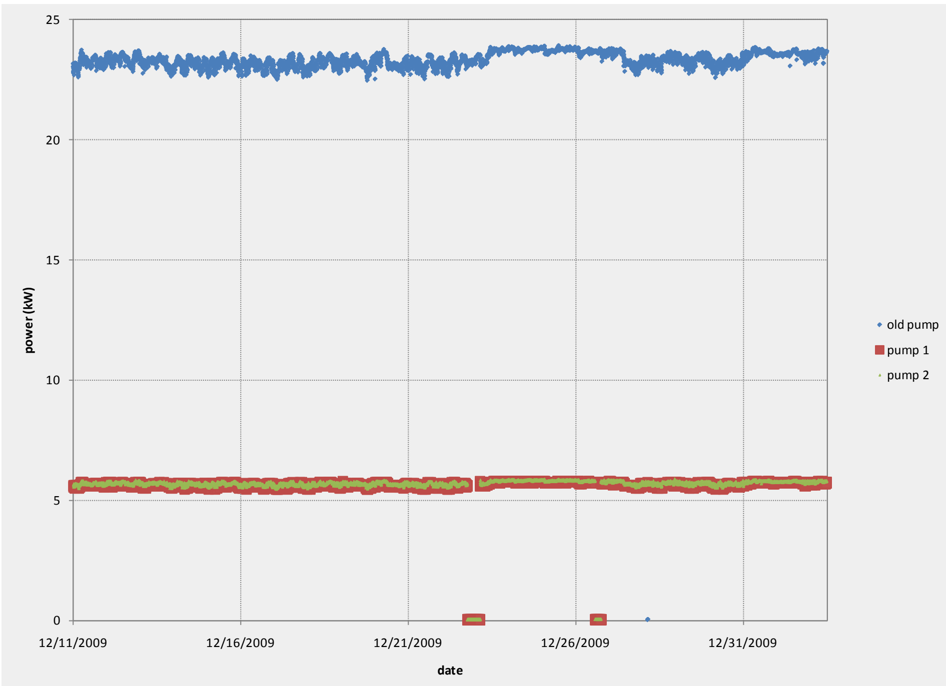


Table D- 21 shows the estimated and verified savings at site 13. The realization rate at the site is 94%. The slightly reduced savings is primarily due to differences in measured power compared to the initial study. A few percent adjustment is not unusual and this is not considered to be a reflection on any problems with the initial estimates.

Table D- 21. Site 13 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Diffusion Pump Replacement	296,438	279,604	94%
Total	**296,438**	**279,604**	**94%**

4.19 Site 14

Project Site 14 involved the installation of a VFD on Well #5 at a City Water System. The annual water consumption has grown from 275 million gallons to over 300 million gallons in the past two years. The water system consists of five well sites and two reservoirs. Of the five wells, four are actively used, with Well #7 remaining available for emergency use only. The four wells deliver approximately 301 million gallons per year with an estimated annual energy consumption of 575,603 kWh.

It should be noted that the City did not accept the Energy Trust's original incentive offer (December 28th, 2005); at the time, the city had more pressing capital improvement projects. Energy Trust does not offer retroactive incentives; therefore, the project did not receive an incentive upon completion in 2008.

Base System

The City Water System Pump configuration is provided in Table D- 22. And as noted earlier, Well #7 is available for emergency use only

Table D- 22. Pre-Installation Pump Summary

Pump Name	Pump HP	Flow Restricting (Y/N)	Age
Well #3	30	No	2004
Well #5	100	Yes	2003
Well #6	30	Yes	2003
Well #8	150	No - VFD	2002

All four of the active wells were equipped with submersible pump/motor assemblies, and two of the four pumps had throttled flow to prevent cavitation in the wells.

Baseline operation turned all four wells on and off together as the levels in the reservoir fluctuated. While this strategy successfully balanced run hours, it caused excessive on/off events dependent on water demand conditions.

Project Measures

The City Water System purchased one 100 HP VFD for Well #5 to improve part load efficiencies. Although improvements to the well staging strategies were recommended to minimize start/stop cycles, the post-installation operating strategy mirrored the baseline configuration. The project was completed in August, 2008.

Measurement & Verification Methodology

Navigant Consulting recognizes that M&V strategies are dependent upon the accessibility of installed measures, and the availability of performance influencing data. In the absence of hourly water demand data, Navigant Consulting used a combination of spot measurements, end-use metering, past billing records, and interviews with project representatives to calculate realized demand and energy savings.

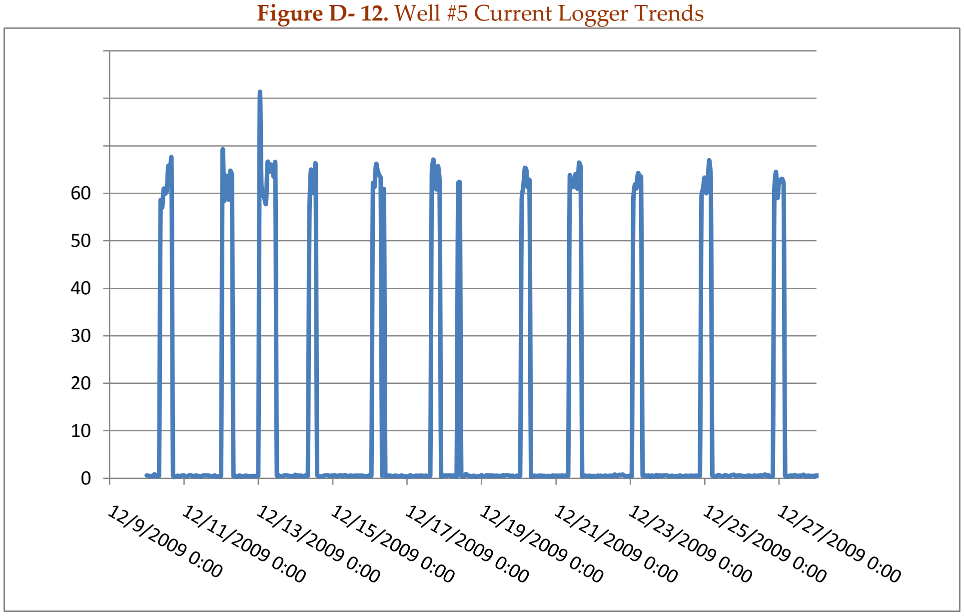
On-site verification activities were conducted on December 9th, 2009 and comprised the following activities:

18.) A visual confirmation of VFD installed on Well #5
19.) Spot measurements and current logger deployment on active Wells[32].
20.) Assessment of water demand profile and billing data from the pre-/post- installation periods.
21.) Investigation of additional equipment/Well staging strategies to that may have affected system performance in the pre-/post-installation periods.

Spot measurements and end-use metering results indicated that the VFD installed on Well #5 was operating as expected. The VFD allowed Well #5 to achieve the same reduction in flow as a throttling valve without increasing the pump's head requirements. This is accomplished by slowing the pump speed, delivering the same flow rate at greatly reduced power consumption. Figure D- 12 provides current logger trends for Well #5 over a period of 3 weeks:

[32] While on-site, Well #6 was physically inaccessible and could not be spot measured/metered.

Figure D- 12. Well #5 Current Logger Trends



A thorough review of the site's billing and water production data, yielded similar results. Table D- 23 compares the pump performance ratio for Well #5 in the pre- and post installation case using the following equation:

$$\textit{Pump Performance Ratio} = \sum kWh \div \sum kGal$$

Where: ∑*kWh*: Annual kWh Consumed During Pre-/Post-Installation Case

∑*Gal:* Annual Gallons Pumped During Pre-/Post-Installation Case

Table D- 23. Well #5 Pump Performance Ratios

Period	Time Interval	kWh	Gallons	Pump Performance Ratio (kWh/kGal)
Post-Installation	9/2008 – 8/2009	117,938	62,823,837	1.88
Pre-Installation	9/2007 – 8/2008	138,966	69,139,950	2.00

It should be noted that the kWh/Gallons ratio may vary due to the following factors:

22.) Amount of mud in the reservoir water being pumped to Water System (Turbidity).
23.) Reservoir water height - pumps operate more efficiently when the reservoir is higher.

Accounting for these factors, along with an improvement in the pump performance ratio, the project savings are calculated to be 8,333 kWh.

Evaluation Results

The installed VFD on Well #5 achieved 8,333 kWh in savings. In the future, optimizing the well staging configurations so that the most efficient wells meet a larger percentage of Water System demand will allow the site to achieve greater savings. Moreover, this strategy will mitigate excessive on/off events for each Well.

Table D- 24. Site 14 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Install VFD on Well #5	17,870	8,333	47%
Total	**17,870**	**8,333**	**47%**

4.20 Site 15

Site 15 is a waste water treatment plant. The site received incentives for one project – installation of VFDs on 6 storm/waste water lift pumps at the influent pump station (IPS). Four 600 HP pumps and two 1000 HP pumps were installed with VFDs for maintaining appropriate levels in two wet wells. All pumps and VFDs were found installed as described for the project.

Table D- 25. Site 15 Project *Ex Ante* Savings

Unit	kWh	Status
VFDs installed on Six Pumps	1,180,854	Operational
Total	**1,180,854**	

Base System

The project is new construction so there is no pre-installation data or system to analyze. The pump station consists of four 600 HP ITT Flygt pumps rated at 25 MGD each and two 1000 HP ITT Flygt pumps rated at 40 MGD each. These pumps stage to maintain desired levels in the two influent wet wells and lift storm and waste water to the treatment plant. In the baseline system the 6 pumps modulate flow with eccentric plug valves on the pump discharge while running at constant speed. When modulating flow in this manner, the pumps ride the pump performance curve.

All of the pump motors are 4160V machines

Project Measures

The selected measure for this project is VFDs installed on each of the six pump motors. With the VFDs, flow is modulated by changing the pump speed thus gaining the efficiency of reduced flow at nearly constant pressure. Savings is generated by the pump affinity laws which show that cube of pumping power is proportional to flow and rotational speed. As system flows decrease, power savings increases rapidly.

$$Power^3 \propto Flow$$
$$Power^3 \propto Rotational\ Speed$$

The incremental cost of the VFDs was more than $1,000,000.

Measurement & Verification Methodology

During the site visit, Navigant Consulting personnel discussed the use and operation of the pumping station with facility personnel to determine operational parameters of the systems. We visually inspected and verified that the project equipment was installed and operating. We discussed the automation systems and trend data capabilities and the history of stored data. Normally, Navigant Consulting would take spot measurements of operating equipment with calibrated field tools. However, our personnel and the customer's personnel on-site are not trained to work with equipment of this voltage; therefore, we deferred to the data collected by the automation system.

The customer provided 16 months of system data for the analysis. The data, in 15-minute intervals, included system flow, and motor speed and kW for each of the six motors. The customer also provided the 2005 Energy Analysis Report that was not part of the project file provided by the Energy Trust . This report included the pump performance curves and discussion of the baseline flow profiles assumed.

Evaluation Results

The calculations included in the Energy Analysis Report are rigorous and accurately constructed. Navigant Consulting repeated a similar analysis based on the historic flow and energy consumption data provided. Figure D- 13 shows the typical relationship between motor speed and input power for these pumps. As anticipated power drops off rapidly as speed (flow) is reduced. Pump 1 is a 600 HP machine.

The pumping sequence monitored for 2009 is characterized in Table D- 26. These data show that a majority of energy is used by two pumps modulating to meet setpoints. Total energy consumed by the pumps in 2009 was about 3.4 GWh. This is well below the 4.3 GWH estimated in the Energy Analysis Report. Furthermore, the estimated savings based on 2009 data is about 50% greater than the ex ante estimate.

Figure D- 13. Site 15 Pump 1 Power (kW) – Typical of all

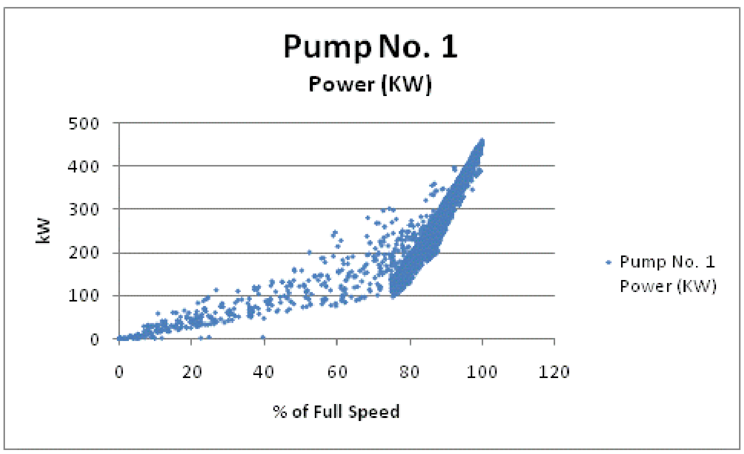


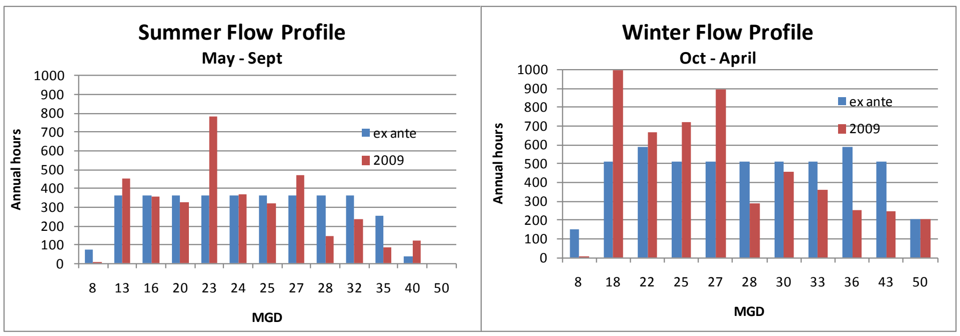
Table D- 26. Site 15 Pump Staging Characteristics

Pump ID	HP	Hours Operating	kWh	% kWh of total
P1	600	4,751	1,154,044	34%
P2	600	6,156	1,607,538	47%
P3	1000	121	42,078	1%
P4	600	1,176	293,722	9%
P5	600	1,204	305,766	9%

P6	1000	14	2,976	0%
Total			**3,406,123**	**100%**

Both of these findings are consistent with 2009 flow patterns. The annual flow in 2009 was considerably below the average flow which is the basis of *ex ante* calculations. Figure D- 14 shows the 2009 (*ex post*) flow profiles is significantly shifted to lower flows as compared to the average flow profile used in the *ex ante* calculations. At low flow conditions overall energy consumption is lower and the measured savings are greater at low flow rates, thus 2009 savings estimates are greater than the *ex ante* estimates.

