Impact Evaluation of National Grid Rhode Island's Custom Refrigeration, Motor and Other Installations

National Grid

Final Report
Date: August 15, 2014

Table of contents

Tables and Figures

1 INTRODUCTION

This document summarizes the work performed by DNV GL during 2013 and 2014 to quantify the actual energy and demand savings due to the installation of six Custom Refrigeration, Motor and Other (RMO) measures installed through National Grid's Commercial and Industrial Retrofit and Commercial and Industrial New Construction energy efficiency programs in 2012 in Rhode Island (RI). This report also summarizes the sampling and analysis procedures used for developing the population level results, which are based on the combined results of the Rhode Island sites and a concurrent study of National Grid Custom RMO projects in Massachusetts.

1.1 Purpose of Study

The objective of this impact evaluation is to provide verification or re-estimation of electric energy and demand savings estimates for a sample of Rhode Island Custom RMO projects through site-specific inspection, monitoring, and analysis, and to develop new realization rates for the combined Custom RMO populations in Rhode Island. The results of the project studies are combined with the results from a concurrent study of National Grid Custom RMO installations in Massachusetts to determine appropriate population level realization rates for the combined Custom RMO populations in Rhode Island.

This impact study consists of the following four tasks:

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

1.2 Scope

The scope of work of this impact evaluation covered the 2012 Custom RMO end-uses, which include new equipment and/or control systems and strategies. This impact evaluation includes only measures which primarily reduce electricity consumption.

2 DESCRIPTION OF SAMPLING STRATEGY

The primary focus of the sample design task was to examine various precision scenarios for the Custom RMO programs in Rhode Island. Due to the fact that Custom RMO measure categories each account for a small proportion of RI's overall energy efficiency portfolio, the decision was made to combine them into one class to reduce the sample size requirements for this study. In addition to estimating realization rates for RI, the results obtained from the RI sample are combined with the MA results to determine a combined realization rate. Results from National Grid's Massachusetts Custom RMO evaluations were developed previously and are described in the final report for the MA-LCIEC Project 16[1].

[1] "Impact Evaluation of 2011 Custom Refrigeration, Motor and Other Installations", prepared for the Massachusetts Energy Efficiency Program Administrators and the Massachusetts Energy Efficiency Advisory Council, by KEMA, June 18, 2013.

The project populations for National Grid, based on projects completed in 2011 (MA) and 2012 (RI) are summarized in Table 2-1.

Table 2-1 RI & MA Population Statistics

Measure	State	Projects	Total Savings (kWh)	Average Savings	Minimum	Maximum
Refrigeration	MA	139	10,750,409	77,341	423	905,623
Motor	MA	15	1,692,613	112,841	5717	314,252
Other	MA	15	4,936,961	329,131	2380	3,849,196
Total MA (2011)		169	17,379,983	102,840	423	3,849,196
Refrigeration	RI	9	391,716	43,524	1536	118,451
Motor	RI	6	1,646,704	274,451	40891	541,086
Other	RI	6	999,750	166,625	65546	443,123
Total RI (2011)		21	3,038,170	144,675	1536	541,086
Total (MA+RI)		190	20,418,153			

The initial design approach was to support the estimation of annual kWh savings realization rates for National Grid's programs in Rhode Island. While annual kWh savings was the primary variable of interest, National Grid was also interested in achieving accurate results for coincident summer peak demand (kW), in order to meet the ISO-NE guidelines for ±10% precision with 80% confidence for their overall portfolio of programs.

The sample design and anticipated precision for annual kWh and summer kW is presented in the following section. The evaluation sample for this study was designed in consideration of the requirements for a 90% confidence level for energy (annual kWh) and an 80% confidence level for coincident peak summer demand (kW).

2.1 Annual kWh Sample Design

DNV GL presented several preliminary sample designs stratified by annual kWh for National Grid's Custom RMO programs in Rhode Island. The parameters considered in the sample design are the number of sample observations planned and the anticipated error ratio of the quantity being estimated which, in this case, is the realization rate for evaluated savings. The error ratio is a measure of the strength of the relationship between the known characteristic (i.e., tracking system savings) and the unknown population characteristic (i.e., evaluated savings).