Figure D- 14. Site 15 *Ex ante* and 2009 Flow Profiles



Navigant Consulting applied the measured speed vs. power relationship to the average flow profiles used in the ex ante estimates to derive gross savings in Table D- 27.

Table D- 27. Site 15 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
VFDs installed on Six Pumps	1,180,854	1,318,000	112%
Total	**1,180,854**	**1,318,000**	**112%**

Navigant Consulting does not recommend any savings adjustments due to the economic conditions over the past several years.

4.21 *Site 16*

Site 16 was a wood products plant containing several large buildings. Twelve kilns process ponderosa and sugar pine and Douglas fir using steam from a hog fueled boiler. Production is currently slowed due to the economy, and this has affected overall savings at the site. Site operation remains 8,760 hours per year, but individual drying kilns are not used as much as they were during previous years.

Base System

Multiple measures were implemented at this site: a VFD for the fans on kiln 12 and several prescriptive premium efficiency motor purchases.

Kiln 12 had an old, broken VFD and the seven 10 HP fans in it were operating at full speed all of the time. Since variable speed operation was not necessary and no dampers were in use, the baseline system was assumed to be full speed operation of all seven fans. This kiln processes ponderosa and sugar pine of varying thicknesses.

The facility uses a large number of motors. The majority of the motors are totally enclosed fan cooled units. The baseline is assumed to be a new, standard efficiency EPACT motor. As this is a prescriptive measure, standard savings values are used for calculations.

Project Measures

The facility installed a new VFD on the fans for dry kiln 12. The single 100 HP VFD operated seven individual 10 HP fans, for a total of 70 HP.

The facility purchased a large number of premium efficiency motors of various sizes. All of these were treated as prescriptive rebates. Table D- 28 shows the incentivized motor purchases during 2009.

Table D- 28. Site 16 Prescriptive Motors

HP	Efficiency	RPM	quantity	kWh Savings
1	85.5%	1800	2	390
1.5	84%	3600	1	339
3	89.5%	1800	1	498
3	90.2%	1200	1	498
5	90.2%	1200	1	607

5	89.5%	1800	2	1,214
7.5	91.7%	1800	1	1,116
10	92.4%	1200	1	1,220
10	91.7%	1800	1	1,220
15	91.7%	3,600	1	1,687
20	93%	1,800	1	1,783
60	93.6%	3,600	1	16,058
100	95.4%	1,800	2	13,166
200	96.2%	1,800	1	22,092
507			**17**	**61,888**

Measurement & Verification Methodology

During the site visit, Navigant Consulting personnel discussed the use and installation of both the kiln fan VFD and the premium efficiency motors with facility personnel. The premium efficiency motors were all believed to be installed and operating as expected, and the VFD on kiln 12 was observed to be operating as well. It was not possible to obtain nameplate information on the seven kiln fans due to their location inside the kiln, however spot measurements of the VFD load were consistent with a lightly loaded 70 HP system.

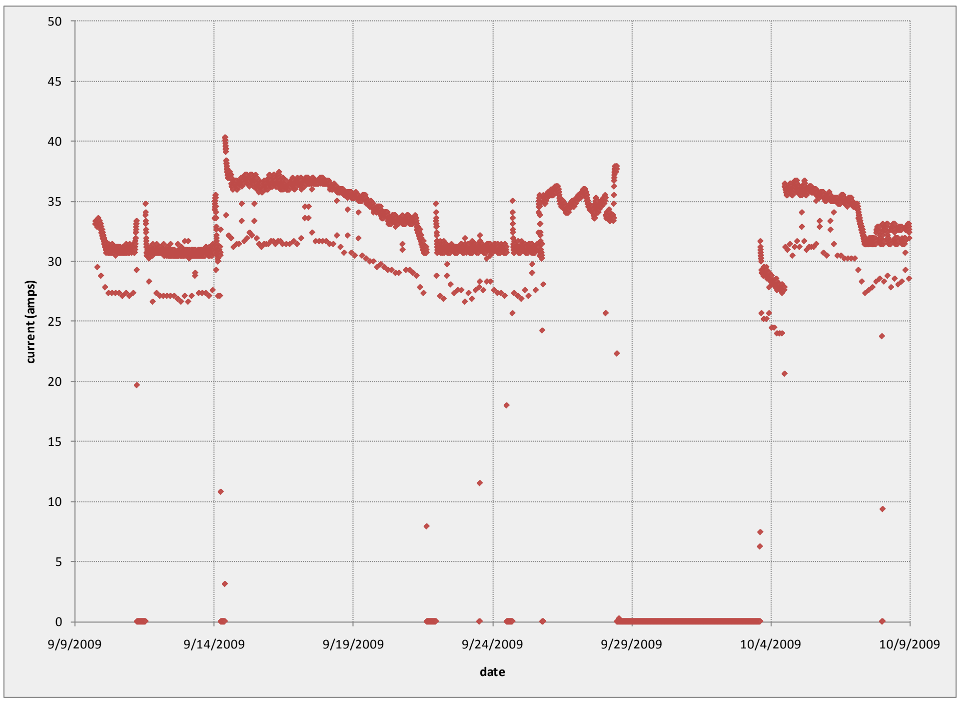
The facility provided processing records for kiln 7 for the year and half preceding the evaluation. Detailed information on the current charge was also provided for the evaluation. NCI took spot measurements of fan power and installed logging equipment to monitor fan operation for a month. In addition, baseline data from the initial study was used for data on processing additional product types which were not observed during the monitoring period.

Evaluation Results

Figure D- 15 shows the operation of kiln 12 during a four week period. During the measurement period, from September 10 through October 9, 2009, kiln 12 ran three charges, the unit of kiln operational cycles used at the facility, with an average of 230.6 in kiln hours, 223.38

of which were run time and 7.22 of which were hold time. There was an average of 95.98 hours between charges. This indicates 883.76 hours, more than the total hours in the month long period. This is because the charges were continuing past the beginning and end of the measurement period. In addition, the system was only shut down for 123.4 hours during the measurement period of 709.6 hours. This indicates a total of 2.54 charges and shows that there was only one down period during the measurement period.

Figure D- 15. Site 16 Kiln Fan Operation during sample period



The average power measured during operation was 31.8 kW. It should be noted that this is not a complete number of charges, and that charges vary in power. However the measurement period of four weeks was long enough to provide a representative sample of power use for the 4/4" and 5/4" sugar pine which was being processed, but this was significantly less than the 55.5 kW measured for 5/4" of this species on kilns 10 and 11 during the initial study. In addition, the peak power consumption observed during the monitoring of kiln 12 was barely above 40 kW, and this appeared to be a start up condition, whereas facility records indicated that the fan was operating at 100% speed for a significant portion of the charge. A spot measurement taken during the site visit at 60 Hz operation similarly showed only 33 kW of usage during 4/4" sugar pine processing. The 5/4" pine which was subsequently processed appeared to have a slightly higher full speed power of around 36 kW based upon data logs.

Based on 70 HP of fans, the maximum power under full loading would be expected to be around 57 kW at full loading, although loading would clearly vary depending on pressure and airflow. The initial study measured a full speed power of 69.9 kW based on kilns 7, 8, 10, and 11.

During the year and a half preceding the evaluation, kiln 12 ran 5/4″ sugar pine 55.7% of the time, 8/4″ sugar pine 14.2% of the time, and 4/4″ sugar pine 13.5% of the time. In addition 8/4 ponderosa pine was processed 8.1% of the time, 5/4″ ponderosa pine 4.7% of the time, and 4/4″ ponderosa pine 3.9% of the time. According to the initial study, 5/4″ ponderosa pine used an average power of 47.4 kW, 8/4″ ponderosa pine used 70.4 kW, and 8/4″ sugar pine used 61.9 kW. The ponderosa pine measurements were on kilns 7 and 8 and the sugar pine data was extrapolated from 5/4″ data on kilns 7 and 8. All of these kilns operated with VFDs, however it should be noted that kilns 7 and 8 had seven 15 HP fans each, rather than the 10 HP fans used on kilns 10, 11, and 12.

The baseline motor loading was estimated using the original study and 100% loading for seven fans. The original study estimated 69.9 kW as the baseline power for seven 15 HP fans, which would be around 82% loading, depending upon motor efficiency. Similar loading for seven 10 HP fans results in 47 kW as a baseline for 8/4″ processing. This was used as a baseline for thicker product, while the measured data was used for 4/4″ and 5/4″ product. The loading was expected to be similar for the same thickness product regardless of species, however since processing varies for the species, power with the VFD was estimated using the ratio of measured power to 5/4″ sugar pine power for the same kilns (7 and 8). This resulted in 56% of the power from the initial study. Weighting is according to percent of time processing each product type. The sum is the average power savings for all types of product. Table D- 29 summarizes the operation, baseline and savings from the VFD for the kilns at site 16.

Table D- 29. Site 16 VFD Savings by Product

Product	% Processed	Initial Study Power	Initial Study Kilns	Estimated Baseline Power (kW)	Estimated VFD Power	Weighted Savings/hour
4/4″ Sugar Pine	13.5%	-	-	33	31.8	0.162
5/4″ Sugar Pine	55.7%	57.0/47.4	7,8/10,11	36	31.8	2.339
8/4″ Sugar Pine	14.2%	70.4	7,8	47	39	1.136
4/4″ Ponderosa Pine	3.9%	-	-	33	31	0.078
5/4″ Ponderosa Pine	4.7%	55.5	7,8	36	31	0.235

8/4" Ponderosa Pine	8.1%	61.9	7,8	47	35	0.972
	100%					**4.922**

According to facility records, kiln 12 ran a total of only 2,318 hours during the year preceding the measurement period, significantly less than the typical 6,430 hours expected in the initial study. There was a notable down period between October 2008 and April 2009 due to the economic downturn. This resulted in a significant reduction in savings. In addition, the baseline motor loading was significantly below what was estimated in the baseline study, resulting in dramatically decreased savings and a realization rate of only 14% as seen in Table D- 30.
Table D- 31

~~Table D- 31~~ shows that under normal economic circumstances, the realization would have been 39% for the kiln fan VFD.

All of the motors listed on the applications were believed to be at the site and installed. Since these were all prescriptive incentives and all of the motors appeared to be at the site, the savings have been deemed acceptable and the realization rate is determined to be 100%.

Table D- 30. Site 16 Estimated & Evaluated Savings at Current Operation

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Kiln Fan VFD	80,462	11,409	14%
Premium Efficiency Motors	61,888	61,888	100%
Total	**142,350**	**73,297**	**51%**

Table D- 31. Site 16 Estimated & Evaluated Savings at Full Operation

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Kiln Fan VFD	80,462	31,648	39%
Premium Efficiency Motors	61,888	61,888	100%

Total	**142,350**	**93,536**	**66%**

4.22 Site 17

Site 17 was a lumber mill occupying slightly over 20 acres and containing several large buildings. Production is currently slowed due to the economy, but much of the facility equipment remains in operation continuously for most of the work week. Operation is currently around 112 hours per week.

Base System

Multiple measures were implemented at this site: a baghouse upgrade and a large number of prescriptive premium efficiency motor purchases.

In order to comply with new federal maximum achievable control technology (MACT) regulations, the facility needed an upgrade to reduce volatile organic compound (VOC) emissions by adding a regenerative catalytic oxidizer (RCO). Prior to sending emissions to this equipment, small wood particles need to be filtered out of the air stream. The facility could have accomplished this using three older baghouses which they already owned. These consisted of two Pneumafil and one Torrit baghouses, each with a 350 HP material handling fan. This scheme comprises the baseline system along with a cleaning blower and five exhaust fans.

The system static pressure was used along with fan curves to calculate the baseline power usage and compared to spot measurements in the initial project study. Table D- 32 shows the power and overall energy use for these units, based on measurements taken during the initial study. The brake horsepower (BHP) for each fan is significantly below the 350 rated horsepower of its drive motor because the fans would need to be sheaved down in order not to overwhelm the VOC equipment downstream. The hours of operation in the initial study were 7,800 per year, but the current operation is only 5,600 hours per year, as shown in the table.

Table D- 32. Site 17 Baseline Baghouse System

Unit	# Units	Total BHP	kW	Hours	kWh
Pneumafil Baghouse	2	241.4	191.6	5600	1,072,960
Torrit Baghouse	1	108.9	86.4	5600	483,840
Cleaning Blower	1	30	24.3	5600	136,080

Exhaust Fan	5	100	40.8	5600	228,480
Total	**8**	**350.3**	**343.1**	**5600**	**1,921,360**

The facility also uses a large number of motors. The majority of the motors are totally enclosed fan cooled units operating at 1800 RPM. The baseline is assumed to be a new, standard efficiency EPACT motor. As this is a prescriptive measure, standard savings values are used for calculations.

Project Measures

Three new baghouses were installed at the site to filter particulates out prior to scrubbing emissions in the new RCO. Each new baghouse used one 150 HP fan and no blower or exhaust fans.

The facility purchased a large number of premium efficiency motors. All of these were treated as prescriptive rebates. Table D- 33 shows the incentivized motor purchases during 2008.

Table D- 33. Site 17 Prescriptive Motors

HP	Efficiency	RPM	quantity	kWh Savings
3	89.5%	1800	1	498
5	89.5%	1800	1	607
10	91.7%	1800	5	6,100
10	91%	3600	1	1,220
15	92.4%	1800	4	6,748
20	93%	1800	2	3,566
20	92.4%	3600	1	1,783
25	93.6%	1800	1	2,759
25	91.7%	3600	1	2,759
50	93%	3600	1	5,328

100	94.1%	3600	2	26,332
150	95.8%	1800	3	51,465
938			**23**	**109,165**

Measurement & Verification Methodology

During the site visit, NCI personnel discussed the use and operation of both the baghouses and facility motors with personnel.

Each new baghouse used a new Air Tech 150 HP fan on a VFD and no blower or exhaust fans. Two of the baghouse fans were logged for several weeks of operation. The third baghouse fan operates along with the second and it was not practical to log its operation, however spot measurements confirmed that the two units had the same operating parameters.

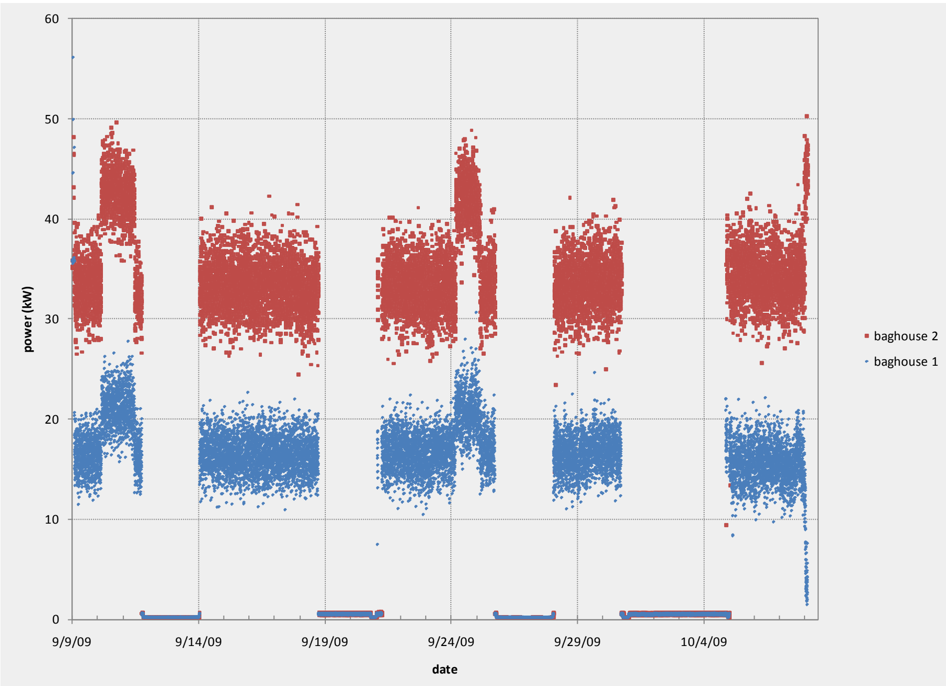
The motors installed and stored in the facility were visually examined to determine that the premium efficiency motors were on site as expected.

Evaluation Results

Facility personnel claimed that the dust collection system was running at 83,696 acfm, significantly higher than the planned 40,000 maximum acfm. The higher flow is necessary to maintain minimum required ventilation in the facility. All three bag-houses were running, although because of reduced production it would be possible to operate only two units, this was not considered the conservative choice from the point of view of safe ventilation if a problem occurred. Although additional power savings could be achieved by shutting off one of the units, the facility indicated that they had encountered some problems achieving the required air quality on a long term basis at reduced flow. A rigorous study of the airflow and operation would be required in order to ensure that reducing the number of fans would not cause air quality problems under all operational conditions.

The results of logging two of the new baghouses, 2 and 1 are shown in Figure D- 16. Baghouse 3 operates in tandem with baghouse 2. Despite the increased operation over the plan, the overall system power was close to what was predicted by the initial study.

Figure D- 16. Site 17 Baghouse Fan Power



All of the motors listed on the applications were believed to be at the site, however many of them were in the spares room rather than installed. The policy at the facility to buy premium efficiency replacement motors had been in place for about five years. The decision to buy new motors instead of rewinding is based on NEEA em2 software analysis. Around half of the motors in the spares room appeared to be premium efficiency units. Similar percentages were seen in the facility, although a detailed count was not conducted.

Table D- 34 shows the savings results. The low dust collection system realization rate is the result of reduced operating hours. When the facility returns to 7,800 hours per year of operation the savings will increase to 1,993,569 kWh per year, a 101% realization rate, unless the fans are also operated at an increased flow rate, which is not likely given that no reduction in flow had been implemented during decreased production.

Table D- 34. Site 17 Full Production Savings

Measure	Estimated Savings (kWh)	Full Production Savings (kWh)	Full Production Realization Rate (%)

Dust Collection System	1,980,943	1,993,569	101%
Premium Efficiency Motors	109,165	109,165	100%
Total	**2,090,108**	**2,102,734**	**101%**

Table D- 35. Site 17 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Dust Collection System	1,980,943	1,431,280	72%
Premium Efficiency Motors	109,165	109,165	100%
Total	**2,090,108**	**1,540,445**	**74%**

4.23 Site 18

Site 18 was a paper mill and assembly facility for pre-fabricated wood building elements spread among several buildings. Projects selected for evaluation at this site include: lighting upgrades, process improvements, compressed air upgrades and motor replacements. All but the compressed air project at the assembly facility are no longer in use. The buildings that encompassed the other projects have been sold, the plant is shut down and the new owners are looking to remove or scrap equipment and sell the structures and/or land.

Table D- 36. Site 18 Projects and *Ex Ante* Savings

Unit	kWh	Status
Lighting upgrades	275,654	Plant closed
Process Improvements	3,281,320	Plant closed
Compressed Air Upgrades	585,077	Operational

Motor Replacement	3,486	Plant closed
Total	**4,421,191**	

Furthermore production at the assembly facility is currently slowed due to the economy, but the compressed air system remains in continuous operation. The system currently operates 168 hours per week.

Base System

Even though multiple measure and projects were installed at this site, the evaluation work only relates to the compressed air system. Realization rates for the other projects are assumed to be 0%.

The replaced compressed air system at the plant was a 250 HP rotary screw compressor with a modulating slide valve to maintain 101 PSIG in the system. Baseline measurements demonstrate that the machine drew about between 175 and 185 kW at all times during production. When there is not production activity the machine operates to supply a much lower volume of compressed air. The modulating slide valve system saves compressor power at low loads, but far less than a system controlled with a variable frequency drive. Unloaded, a machine controlled with a modulating slide valve still consumes 70% of its rated-flow power or approximately 130 kW in this case.

In comparison, new machine modulated with a VFD consumes power roughly proportional to compressed air production throughout the modulating range.

Project Measures

The replacement air compressor is a Quincy Northwestern QNW-V-300 machine with a rated 300 horsepower motor. This machine is 20% larger than the replaced equipment, but uses a VFD to modulate output. As a result, when unloaded this machine uses far less power than the machine it replaces and when loaded it is more efficient than the machine it replaces.

Measurement & Verification Methodology

During the site visit, NCI personnel discussed the use and operation of the compressed air system with facility personnel to determine operational parameters of the system. We visually inspected and verified that the project equipment was installed and operating. We also installed true power and amp data loggers on the air compressor to trend data for 20 days.

Evaluation Results

Facility personnel confirmed that the compressed air system continues to operate continuously 24/7, in part to pressurize the fire safety system. The plant operates 24/5 from 6:00 Monday to 16:30 Friday afternoon. Prior to 2008 the plant operated 24/7, and the plant manager expects that production will ramp up in 2010 and 2011.

Even with current production the compressed air system is operating at lower capacity than when the application was submitted. Based on *ex ante* measured power of the baseline system, NCI estimates the system operated at 85% of rate compressed air flow (about 1000 cfm @ 100 PSIG). Based on our evaluation measurements we estimate the current system is producing about 500 cfm when loaded or 30% of the rated capacity of the larger equipment. Furthermore, the new compressor transitions frequently between loaded and unloaded conditions as shown in Figure D- 17.

Figure D- 17. Site 18 Air Compressor Amps (mid-week)

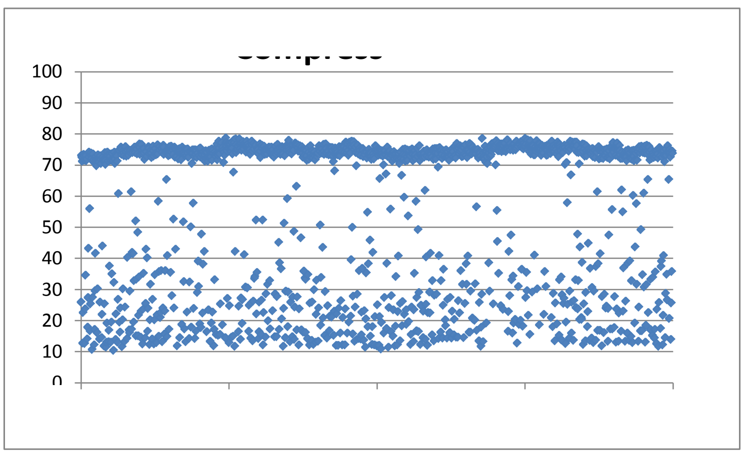


Table D- 37 shows the savings results. The results show savings for current operations of like-for-like air production for current operations. The comparison is between a 250 HP modulating rotary screw compressor versus the installed machine.

The high realization rate is due to lower compressed air demand during current economic conditions. The advantage of the variable speed motor over slide valve control increases at lower demand.

Table D- 37 shows the predicted savings of the new equipment were it operating at increased compressed air demand as derived from pre-installation measurements. The difference between the ex ante and predicted savings hinges on the assumptions for hours of part load and specifically low-load operation. Navigant Consulting has inadequate information to make this a strong estimate.

Table D- 37. Site 18 Estimated & Evaluated Savings

Unit	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Lighting upgrades	275,654	0	0%
Process Improvements	3,281,320	0	0%
Compressed Air Upgrades	585,077	906,000	155%
Motor Replacement	3,486	0	0%
Total	**4,421,191**	**906,000**	**20.5%**

Table D- 38. Site 18 Estimated & Predicted Savings – Economy Corrected

Unit	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Lighting upgrades	275,654	0	0%
Process Improvements	3,281,320	0	0%
Compressed Air Upgrades	585,077	468,200	80%
Motor Replacement	3,486	0	0%
Total	**4,421,191**	**468,200**	**10.6%**

4.24 Site 19

Site 19 was a wood products manufacturing company making engineered wood and lumber products. At this particular site the company uses rotary material dryers to produce material for particle board. Multiple measures were implemented at this site: a VFD on the facility's regenerative catalytic oxidizer (RCO) induced draft (ID) fan, a wood fired rotary dryer, a lighting upgrade, and 24 prescriptive premium efficiency motor purchases. The facility had recently reduced operation from five to four days a week because of the economic downturn.

Base System

Multiple measures were implemented at this site: a VFD on the facility RCO ID fan, a wood fired rotary dryer, a lighting upgrade, and twenty-four prescriptive premium efficiency motor purchases. Each measure has its own baseline.

RCO ID fan

In order to meet new EPA MACT (maximum available control technology) requirements the facility replaced four of five existing scrubbers with a single regenerative catalytic oxidizer (RCO). This system required the installation of a new induced draft (ID) fan to provide air flow to the RCO. The base ID fan system would use an inlet vane to vary flow to the RCO with varying production levels. Some flow control is required because reduced flow is required during startup and also because the system must be oversized by 20% in order to meet regulatory emissions requirement in the case of excess production.

At full production the fan would run 8,760 hours a year; in reduced production periods operation is expected to be only 5,760 hours per year. The RCO must run when the facility is operating.

Rotary Dryers

The baseline for this measure is the existing system of 6 gas-fired rotary dryers plus *required* upgrades to the wet electrostatic precipitators (WESPs) and regenerative thermal oxidizer (RTO) to comply with EPA regulations. The latter two elements of the baseline are included because implementing the proposed measure would affect the scale or necessity of this new equipment. The baseline rotary dryers include more than 10,100 HP of motors. The required WESP upgrades total more than 120 kW of equipment and the RTO upgrades are another 1,220 *brake* HP of motors. The Energy Analysis Report cites 6,000 annual hours of operation for all baseline dryers and their component motors.

Lights

The lights in the facility were originally a combination of 400 and 1000 watt metal halide high bay fixtures as well as some T12 fluorescent units. The initial study used wattages that indicated standard magnetic ballast with efficient T12 lamps. However, since there was no documentation of why standard efficiency ballasts were assumed, Navigant has used efficient magnetic ballasts along with efficient lamps in the baseline. No occupancy sensors were in place on this base system, and all of the fixtures were left on 24 hours a day, seven days a week, regardless of facility operation.

High Efficiency Motors

The facility uses a large number of motors. The majority of the motors are totally enclosed fan cooled units. The baseline is assumed to be a new, standard efficiency EPACT motor. As this is a prescriptive measure, standard savings values are used for calculations.

Project Measures

RCO ID fan

The facility installed a variable frequency drive (VFD) on the new RCO ID fan instead of using an inlet vane damper. This allows for continuous variation in airflow at a reduced power consumption compared to a damper.

Wood-fired Rotary Dryers

The rotary dryer project removal of existing gas-fired equipment and installation of a large wood-fired replacement dryer system with almost 7,200 HP of motors. The wood-fired system does not require WESPs so that equipment type is not necessary. The new RTO equipment requirement is also much smaller with the wood-fired dryer, requiring only 549 brake HP versus 1220 brake HP that would have been needed with the six existing gas-fired dryers. Operating hours are assumed to remain unchanged and there is no mention of increased or decreased capacity.

Lights

The metal halide lights in the facility were replaced with a combination of four and six lamp high bay, high output T5 fixtures. The four foot T12 fixtures were replaced with a standard output T8 fixtures, on a one-for-one basis. Eight foot T12 fixtures were replaced with eight foot fixtures containing twice as many reduced output T8 lamps. All of the new fixtures were attached to occupancy sensors.

High Efficiency Motors

The facility purchased 24 premium efficiency motors. All of these were treated as prescriptive rebates. Table D- 39 shows the incentivized motor purchases during 2009.

Table D- 39. Site 19 Premium Efficiency Motors

HP	Efficiency	RPM	quantity	kWh Savings
2.0	88.5%	1200	2	634
2.0	87.5%	1800	1	317
3.0	89.5%	1800	3	1,494

5.0	89.5%	1200	2	1,214
5.0	89.5%	1800	6	3,642
7.5	91.7%	1800	1	1,116
10.0	91%	1200	1	1,220
10.0	91.7%	1800	2	2,440
20.0	93%	1800	1	1,783
20.0	91.7%	3600	2	3,566
25.0	93%	1200	1	2,759
25.0	93.6%	1800	1	2,759
100	95%	1200	1	13,166
			24	**36,110**

Measurement & Verification Methodology

During the site visit, Navigant personnel discussed the use and installation of all of the new equipment with facility personnel. Installation of all of the new equipment was confirmed, along with hours of operation of the facility. Spot measurements of power consumption were taken on the new RCO ID fan. Additionally measurements were taken on some of the dryer system affiliated equipment: RTO ID fan, a dryer ID fan, and a 250 HP drive motor to determine loading and operation. Measurements on the WESP fans and discharge fan dryers were not possible due to accessibility problems and because some units were off. Current loggers were installed on the VFD of the RCO ID fan to determine usage. Logging took place over a one month period during September and October 2009 to obtain a good view of overall operation. Current loggers were also installed on four area lighting power feeds during this time. Facility wiring data and maximum power use were used to determine the number of lighting fixtures on the circuits logged.