Since the number of sample points that are required to achieve a desired level of precision depends upon the expected variability of the observed realization rates, DNV GL looked at prior custom measure evaluation studies to identify possible error ratios. Based on historical studies of custom measures in MA, the error ratios for realization rates for annual energy savings have ranged from about 0.3 to 0.5. For demand savings, error ratios tend to be slightly higher, ranging from about 0.6 to 0.9 for summer kW and 0.6 to 1.3 for winter kW. To be conservative and provide confidence that precision targets will be met, the sample designs presented here are based on error ratios of 0.4, 0.5 and 0.6 for annual kWh savings for Refrigeration, Motors and Other, respectively. The error ratios for summer and winter kW savings for Motors were assumed to be 0.6. For Custom Refrigeration, the kW error ratios were varied by season: 0.8 for summer and 1.3 for winter. For Custom Other, the kW error ratios were also varied by season: 0.9 for summer and 1.3 for winter. These are the same as the error ratios used for planning the 2011 MA statewide study.

The final annual kWh design, which served as the basis for the RI sample size of 6 sites, is shown in Table 2-2.

Table 2-2 Custom RMO Sample Design

Stratum	Maximum Savings	Projects	Total Savings (kWh)	Planned Sample	Inclusion Probabilities
1	224,085	17	1,162,229	3	0.1765
2	541,086	14	1,875,941	3	0.7500

Based on assumptions about error ratios, and the proposed sample sizes, an analysis of the anticipated precisions from this design was performed. Table 2-3 lists the calculated precision estimates for this scenario. The anticipated precisions are shown by measure, by state and overall for National Grid. When the RI sample is stratified optimally, the statewide precision of ±27.18% is reasonable. When combined with the MA anticipated results, the National Grid total would be expected to achieve a precision of ±12.01%.

Table 2-3 Custom RMO Anticipated Precisions for Annual kWh

State	Projects	Total kWh Savings	Error Ratio	Confidence Level	Sample	Anticipated Relative Precision	Error Bound
MA	169	17,379,983	0.5	90%	24	±13.29%	2,310,081
RI	21	3,038,170	0.5	90%	6	±27.18%	825,757
Total	190	20,418,153	0.5	90%	30	±12.01%	2,453,233

2.2 Summer kW Precision

In order to ensure that ISO-NE requirements for the Forward Capacity Market are met, it was useful to examine the estimated summer kW precision that could be achieved with a sample of this size. The error ratios for summer kW savings realization rates tend to be higher than those for annual energy savings, so the error ratios described above for summer kW were used. Given the ISO-NE requirement of ±10% precision at 80% confidence for each PAs total portfolio of resources, this analysis was run at an 80% confidence level. The results of this precision calculation are in Table 2-4. The anticipated precisions are somewhat higher than those for the annual kWh savings calculation because of the very conservative error ratio assumptions. Given that these measures represent such a small fraction of National Grid's Rhode Island's portfolio of programs, these are not expected to reduce their overall portfolio precision significantly.

Table 2-4 Anticipated Precisions for Summer kW

State	Projects	Summer kW Savings	Error Ratio	Confidence Level	Sample	Anticipated Relative Precision	Error Bound
MA	146	1,600	0.8	80%	24	±15.30%	245
RI	21	400	0.7	80%	6	±29.65%	119
Total	167	2,000	0.8	80%	30	±13.60%	272

2.3 Winter kW Precision

The calculation of anticipated precisions for winter KW is provided in Table 2-5. Due to the higher error ratios assumed for the winter kW design, the anticipated precisions are worse than those for summer kW.

Table 2-5 Anticipated Precisions for Winter kW

State	Projects	Total kWh Savings	Error Ratio	Confidence Level	Sample	Anticipated Relative Precision	Error Bound
MA	146	1,462	1.2	90%	24	±22.95%	336
RI	21	385	0.9	90%	6	±38.13%	147
Total	167	1,847	1.1	90%	30	±19.83%	366

2.4 Final Samples

Based on these stratified designs, random samples of projects were selected from the tracking system data. Table 2-6 presents the list of six projects selected as the final sample for RI Custom RMO projects. Note that two sites (1745819 and 1864209 and shaded gray in the table below) were ultimately dropped and replaced as they were unable to be successfully recruited into the evaluation.