Evaluation Results

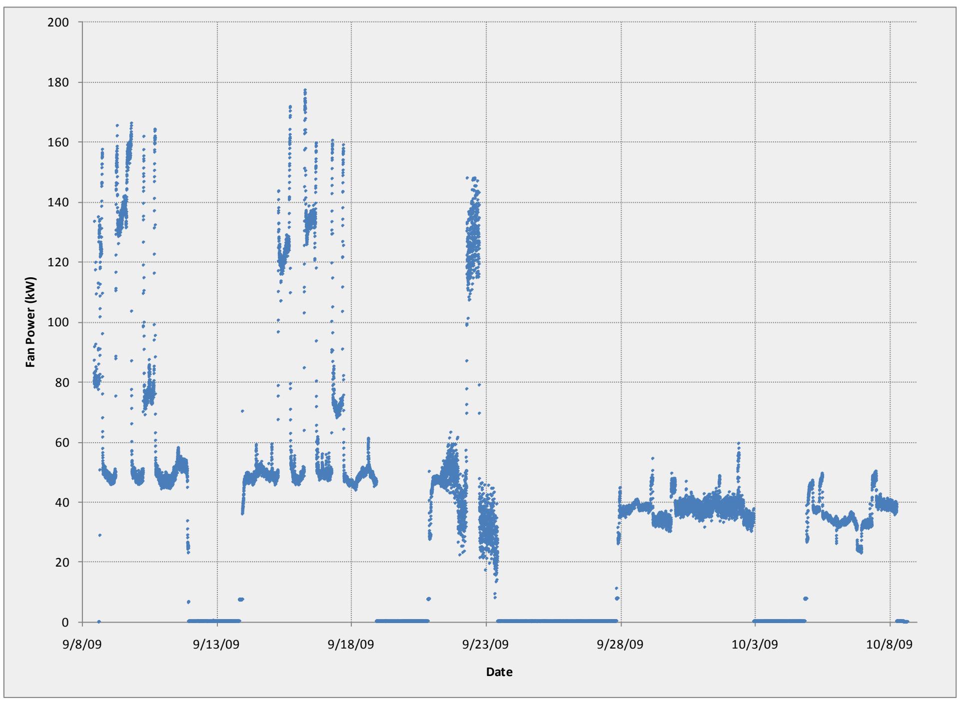
All of the equipment listed on the applications was believed to be at the site and installed.

RCO ID Fan

Figure D- 18 shows the operation of the RCO ID fan over the measurement period. As can be seen in the plot, the fan was operating well below capacity much of the time. The brake HP in the inlet vane situation was estimated using the fan curve for the unit and adjusted for motor efficiency to provide a baseline power usage under varying conditions. This was compared to the measured power consumption to estimate savings for this measure.

It should be noted that savings are affected by the current reduced operation. During shutdown periods savings would be expected to be reduced, while during operation they would expect to be increased. There is not expected to be a severe overall effect on operation, although only monitoring during full operation could determine this for certain. Even during full operation sometimes reduced flows would be expected.

Figure D- 18. Site 19 RCO ID Fan Power



Rotary Dryers

Navigant consulting observed the new dryer system and reviewed the calculations used in the ex-ante estimates. Several calculation errors, such as misapplied motor loading factors and motor efficiency, result in verified savings lower than ex-ante estimates.

Lights

Logging data indicated that the high bay T5 lights were on only 55% of the time on average, compared to an assumed 75% on-time. This has resulted in a significant increase in savings relative to initial estimates, although savings may be reduced during times of heavier operation. However, since a 45%reduction is not unusual for similar facilities, it has been taken as typical operation. The T8 fixtures were not logged and 75% operation has been taken to be a reasonable estimate for these areas.

High Efficiency Motors

Since these motors were prescriptive incentives and all of the motors appeared to be at the site, the savings have been deemed acceptable and the realization rate is determined to be 100%.

Table D- 40. Site 19 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
VFD on ID Fan	279,906	780,785	279%
Wood Fired Rotary Dryer	7,934,362	6,490,000	82%
T5 HO High Bay Lights	1,656,533	2,125,463	128%
Premium Efficiency Motors	36,110	36,110	100%
Total	**9,906,911**	**9,432,358**	**95%**

4.25 Site 20

Site 20 was a wood products plant which refines logs into veneer. The facility includes a system to supply compressed air for machine operation and air powered tools. Facility operation is currently around 80 hours per week, but the compressed air system operates 24 hours a day, six days a week, with the exception of a few holidays.

Base System

Multiple measures were implemented at this site: a compressed air system upgrade and five prescriptive premium efficiency motor purchases.

The facility formerly used an old 150 HP modulating rotary screw compressor to provide air to the plant. This QNW 740 D/S also had a backup 150 HP Sullair 25-150L. A Zurn 183-P heated dessicant dryer was used to reduce moisture in the output air.

The facility uses a large number of motors. The majority of the motors are totally enclosed fan cooled units operating at 1800 RPM. The baseline is assumed to be a new, standard efficiency EPACT motor. As this is a prescriptive measure, standard savings values are used for calculations.

Project Measures

A new variable speed Quincy Northwest QNW-V-150-F 150 horsepower compressor was installed and the old QNW 740 D/S was kept as a backup system. The new air compressor also has a small 7.5 HP variable speed drive on its cooling fan. A new Zeks 800Z desiccant dryer was installed with controls to regenerate the desiccant only when needed.

Site 20 purchased five premium efficiency motors. All of these were treated as prescriptive rebates. Table D- 41 shows the incentivized motor purchases during 2009.

Table D- 41. Site 20 Prescriptive Motors

HP	Efficiency	RPM	quantity	kWh Savings
7.5	91.7%	1800	2	2,232
25	93.6%	1800	1	2,759
75	95.4%	1800	1	9,385
150	95.8%	1200	1	17,155
265			**5**	**21,531**

Measurement & Verification Methodology

During the site visit, NCI personnel discussed the use and installation of both the compressed air system and the premium efficiency motors with facility personnel. The premium efficiency motors were believed to be installed and operating, although it was not possible to identify individual motors within the operation.

Spot measurements of power usage were taken on both the air compressor and the dryer and three weeks of data logging was performed to determine operation over a longer period of time. The first week included some shut down time over the Christmas holiday, but the facility operated normally over the remainder of the measurement period, including New Years Day.

Figure D- 19 shows air compressor operation and projected operation of the old compressor for the same airflow. The old backup Sullair compressor would not have been needed to meet airflow demands under the observed operational conditions and so was not included in the baseline calculations. Operation appears to have been adjusted since the baseline study was performed, so the study's measured data was not used as a baseline. Instead the manufacturer's data for the old compressor was used to estimate power use under the observed airflow conditions based on the measured data. The power measurement of the new air compressor included the power for the cooling fan, but this was not a significant percentage of system power and so subtracting it from power use prior to estimating air flow is not believed to significantly improve the accuracy of the calculation considering the difficultly of determining its operation.

Figure D- 19. Site 20 Measured and Baseline Air Compressor Power Consumption

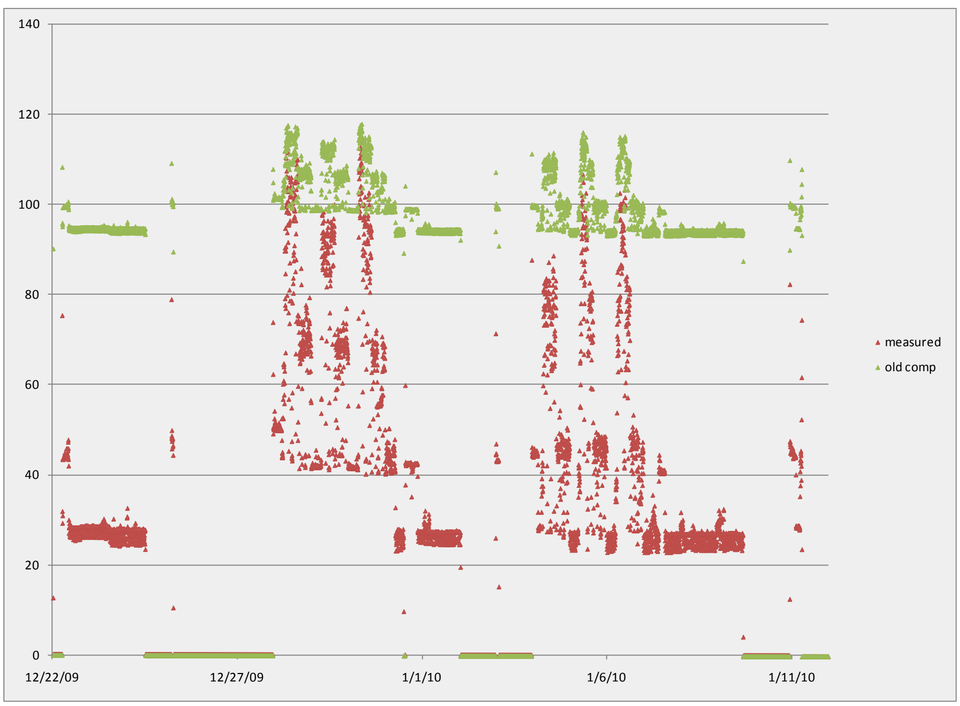
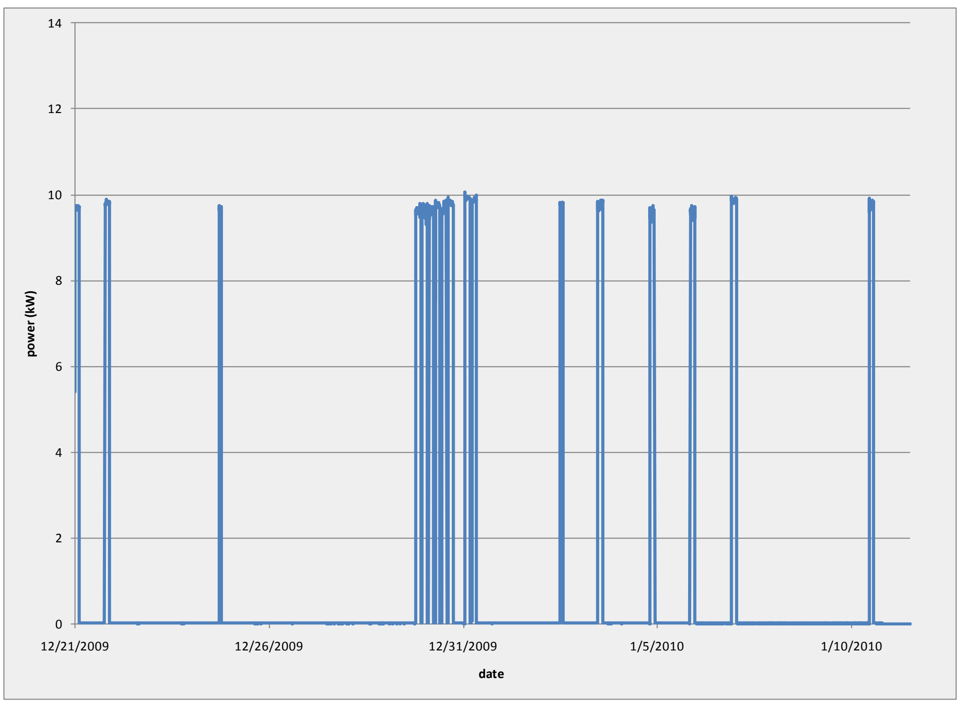


Figure D- 20 shows the observed dryer operation. These data were compared to the projected use in the initial project evaluation. The baseline use of 154,000 kWh provided in the report for the old dryer, which corresponds to around 2,960 kWh/week and an average use of 17.6 kW. Since the old dryer was not available for measurement, and was not controlled as the new unit was, this baseline was considered to be reliable. The initial study used ambient humidity data to estimate dryer savings. The observed data were compared to the December and January savings estimates, which averaged 1.14 kW. The measured data averaged to 1.13 kW, very close to the estimate provided. The adjustments for humidity at different times of the year were made as in the initial study along with the assumption of only 50 weeks of operation allowing for maintenance shutdowns. These adjustments resulted in a total use of 15,266 kWh/year. The baseline was also adjusted for 50 weeks of operation, resulting in a baseline of 149,781 kWh/year and savings of 134,515 kWh/year.

Figure D- 20. Site 20 Air Dryer operation during sample period



Evaluation Results

The compressed air system was installed and operating as expected. The new compressor was verified to be saving 351,477 kWh/year and with a realization of 115%. Both the compressor and dryer operation was as expected, but there were short down periods for maintenance so savings are based on 50 weeks a year.

The adjustments based on measured dryer operation data resulted in a total use of 15,266 kWh/year. The baseline was also adjusted for 50 weeks of operation, resulting in a baseline of 149,781 kWh/year and savings of 134,515 kWh/year. The new compressed air dryer was verified to be operating with a 97% realization rate. These results are summarized in Table D- 42.

All of the motors listed on the applications were believed to be at the site and installed, although it was not possible to pinpoint individual units. Since these were prescriptive incentives and all of the motors appeared to be at the site, the savings have been deemed acceptable and the realization rate is determined to be 100%.

Table D- 42. Site 20 Estimated & Evaluated Savings

Measure	Ex-Ante Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
New Air Compressor	304,689	351,477	115%
New Compressed Air Dryer	137,970	134,515	97%
Premium Efficiency Motors	21,531	21,531	100%
Total	**454,190**	**507,523**	**112%**

4.26 Site 21

Site 21 was a wood products facility. The facility processes particleboard and plywood and is currently operating at reduced production due to economic conditions. No equipment has been permanently removed and production is expected to return to full capacity when market conditions permit it.

Base System

The facility uses a regenerative thermal oxidizer (RTO) to eliminate volatile organic compounds (VOCs) from its airstream in compliance with the new EPA maximum achievable control technology (MACT) standards. An induced draft (ID) fan is used to pull gases through the RTO.

The fan could use a variable inlet vane (VIV) damper to vary flow, which is taken as the base case for this project.

Two separate compressed air system at the facility were located in separate areas. The particleboard plant used a 300 HP QNW-1500-A modulated air compressor and a Pneumatech PE-1600 heated regenerative dryer, with two rarely used compressors available as backup. The plywood plant operated two similar 150 HP modulated compressors, a QNW-740-B and a QNW-751-D/S along with a Zeks 2000-HSE cycling refrigerated dryer. The original baseline total air usage was an average 2,098 cfm, with a peak of 2,705 cfm.

Project Measures

Two measures were implemented at the site: a VFD was installed on an RTO ID fan and the two compressed air systems were linked to reduce overall usage.

The facility installed a VFD on the ID fan for the RTO. This fan operates any time the RTO is in use, whenever the plant is operating.

The two compressed air systems were linked together to reduce overall operation. In addition some air knives were installed to reduce demand on the system and two 10 HP blowers were installed to supply increased air pressure to them. The regenerative dryer in the particleboard plant was replaced with a Zeks 2000HSF cycling refrigerated dryer.

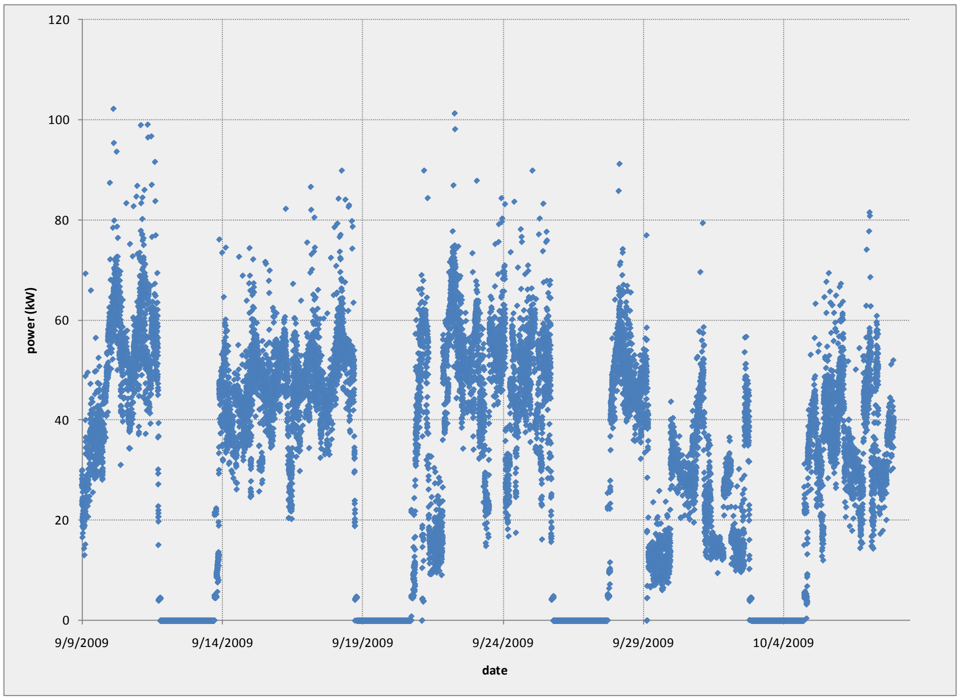
Measurement & Verification Methodology

During the site visit, NCI discussed the use and installation of the new systems with facility personnel. All of the equipment was installed and operating as expected, although usage was somewhat reduced from the predicted conditions because of the economic downturn.

Fan VFD

Current was measured for a month in 2009 and converted to power using spot measured power factor and voltage. Power was also logged for some of the time and compared to the estimates from current measurements. Comparison of these two measurements indicates that the current derived power measurements are suitable for analysis. Figure D- 21 shows the ID fan operation during the evaluation period. Multiple measurements of the fan power at two speeds indicated an affinity law exponent of 2.54, which was used to estimate fan speed from power measurements.

Figure D- 21. Induced Draft Fan Power



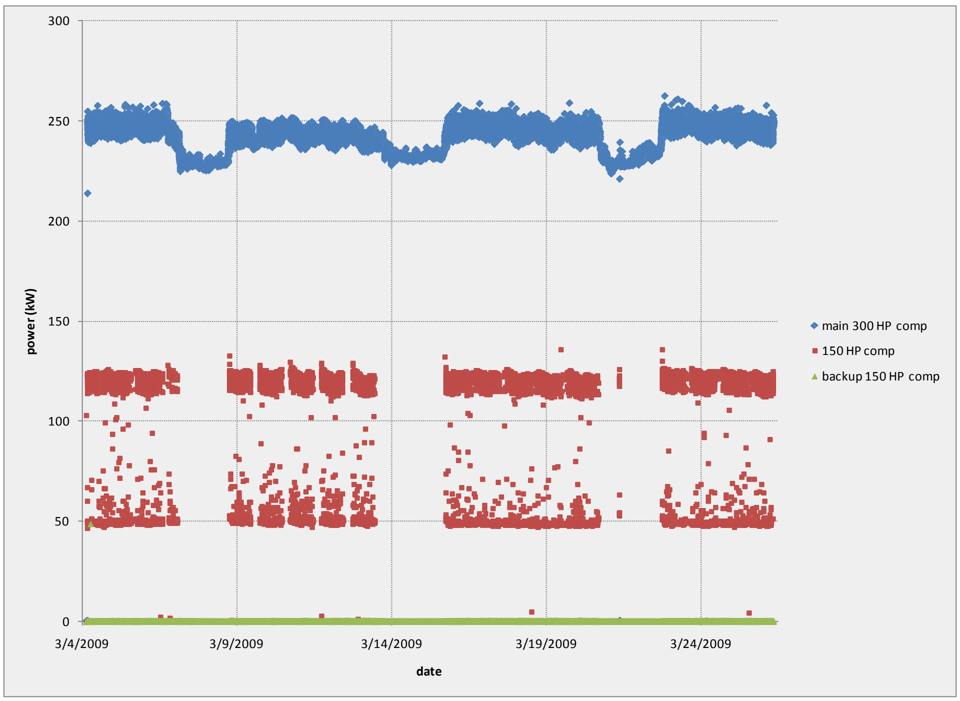
The ID fan operated up into the 90%+ speed range. Brake horsepower information obtained from the manufacturer's fan curves was compared to onsite measurements. Based on this, the actual operational power was around 86% of that predicted from the curves, indicating the static pressure was lower than predicted by the original study. Because the manufacturer's curves were only available under certain conditions it was assumed that:

- Above 90% speed, power consumption was similar with and without the VFD, in part because of the expected 3% usage of the VFD itself;
- The variation in power consumption with a variable inlet vane was approximately linear between available data points;
- And the 86% power usage relative to the assumed conditions held for the inlet vane case.

Compressed air system

Based on the four weeks of logged current data from all the air compressors at Site 21, compressed air use has decreased since the initial ATAC study was performed.

Figure D- 22. Site 21 Air Compressor Operation



The original baseline total air usage was an average 2,098 cfm, with a peak of 2,705 cfm. The restructuring of the piping and replacement of the dryer were expected to reduce this by an average of 125 cfm and 70 cfm peak. Installing the air knives, and two 10 HP blowers, was expected to further reduce airflow by an average of 174 cfm and a peak of 222 cfm. Based on this, an average usage of around 1,800 cfm would be expected after the project's installation. However, the logged data showed an average air usage of only 1,364 cfm, 25% below the predicted value. This is due to reductions in production during the economic downturn.

It is difficult to disaggregate air usage in the particleboard and plywood plants without individual flow data. However it is reasonable to make the following assumptions:

- One of the two compressors in the plywood plant would have been on over weekends and

- The second compressor in the plywood plant would have been on when the plant was in use at least in an unloaded but modulated state if the two systems were not connected.

In addition, similar ratios of air usage may be attributed to the two plants in both the reduced output and previous production conditions. During the original baseline observations, the particleboard plant used an average of around 46% of the air and the plywood plant used the remaining 54%. Given the uncertainties of this ratio, half the air usage is attributed to each plant in this analysis. This would mean each plant has an average of only 682 cfm. Peak flow was slightly above 2,400 cfm, which would imply around 1,200 cfm for each plant. This peak airflow for the plywood plant is in excess of the capacity of a single 150 HP compressor. It does not exceed what the 300 HP compressor could supply to the particleboard plant. Peaks above the capacity of one 150 HP compressor were seen regularly and so it is safe to assume that both 150 HP units would have been operating at these conditions in the base case under the current operating requirements.

Adding a single 150 HP compressor to the installed load, even at its modulated unloaded power, would add 86 kW to the system on a continuous basis, for a total of 753,360 kWh/year. If the unit was shut down half the time, it would add 376,680 kWh/year. Based on the amount of time the system was actually at peak power, the second compressor could be expected be running loaded around 33% of the time (361,350 kWh/year) and unloaded 14%-67% (105,470 kWh/year-504,751 kWh/year) of the time, depending on if it was shut off over weekends.

Three conditions were observed for the compressed air system, 33% of the time it averaged a flow of 2161 cfm, 14% of the time it averaged a lower flow of 1442 cfm, and 53% of the time the small compressor was shut off and there was a total flow average of 467 cfm. Assuming that each plant used about half of the flow and using these values to estimate power from the compressor curve, assuming at least one of the 150 HP compressors was operating at all times, results in an annual baseline consumption of 3,118,297 kWh/year.

In addition to the current compressed air power usage of 2,109,328 kWh/year, the two added blowers can be expected to consume 11 kW on average, reducing savings by 96,360 kWh/year. The dryer replacement reduced usage by an average of about 8 kW based on specifications and provided measurements, resulting in a reduction of 70,080 kWh/year.

Evaluation Results

Using the assumptions described above for the ID fan project, the estimated baseline power was 421,956 kWh/year compared to a current consumption of 275,828 kWh/year. This corresponds to a savings of 146,364 kWh/year, a 94% realization rate. This is not expected to vary significantly with increased production because the unit is already running with fairly high airflow, and any increase in airflow is likely to be balanced by increases in uptime.

The compressed air system is difficult to disaggregate. If the plywood plant is assumed to require continuous air, and the loading estimates above are used, the verified savings is

1,008,969 kWh/year for the compressed air system. In addition to this, the two added blowers can be expected to consume 11 kW on average, reducing savings by 96,360 kWh/year. The dryer replacement reduced usage by an average of about 8 kW based on specifications and provided measurements, resulting in a reduction of 70,080 kWh/year. The overall project savings are therefore 842,529 kWh/year, an 87% realization rate. Under full operation this would be expected to increase to closer to the original estimate, however because of the significant uncertainties it is not possible to precisely calculate savings for these conditions.

Table D- 43. Site 21 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
VFD on RCO ID fan	154,915	146,364	94%
Compressed Air System Improvements	960,164	842,529	88%
Total	**1,115,079**	**988,893**	**89%**

4.27 Site 22

Site 22 is a corporate office and manufacturing campus with a central chilled water plant. The site received incentives for a project to install equipment and improved controls to optimize the condenser water temperature for the chillers and recover heat from the condenser water to offset process heating elsewhere in the facility. The measure was installed, but then promptly disabled due to poor execution.

Table D- 44. Site 22 Project *Ex Ante* Savings

Unit	kWh	Status
Condenser Water Optimization	1,364,304	Disabled
Total	**1,364,304**	

The condenser water project was not eligible for ETO incentives for implementation, but the Energy Trust did fund half of the study, therefore, the ETO wishes to claim savings from this project, if there are any.

Base System

The baseline system for this measure is a cooling tower rejecting heat from the chillers and process heat from boilers used to preheat boiler make-up water and water used in a reverse osmosis (RO) process.

Project Measures

The optimized condenser water controls were supposed to recover heat from condenser water to pre-heat boiler make-up water and to warm water used in a RO process. Due to heat extraction for these other purposes, the condenser water could be cooled below what the cooling tower might otherwise achieve with far less power input to cooling tower fans. Cooler condenser water lets chillers operate more efficiently. Controls were to limit condenser water to a minimum 72°F. Algorithms and equipment, that were to limit lower condenser water temperatures, failed with large economic consequences. As a result, these improvements were disabled.

Measurement & Verification Methodology

Navigant personnel discussed this project with the operating engineer at the chilled water plant. Though not working in this position at the time of the project, he described the intent of the measure, its failure and the decision to disable the new controls. Because the measure was not enabled, no further methods were developed to measure impacts.

Evaluation Results

At the time of our EM&V activities the project controls were still disabled, though new facility staff were considering a review of the project with the potential to re-enable the project. The savings and realization rate for the condenser water optimization is assumed to be 0%. The ETO may wish to re-evaluate this measure at a later date if efforts to re-enable controls are successful.

4.28 Site 23

Site 23 is a large paper mill producing a variety of paper products. The efficiency project at the site involved removing from active service a redundant 600 HP vacuum pump from one of the paper machines. The site did not receive an incentive for this project as there was no cost associated with it. However, the project was inspired by an ATAC study that did receive a Production Efficiency incentive in 2008.

Base System

The site employs several vacuum zones throughout the stages of the paper formation. The Production Efficiency study indicated that more vacuum than was necessary was being drawn throughout the process. The final high-vacuum zone, which held a vacuum pressure of approximately 21 inches of mercury, was creating drag on the forming wire, increasing the motor power required to run that process.

The base system assumes this to be unchanged.

Project Measures

The site removed the final vacuum zone from the paper making process on this paper machine. The removal of this zone allowed the site to decommission a 600 HP vacuum pump that had been running 8760 hours per year to maintain the desired vacuum pressure. It also reduced the required motor power for the forming wire process. There was no cost associated with the decommissioning of the vacuum pump.

Measurement & Verification Methodology

NCI personnel discussed the retrofit with site personnel in April 2010 to verbally verify that the process continued without significant change since the retrofit. Hourly amp data from the site's power management system was provided for one year prior to the retrofit and three months after the retrofit for both the pump and the forming wire motors. This data confirmed that the pump was no longer operating after the project completion and that the forming wire motors recognized decreased loading.

Savings from the pump were calculated based on its average power use for the prior year.

Savings due to the interactive effect of on the forming wires were based on the average power before and after the retrofit with the assumption that current production levels remain unchanged.

Evaluation Results

Savings due to removal of the high vacuum zone were found to be 3,646,000 kWh/year, which is 100% of the estimated savings as seen in Table D- 45. In this case, the estimated savings had been based on a detailed post-inspection report, *not* based on the initial ATAC study. The data used to estimate the savings was the same data used to verify savings resulting in identical savings and differences between NCI's verified savings and the estimated savings are due to rounding.

There is a possibility of increased or decreased savings as the mix of paper types produced is in constant flux. Discussion with site personnel indicate that the major paper types produced have not changed since the measurement periods. While future changes are likely, it is unknowable if they would increase or decrease savings.

Table D- 45. Site 23 Estimated & Evaluated Savings

Measure	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
Vacuum pump removal	3,646,117	3,646,000	100%
Total	**3,646,117**	**3,646,000**	**100%**

4.29 Site 24

Site 24 was a large electronics manufacturing facility. The campus is comprised of more than a dozen buildings including cleanroom manufacturing facilities. There were a large number of makeup air handlers (MAHs) and return air handlers (RAHs) in different areas, some of which were affected by projects under the program.

In 2008, eleven projects were incentivized under the Energy Trust Production Efficiency Program. Table D- 46 shows the measures and their expected savings according to the initial ATAC studies.

Table D- 46. Measures Included in the Evaluation

Measure Number	Project Description	Estimated Savings (kWh)
EEM1	Compressed Air Dryer Controls	998,446
EEM2	CW Temp Reset/Cooling Tower Ops	817,941
EEM3	MAH Prefilters	421,788
EEM4	MAH Fan Wall Conversion	573,399
EEM5	RO Pump VFDs	223,711
EEM6	RODI Pump Consolidation	148,696
EEM7	RAH Prefilters Phase 2	690,538
EEM8	MAH Replacement	108,862
EEM9	MAH Humidity Controls Removal	121,757
EEM10	Exhaust Control for Web Press Fans	88,181
EEM11	Lighting	1,083,759
Total		5,277,078

A Supervisory Control and Data Acquisition (SCADA) system records data for systems throughout the location. As such, it is possible to evaluate some projects through a thorough review of system trend logs, circumventing the need to log their operation. However, not all of the projects had adequate SCADA data to accurately calculate savings without onsite measurements.

Prior to the site visit, Navigant coordinated with the PDC to create verification plans and obtain site data. This process streamlined the site visit and decreased the amount of time required of site personnel to aid with the onsite verification work.

EEM 1 Compressed Air Dryer Controls

Base System

The facility contained ten dual desiccant compressed air dryers in three buildings. Each of these dryers consisted of two towers and was designed to perform a compressed air purge cycle every two minutes to keep the desiccant beds from saturating.

Project Measure

This project involved new dew point air dryer controls in three buildings to control the purge cycle on the eight dual desiccant tower dryers. The purge was set to take place based on a dew point of -45 °F instead of the factory set two minute cycle. The compressed air system in one of the buildings, including two dryers, was removed between the time of the project and the time of this verification. This left a total of eight dryers operating, six of which were affected by this project.

Measurement & Verification Methodology

The facility's SCADA system does not track the dryer purge cycling. The 5 volt control signal for the purge cycle was monitored for a period of a month on one dryer in each of the two buildings with operating dryers. The two dryers in the third building had been shut down as part of another project.

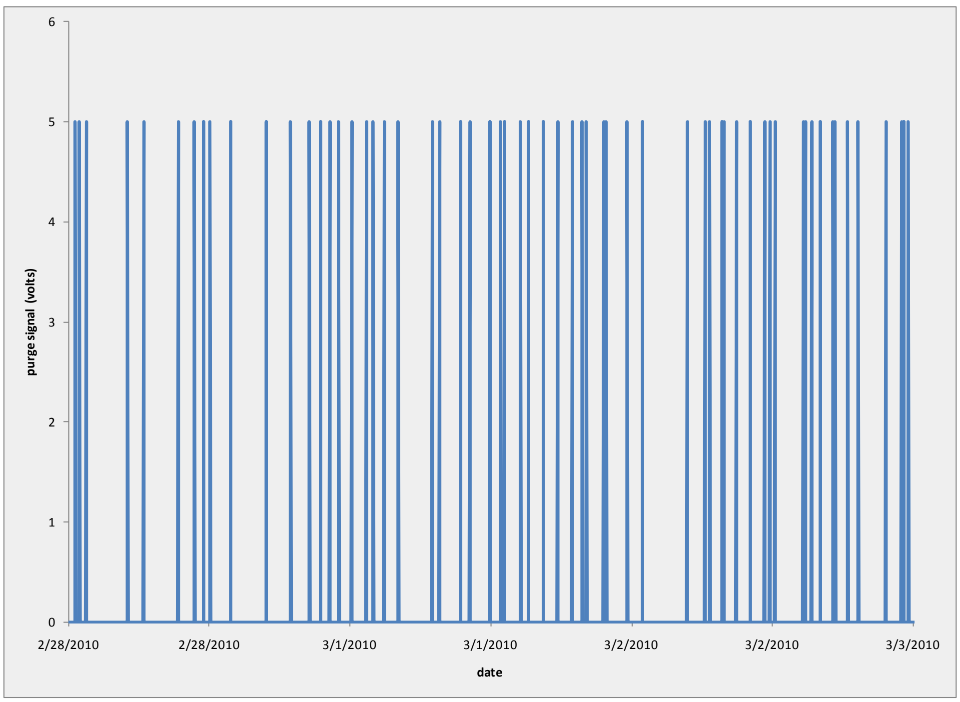
The power of 0.25 BHP per scfm with a motor efficiency of 92% provided in the initial report was used to calculate the energy usage of 0.203 kW/scfm during a purge cycle. The purge volumes of 425 scf in one building and 880 scf in the building feeding the others used in the initial study were accepted as reasonable for the dryers affected by the project. The baseline of one purge cycle every two minutes was used to calculate the baseline power use. The third building was presumed to be shut off in the new base case, so the 150 scf of purge flow there was excluded from the baseline.

Evaluation Results

During the initial inspection, from which the estimated savings for EEM1 were calculated, the dryer purge was tracked over a relatively short period of time of less than an hour, and found that dryers in two of the buildings experienced 2-3 regeneration cycles per hour while the dryers in the building which fed air to the other two performed 6-8 cycles per hour. The increased cycles in the last building were expected because air there had not been previously dried, whereas the other two received air from its dryers.

The monitors on the dryers showed significantly less use overall than the post-installation study had found. Although the purge cycle of once every twelve minutes in the smaller building and once every 7.5 minutes in the building with the main dryers was observed at some times, the overall purge cycles were much less frequent than this, occurring only around once an hour on average. This is most likely due to variations in air usage with varying building operation and occupancy during a normal business week. Figure D- 23 shows the signal over a three day period (Sunday-Tuesday) for one of the dryers. The variations in operation can be observed during over time. The full monitoring period is not shown because of the resolution of the graph.

Figure D- 23. Site 24 Dryer Purge Signal



Based on the monitored purge cycles and the shutdown of the two dryers in one building as part of an unrelated project, the savings was found to be 1,123,030 kWh/year, 112% of the claimed savings value. The baseline usage was adjusted to account for the reduced number of dryers in order to calculate the current savings but the savings claimed on the application were not adjusted.

EEM 2 Cooling Water Temp Reset/Cooling Tower Operations

Base System

The facility has four cooling towers on separate buildings. All of these cooling towers operate on 4,160 V three phase power. The towers provided water at a set point of 70 °F for three of the buildings and 74 °F for the fourth building. They operate independently. All of the cooling towers supply water, much of which is subsequently cooled further by chillers for various processes.

Project Measure

This project installed software to decrease the chiller condenser water return temperatures to 65 °F, except in one building which was intended to supply water at 60 °F in cooler weather, and adjust the cooling tower sequencing for all four chilled water plants. Energy savings were primarily attributed to a reduction in the cooling towers' set point allowing for decreased cooling by the chillers. Additional savings were expected by decoupling the chillers from the cooling towers to increase cooling tower capacity.

Measurement & Verification Methodology

To verify this measure, NCI reviewed the data from the SCADA system and interviewed site personnel. Data for the chiller operation and water temperatures since the initial verification was used to determine if any set points had changed. Screenshots from the SCADA system also showed current set points for the cooling towers' operation. SCADA data showed that the lower set points had not been in use for the last year.

The initial study assumed 0.025 kW/ton for cooling tower savings, which appears reasonable but is difficult to verify. The SCADA system provided cooling water flow data and weather data. Specifications on the chillers and cooling towers were used to estimate efficiency. The SCADA system also includes chiller motor current and water temperatures for the inputs and outputs of the chillers and condenser. The data from the SCADA system do not include information on cooling tower operation, although the initial verification included measurements of fan power.

Data for the chiller operation and water temperatures since the initial verification was used to determine if any set points had changed. Screenshots from the SCADA system also showed current set points for the cooling towers' operation. The SCADA data provided did not include current or power for the tower, so it would be necessary to find submetering data for the towers to confirm this savings value.

Evaluation Results

The facility has encountered problems with the software used for this measure and the cooling towers are currently operating with their original set points and controls. SCADA data from the cooling towers showed that the lower set points had not been in use for the last year.

Facility personnel indicated that a software glitch was causing the cooling towers to shut down and so it had to be disabled. The facility intends to reinstate the use of this measure, but they have not been able to get the software fixed as of this time, so there are no savings currently. Once this measure is re-enabled, it would be necessary to obtain updated operational data from the SCADA system to assess savings due to the project. However since it has been disabled for over a year, it is reasonable to report zero savings for the project.

EEM 3 MAH Prefilters

Base System

One of the buildings at the facility included two makeup air handlers (MAHs) serving a cleanroom area as part of an air filtration system. These MAHs included pre-filters to shield the pre-heating coils from dirt infiltration, which causes excess pressure drops across the fans.

Project Measure

The facility had the preheat coils cleaned which reduced the overall pressure drop. Subsequent to preheat coil cleaning, the facility installed new pre-filter racks on the two MAH systems to reduce the pressure drop across the preheat coils.

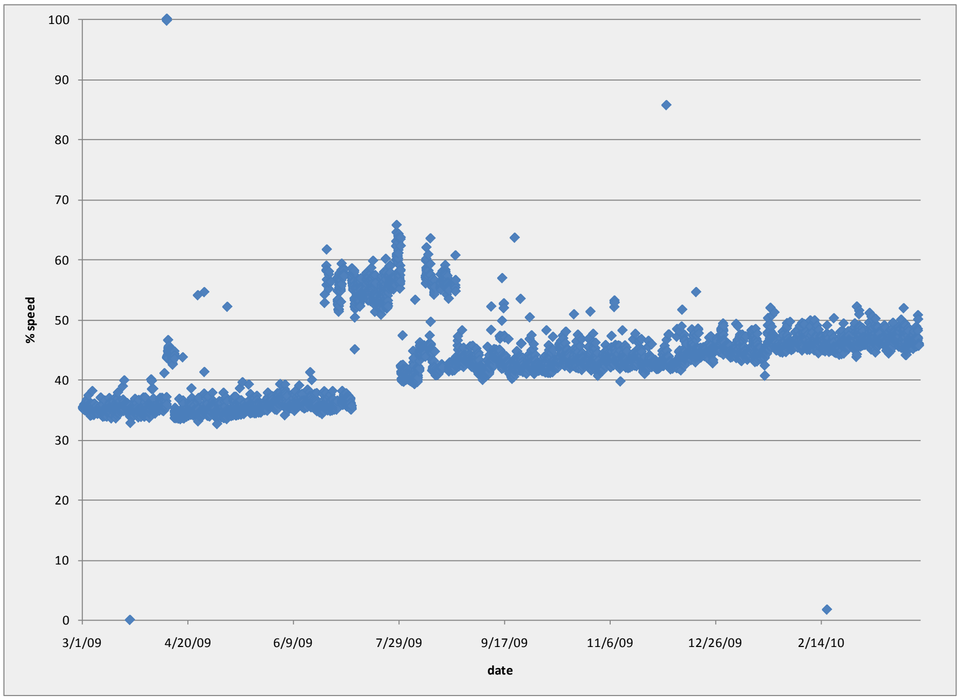
Measurement & Verification Methodology

SCADA data of MAH fan motor speed was used along with onsite measurements to estimate system energy usage. A pre- and post-pressure drop test was performed for this project, and the report was provided to Navigant Consulting for this evaluation. This data was used along with fan performance specifications and the measured motor current data to estimate the energy savings for this project.

CFM data is not available from the SCADA system; however fan speed was used to estimate airflow. As seen in Figure D- 24, the SCADA data shows the fan speeds have slowly increased over time, but have stabilized in recent months. Since there was no correlation to outside air temperature this was taken to be influenced by process changes and the current month of logged data was used to estimate power usage.

The base case assumed steady airflow and was based on spot measurements so this was accepted as the correct baseline for this project. In addition, since the current conditions were very similar to those predicted by the initial study, the base case was considered to be reasonably accurate.

Figure D- 24. Site 24 MAH Fan Speed



Evaluation Results

During the four week logging period, the average fan power was found to be 14.1 kW for one of the four fans, without any significant variation with time of day or weather conditions. Since all four fans were the same size and were controlled together, this power was assumed to be applicable to each unit. The fans operate 8,760 hours per year, resulting in a total energy consumption of 494,067 kWh/year, slightly less than the predicted amount. This resulted in a realization rate of 104%.

EEM 4 MAH Fan Wall Conversion

Base System

The facility included an oversized make up air handler (MAH) that operated continuously 24 hours a day, 7 days a week as part of the HVAC system. The area being served by this unit did not require the air volume provided by this unit.

Project Measure

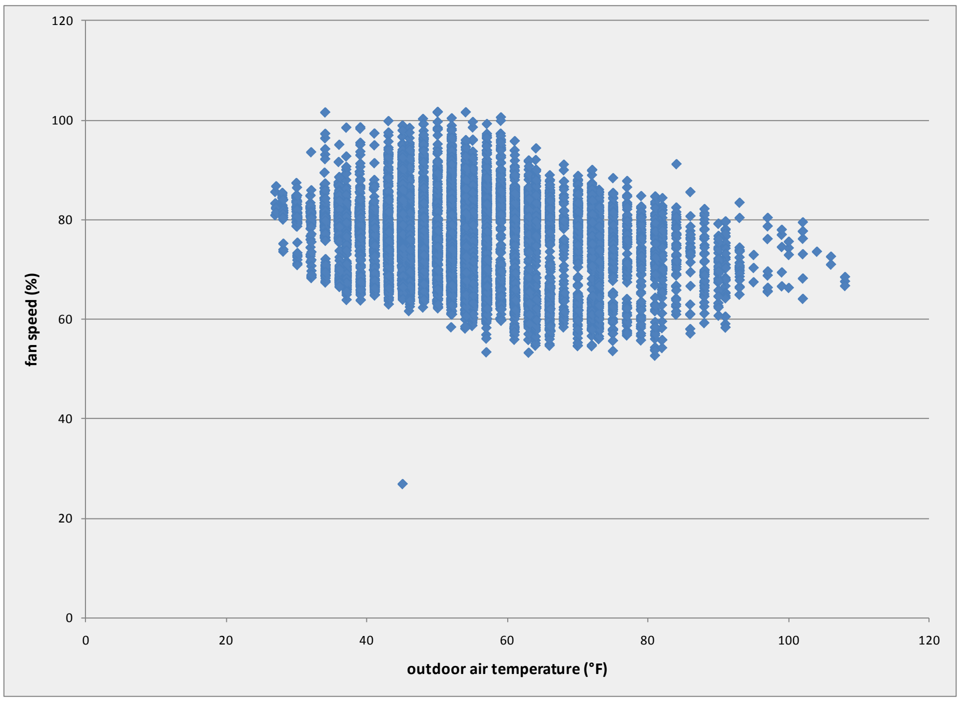
This project replaced the existing make-up air handler with eight smaller fans on individual VFDs, but with a single control signal. The ductwork, controls, and wiring were revised to support the new system. The variable speed make-up air fans also allowed a reduction in HVAC loads because of the reduced volume of outside air. In addition, it was possible to use only some of the eight fans for fan maintenance allowing for increased uptime of the facility since the system would remain operational.

Measurement & Verification Methodology

During the site visit, Navigant took spot measurements of fan power and readings of VFD speed from the control panels. A power monitor was installed for a period of a month on the power to the VFDs. The SCADA system provided fan speed control signal data, but did not specify how many fans were operating at a given time since all fans used the same control signal. The baseline was calculated using the old system specifications and measurements available in the initial report. HVAC operational data was also provided in the initial site report.

During the site visit, all eight fans were operating, but the speed readout was not consistent with what was expected based on the SCADA data. While the readings were not simultaneous, the panel indicated a slower speed than was typical in the SCADA logs. This raised some question as to the accuracy of the logs or panels. In addition, since the SCADA logs did not indicate the number of fans operating, it was difficult to use them to reliably estimate fan power or airflow. Estimates of fan power based on the SCADA speeds and 6 units operating, as was expected in the initial project report, were consistent with observed operational power, however all eight fans were operating during the onsite verification so this raises additional questions about the accuracy of the SCADA data. However, since it was important to determine if outdoor temperature conditions influenced air volume, the SCADA data was compared to weather data. Figure D- 25 shows the results.

Figure D- 25. Site 24 EEM 4 Fan Wall Speed as a Function of Outdoor Temperature

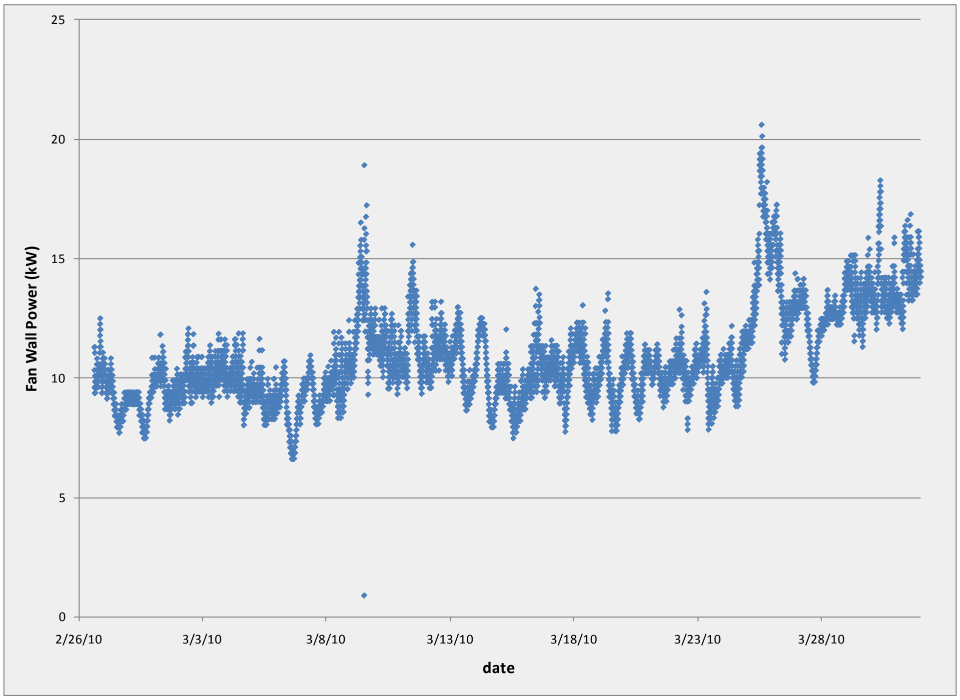


There was not a significant correlation between outdoor air temperature and fan speed, and it is likely that the decrease in speed with higher temperatures indicates additional fans are operating in warmer weather. Onsite measurements and power logs for one month were used to estimate overall power usage rather than the longer term SCADA data. The power logs were used to estimate airflow using the affinity law with a factor of 2.5. Maximum airflow was estimated using fan specifications and data provided in the initial verification report. These airflow calculations were used along with BIN data and HVAC efficiencies from the initial report to estimate HVAC savings.

Evaluation Results

Figure D- 26 shows the logged power for all eight fans during the month following the onsite verification visit. This operation was taken to be typical of a year since there was no definitive correlation with outdoor weather conditions, as is common in large industrial facilities.

Figure D- 26. Site 24 Fan Wall Power



The average fan wall power during the monitoring period was found to be 10.1 kW. The estimated average airflow was 12,813 cfm using this data, so an average airflow of 12,800 cfm was used for calculations. The onsite measured fan wall power was 9.2 kW. This resulted in fan power use of 88,627 kWh/year and additional HVAC usage of 897,047 kWh/year. The HVAC savings included heat pumps, cooling towers, water pumps, and air conditioning loads and was based on system efficiencies provided in the initial study combined with the calculated fan airflow. The original baseline was retained for fan usage of 227,828 kWh/year and HVAC energy of 1,094,217 kWh/year. This resulted in total savings of 336,372 kWh/year, a 59% realization rate. This is primarily due to the new airflow being significantly higher than predicted.

EEMs 5 and 6 RODI Pump Consolidation and VFDs

EEMs 5 and 6 have been combined for the purposes of this evaluation, since EEM 5 affected the results of EEM 6 and the baseline energy usage had been shifted as well to account for the shutdown of one of the buildings. Since two of the systems have been removed, their specifications will be used along with available data on pre-installation pump usage to estimate energy savings.

Base System

Four buildings at the facility contained a total of five reverse osmosis de-ionized water (RODI) pumps. All of these units operated continuously along with additional equipment used for pretreatment of the water.

Project Measures

EEM 6 involved consolidating four reverse osmosis de-ionized water systems into one by adding additional piping and controls between buildings. This permitted the shut down of the pumps in two of the four buildings, leaving only three pumps operating.

EEM 5 involved the installation of three new 40 HP pump VFDs on the remaining reverse osmosis de-ionized water (RODI) pumps.

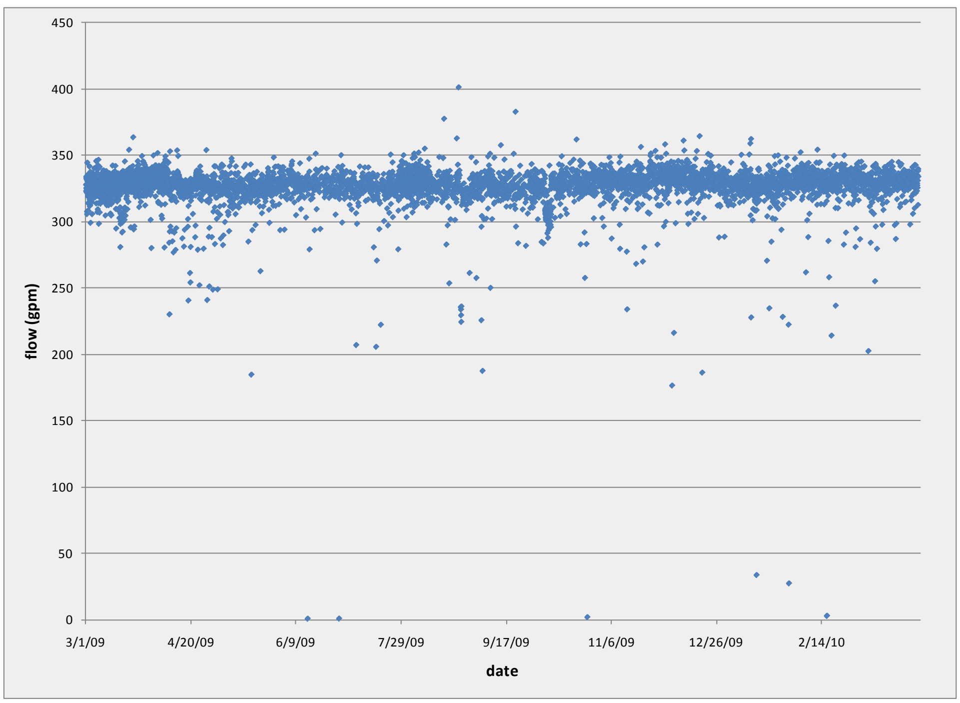
Measurement & Verification Methodology

Spot measurements of system power were taken to provide a point of comparison to specifications and SCADA flow data. Some short-term measurements of pump operation were taken as part of the initial project and were used for baseline calculations. Current loggers were installed on the three operating pumps during the site visit and this data was used along with the spot measurements to calculate pump power usage.

Evaluation Results

One of the four areas involved in this project was shut down in 2009 and the baseline energy use had to be adjusted to account for this since the pump in that area would be shut off regardless of the implementation of these projects. The three pumps that were still operating were not directly affected by this shutdown. This adjustment affected the savings calculated during this evaluation but did not affect the savings reported to the program which were still used to calculate the realization rate.

Figure D- 27. Site 24 RODI Total Pump Flow



As shown in Figure D- 27, SCADA logs showed relatively constant flow from the pumps. Based on the lack of variation in flow over time, the month of logged data was taken to be representative of annual usage.

Although the overall flow did not vary significantly as shown by the SCADA data, the logged data indicated each pump was pumping only about 50% of the time. Average power use for the pumps, along with operational hours resulted in total pump energy usage of 96,192 kWh/year.

The baseline energy use for this evaluation was adjusted for the shutdown of one area which resulted in annual energy use of 427,061 kWh/year and savings of 330,869 kWh/year, an 89% realization rate relative to the reported savings for these two measures combined.

EEM 7 RAH Prefilters Phase 2

Base System

The facility contains a large number of recirculation air handlers (RAHs) for a clean room production area. These units are installed with a standard pre-filter, as part of the air filtration system, which causes a pressure drop in the system and increases the load on the fans. Phase 1 of the RAH prefilters had already been completed in a previous program year and was a similar project on RAHs.

Project Measure

Low-pressure drop, 30% efficient air pre-filters were installed on 103 recirculation air handlers replacing the previously existing 90% efficient air pre-filters. This left the remaining filtration to HEPA clean room filters and lowered the static pressure in the recirculation air handlers. Savings calculations were based on return air totals in balancing reports, motor efficiency, and the number of RAHs.

Measurement & Verification Methodology

Since the facility has performed multiple replacements of filters on different air handlers, and has continued to install new recirculation air handlers, some units had the baseline-style filters and there were more than 103 units with the new efficient pre-filters. Consequently, it was not possible to accurately count which units were upgraded as a part of this project. However, it appeared that the measure was installed and operating as planned.

A Fluke 992 airflow meter was used to take spot measurements of pressure drop across a sample of the filters in the facility. Since the facility contained both new and old style filters a comparison of pressure drops was made on units operating at similar speeds. However, the majority of the units with the new filters were operating around 55 Hz, and the older style units were generally operating at lower speeds, so a large sample of measurements was not possible. In addition, the pressure drop can be expected to vary with system operation, so these measurements were only used for comparison to the expected values based on the available balancing report, which was used in the initial project verification.

Measuring air handler power was not practical so the existing balancing reports were reviewed to determine pressure drop and airflow. Airflow, static pressure, and efficiencies were used to calculate savings using:

$$\frac{kWh}{yr} = \frac{0.746 * (\frac{Q * P}{6356})}{\eta_{fan} * \eta_{motor}} * (number\ of\ units)$$

where: Q=flow in cfm=11,141

P=static pressure in inches water gauge (WG)

η_{fan}=fan efficiency=0.65

η_{motor}=motor efficiency=0.92

Evaluation Results

The balancing and initial verification reports indicated airflow of 11,141 cfm and system static pressure drop across older filters of 2.54" and newer ones of 2.19". Onsite measurements showed the difference between the two of 0.35" to be realistic, although the absolute numbers were somewhat lower, probably due to the method and location of measurement. The difference was greater at higher speeds as would be expected.

Since the same balancing report and methodology were used for this evaluation as for the initial verification, the savings of 690,538 kWh/year resulted in a 100% realization rate.

EEM 8 MAH Replacement

Base System

Two fans on a makeup air handler (MAH) operated at fixed speed on a continuous basis to supply air to one of the buildings at the facility.

Project Measure

This project involved the replacement of two damaged fans in a makeup air handler with six new, smaller makeup air fans with VFDs to control their speeds. The baseline was a one-for-one replacement of the old fans, for which specifications are available.

Measurement & Verification Methodology

The area served by these air handlers is currently shut down. Consequently, the air handlers are not turned on. The SCADA system does not monitor the VFDs for these units so historic data is not available. Operation is locally available at the VFD panels when they are operating. Power consumption of these fans would normally be measured for at least a week to determine current operation. These data would be used along with fan specifications to calculate energy savings.

Evaluation Results

Since these units would be off regardless of the status of this project, there are no savings currently associated with it. Consequently the realization rate for the project is 0%. The building may be used in the future at which point savings would need to be re-evaluated. Since this building is part of a larger complex at the site, it is likely it will be used in some form in the future, but any use of the air handlers will depend upon the eventual configuration of the building systems.

EEM 9 MAH Humidity Controls Removal

Base System

A makeup air handler (MAH) included humidity controls which had not been required for some time. These controls preheated incoming air to 92 °F, then cooled it to 50 °F to remove moisture, and then reheated it to around 60 °F before supplying it to the facility. The heating was performed with waste heat and gas based systems. The cooling was electric through the site's secondary chilled water system.

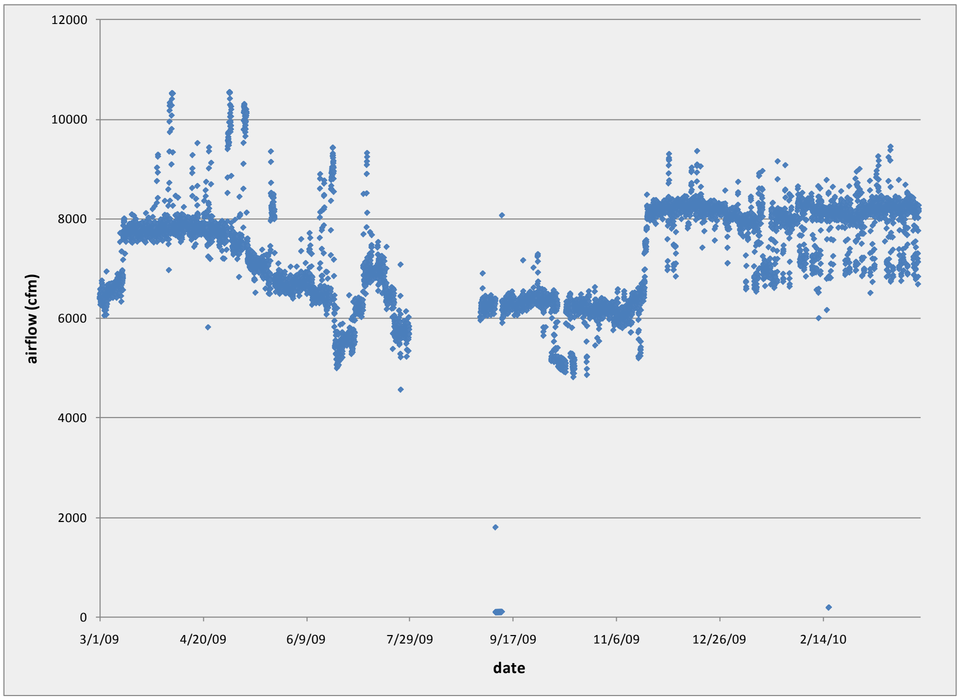
Project Measure

This project involved changing the temperature set points for this MAH, eliminating the humidity control cycle. The new control scheme simply cools to 61 °F or heated to 57 °F. The heating uses waste heat recovery. Additionally, the project changed the control scheme to reduce pumping loads on the secondary chilled and heating water systems. The initial savings estimates were revised downward during the final project verification due to changes in flow rates.

Measurement & Verification Methodology

SCADA data was used to verify the current set points and airflow for the system. As shown in Figure D- 28, the average airflow during the year of SCADA data was found to be 7,002 cfm (although the August data was missing from the SCADA logs). This was rounded to 7,000 cfm average flow. Variations in flow appeared to depend upon facility or process changes rather than weather, so 7,000 cfm was taken as an average to be used for all calculations, despite the current value being closer to 8,000 cfm.

Figure D- 28. Site 24 EEM9 MAH Airflow



An efficiency of 0.65 kW/ton was used to estimate cooling savings. This is a fairly typical value for such systems, but is slightly less efficient than the 0.61 kW/ton that was used in the initial calculations. Weather data bins were used to determine the hours per year for which cooling would be required. A cooling set point of 60 °F was used in calculations to maintain a conservative estimate based on variations shown in the SCADA logs. Actual savings may be slightly higher since the set point is one degree higher.

Evaluation Results

The average airflow of 7,000 cfm was significantly less than the 18,200 cfm assumed in the original project study, in fact Figure D- 29 shows that the airflow never exceeded 11,000 cfm. However the verification calculations adjusted this and the reported project savings estimate accounted for the lower airflow, so it has not affected the realization rate. The resulting savings of 129,579 kWh/yr were 106% of the claimed value.

EEM 10 Exhaust Control for Web Press Fans

Base System

This project was in a new work area. The baseline fan system is what would have been installed in the absence of efficiency measures. Seven stations in the area require 1,400 cfm of exhaust flow each, although not all of them would always be operating. The base system would consist of three 5 HP fans running at constant speed 24 hours a day, 7 days a week. Dampers would be used to reduce flow when some of the stations were not in use. A negative pressure of -0.1" WC is maintained in the area served by these fans.

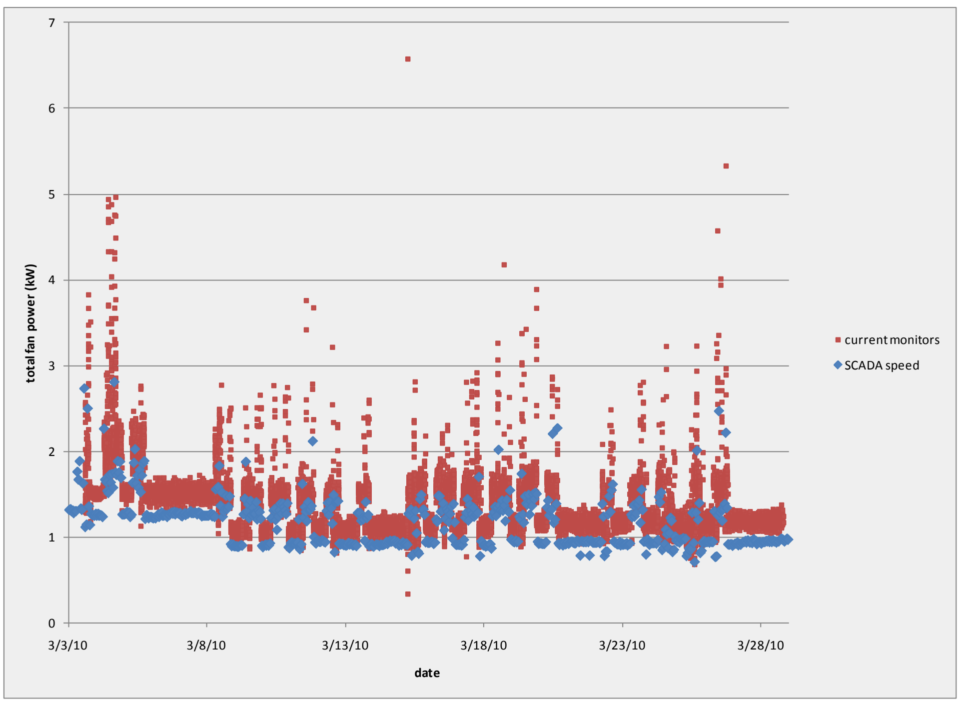
Project Measure

This project consisted of the installation of a programmable logic controller (PLC) to control the duct dampers and two 7.5 HP exhaust fans operated on a staged basis controlled by VFDs.

Measurement & Verification Methodology

The SCADA system monitors VFD speed for these fans, but they were in a confidential area where Navigant personnel were not able to observe them. Additionally, there is no pre-installation measured data available for this project since the system did not yet exist. Site personnel installed current logging equipment on the two fans, but were not able to take spot measurements of power. Consequently, a voltage of 480 phase to phase was assumed along with a power factor of 0.75, based on similar fans elsewhere at the site. Current was monitored for a period of four weeks. Hourly SCADA data was compared to estimated power from the current monitors to confirm that the estimates made on this project were reasonable. Figure D-29 shows the comparison of estimated fan power. The two estimates provide similar results, indicating that

Figure D- 29. Site 24 EEM10 Exhaust Fan Power



In addition to the direct power use of the exhaust fans, this project had savings associated with a makeup air fan and HVAC usage reductions. The makeup air fan was assumed to operate with the same air volume as the exhaust fans. This air volume was used with system ratings to calculate both the makeup air fan power use and HVAC savings for the building.

The fans were found to be operating at a significantly higher airflow and power than was predicted by the initial study and verification report. The baseline also had to be adjusted substantially upward for this increased airflow, which reduced the affect of this increase on the overall project savings. The power consumption was also substantially off from the ex-ante estimates, but this also affected both the baseline and current usage so that overall savings were not severely affected.

The initial study and verification report assumed an average baseline airflow of 7471 cfm and an efficient case flow of 1464 cfm. The baseline airflow was estimated to be 7994 cfm but the current airflow averaged 6212 cfm, which significantly reduced HVAC and makeup air fan savings. Additionally, the average power consumption was found to be 43,173 kWh/year compared to the previous estimate of 4,662 kWh/year. The baseline exhaust fan power consumption was estimated to be 102,326 kWh/year based upon measured airflow values for this study, compared to only 28,356 kWh/year according to the initial study. Based upon these data, the exhaust fan savings were 59,153 kWh/year. An additional 16,416 kWh/year was estimated for the makeup air fan and 2,703 kWh/year of HVAC savings based on rated operation and calculated airflow. This corresponds to overall savings of 78,272 kWh/year, 89% of the ex-ante estimate of 88,180 kWh/year.

EEM 11 Lighting

Base System

The affected lights in the facility were a combination of 1,419 T12 and 192 high output T8 linear fluorescent fixtures. The T12 systems included both high output, high bay units and magnetically ballasted standard output fixtures. No motion sensors were installed on any of the fixtures. All the lights operated almost continuously, 8,541 hours per year, only being shut off during holidays.

Project Measure

The T12 linear fluorescent fixtures were all replaced with T8 fixtures with high output ballasts. Motion sensors were installed on 177 of these new T8 fixtures and on all 192 of the existing T8 fixtures.

Measurement & Verification Methodology

During the site visit, Navigant Consulting observed the new fixtures in many of the areas where they had been installed. The motion sensors were installed and operating as expected, however no logging was performed on these units to determine exact savings. Instead the standard value of 25% savings for motion sensors was used to determine usage. This is a conservative figure, so it is possible that savings are somewhat higher in actuality.

Standard wattages were used to calculate energy usage of the light fixtures. The new fixtures were primarily 74 watt, two lamp high output T8 units. The removed fixtures were primarily four lamp magnetically ballasted T12 units using 164 watts each.

Evaluation Results

The listed fixtures and motion sensors were installed and operating as expected. The savings calculated for this site were 1,063,060 kWh/yr, 98% of the predicted value. The difference in savings is entirely due to different assumed wattages for some of the removed fixtures. These are relatively minor differences and it is not possible to determine the exact wattage of the units.

Evaluation Results

All of the equipment listed on the applications was believed to be at the site and installed, although some of it was no longer in use.

Table D- 47 shows the savings for each of the eleven measures at site 24. As previously mentioned, EEMs 5 and 6 have been combined due to the impracticality of disaggregating their savings, particularly with the shutdown of part of the affected system. The overall site realization rate is 79%. This is primarily due to the shutting down of one area affected by EEM 8, and the operational problems with EEM 2. This realization rate can be expected to rise substantially when EEM 2 is eventually re-enabled.

Table D- 47. Site 24 Estimated & Evaluated Savings

Measure	Measure Description	Estimated Savings (kWh)	Verified Savings (kWh)	Realization Rate (%)
EEM1	Compressed Air Dryer Controls	998,446	1,123,030	112%
EEM2	CW Temp Reset/Cooling Tower Ops	817,941	0	0%
EEM3	MAH Prefilters	421,788	439,889	104%
EEM4	MAH Fan Wall Conversion	573,399	336,372	59%
EEM5	RO Pump VFDs	223,711	330,869	89%
EEM6	RODI Pump Consolidation	148,696		
EEM7	RAH Prefilters Phase 2	690,538	690,538	100%
EEM8	MAH Replacement	108,862	0	0%
EEM9	MAH Humidity Controls Removal	121,757	129,579	106%
EEM10	Exhaust Control for Web Press Fans	88,181	78,272	89%
EEM11	Lighting	1,083,759	1,063,060	98%

	Total	**5,277,078**	**4,191,609**	**79%**

Site-Specific Measurement and Verification Plan

PROJECT SITE

DATE

SUMMARY INFORMATION

PROJECT

Program Being Evaluated	
Project ID	
Company Name	
Site Name	
Site Address	
Site Type	
Company Business/Product	

PRINCIPAL SITE CONTACT

Name		**Telephone**	
E-mail		**Title**	

ASSIGNED LEAD ENGINEER

Name	

AUTHOR

Name	

GOALS AND OBJECTIVES

This M&V Plan is part of the impact evaluation of the Production Efficiency Program. The primary goal of the impact evaluation is to assess the net program-specific energy and demand impacts for the various projects implemented in the 2007 Program Year

More specifically, the objectives of the impact evaluation are to:

- Determine the impacts of all retrofit measures and activities on annual gross energy and peak demand, while accounting for interactions among them.
- Establish post-implementation performance profiles for installed measures and activities.
- Account for the energy and peak-demand effects of spillover at this site, if applicable.
- Explain discrepancies between the results of this study and the ex-ante savings estimates.

MEASURE DESCRIPTION

Measures Included in the Evaluation

Program Measure Number	System	Measure Name	Measure Description
M1			

Annual Measure Savings

Project Measure Number	Electric		Gas		% of Total Savings
	kWh/Yr	Peak kW	Therms Input Cooling	Therms Input Heating	
M1					

Impact Type

Baseline Type

Sample Type

Pre-Installation Equipment and Operation

Program Measure Number	Equipment and Operation – Pre-installation
M1	

As-Built Equipment and Operation

Program Measure Number	Equipment and Operation – As-Built
M1	

Seasonal Variability in Schedule and Production

ALGORITHMS FOR ESTIMATING SAVINGS

Ex-Ante Algorithms

Evaluation Measure Number	Algorithm
M1	

Level of Rigor in Evaluation

Energy Savings Algorithms Used in the Evaluation

Evaluation Measure Number	Algorithm
M1	

Peak Demand Algorithms Used in the Evaluation

Evaluation Measure Number	Algorithm
M1	

DATA COLLECTION

Site-Specific Parameters and Data-Collection Methods

Evaluation Measure Number	Site-Specific Parameters
M1	

Sampling Strategy

Evaluation Measure Number	Sampling Strategy
M1	The evaluation will be based on a census of affected equipment.

Data Accuracy

Quality Assurance Procedures

Uncertainties

Data Products

Data Reporting Formats

Supporting Data for this Plan

All files referenced in this plan are attached.

Appendix D: Ex-Post Adjusted Estimates by Industry (NAICS)

Table D- 48. 2008 Ex-Post Adjusted Estimates by Industry (NAICS)

	Program Project Count	Evaluation Sample Project Count	Total Program Working Savings (kWh)	Evaluation Sample Working Savings (kWh)	Percentage of Total Program Working Savings	Percentage of Evaluation Sample Working Savings	Evaluation Sample Verified Savings (kWh)	End Use Category Realization Rate	Evaluated Program Working Savings (kWh)
Wood Products	115	40	29,611,594	17,864,175	38%	44%	13,448,516	75%	22,292,213
Electronic Manufacturing	20	9	12,729,947	11,222,042	16%	27%	8,431,256	75%	9,564,163
Food Products	64	1	8,980,759	765,941	11%	2%	702,991	92%	8,242,662
Other	27	2	6,414,471	802,535	8%	2%	781,636	97%	6,247,430
Paper Product Manufacturing	14	4	6,092,845	3,770,369	8%	9%	3,818,223	101%	6,170,176
Cold Storage	8	5	4,490,187	4,429,639	6%	11%	3,719,116	79%	3,539,922
Agriculture	48	2	4,270,621	297,500	5%	1%	171,430	58%	2,460,883
Utility	10	2	2,266,877	1,198,724	3%	3%	1,326,333	111%	2,508,195
Metals Manufacturing	34	3	2,380,225	422,460	3%	1%	390,591	92%	2,200,669
Metals Foundry	14	1	1,450,428	188,728	2%	0%	119,298	63%	916,839
Total	***354***	***69***	***78,687,954***	***40,962,113***			***32,909,390***	***81%***	***63,458,641***