Table 2-6 RI Final Sample Selection

Stratum	Application ID	Measure Type	Total Gross kWh Savings	Summer kW Savings	Winter kW Savings	Description
1	824282	Motors/Drives	113,224	19.16	1.45	Exhaust fan is used to automatically control using a VFD to maintain a SP set point in the bag house. Dampers are locked out to 100% open or removed.
1	1438841	Refrigeration	52,044	5.94	5.94	Installation of 58 more efficient ECMs.
1	1794980	Refrigeration	84,389	10.94	8.63	Glass doors with LED lighting added to existing cases.
2	2099672	Motors/Drives	409,041	67.09	67.6	Recirculation Fans speeds will be controlled by weight or differential pressure across the material to be dried. Exhaust fan speed will also be adjusted by weight of material being dried.
2	2202620	Motors/Drives	482,691	79.2	79.8	Backup-Recirculation Fans speeds will be controlled by weight or differential pressure across the material to be dried. Exhaust fan speed will also be adjusted by weight of material being dried.
1	1310864	Other	86,630	0.0	0.0	Backup-CAIR to bearings only when edge grinders operate.
2	1745819	Other	443,123	50.59	50.6	Dropped-Customer Unresponsive
2	1864209	Motors/Drives	541,086	57.03	69.76	Dropped-Customer Unresponsive

3 DESCRIPTION OF METHODOLOGY

3.1 Measurement and Evaluation Plans

Following the final sample selection of 2012 Custom RMO applications and prior to beginning any site visits, DNV GL developed detailed measurement and evaluation plans for each of the 6 applications. The plans outlined on-site methods, strategies for monitoring equipment placement, calibration and analysis plans. National Grid provided comments and edits to clarify and improve the plans prior to them being finalized.

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

3.2 Data Gathering, Analysis, and Reporting

Data collection included physical inspection and inventory, interview with facility personnel, observation of site operating conditions and equipment, and long-term metering of usage or specific parameters needed to calculate usage. At each site, DNV GL performed a facility walk-through that focused on verifying the installed conditions of each energy conservation measure (ECM). Evaluators viewed EMS screens to verify schedules and operating parameters where applicable. Power meters and Time-Of-Use (TOU) current loggers were installed to monitor the usage of the installed equipment and associated affected spaces.

Collected data were analyzed to verify implementation of each ECM, and savings analyses were performed to estimate hourly energy use and diversified coincident peak demand. Each site report details the specific analysis methods used for each project including algorithms and assumptions.

DNV GL submitted draft site reports to National Grid upon completion of each site evaluation, which after review and comment resulted in the final reports found in Appendix A. This executive summary provides a concise overview of the evaluation methods and findings.

3.3 Analysis Procedures

In order to aggregate the individual site results from the RI RMO samples, DNV GL applied the model-assisted stratified ratio estimation methodology.[2,3] The key parameter of interest is the population realization rate, i.e., the ratio of the evaluated savings for all population projects divided by the tracking estimates of savings for all population projects. This rate is estimated for the Rhode Island populations only, as well as for National Grid's combined populations of Rhode Island and Massachusetts. Of course, the population realization rate is unknown, but it can be estimated by evaluating the savings in a sample of projects. The sample realization rate is the ratio between the weighted sum of the evaluated savings for the sample projects divided by the weighted sum of the tracking estimates of savings for the same projects. The statistical precisions and error ratios are calculated for each level of aggregation.

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

- Coincident Summer On-Peak kW Reduction is the average demand reduction that occurs over all hours between 1 PM and 5 PM on non-holiday weekdays in June, July and August.

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

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

- Coincident Winter On-Peak kW Reduction is the average demand reduction that occurs over all hours between 5 PM and 7 PM on non-holiday weekdays in December and January.

Relative precision levels and error bounds are calculated at the 80% confidence level for demand values, since that is the requirement for portfolios participating in the ISO-NE Forward Capacity Market. For all kWh realization rates, the standard 90% confidence level is used.

4 CUSTOM REFRIGERATION, MOTOR, AND OTHER RESULTS

Evaluated savings data for the Rhode Island sample points were analyzed to develop Rhode Island realization rates, and then combined with National Grid Massachusetts results (previously reported as discussed above) to represent overall results for use in Rhode Island.

In preparation for analyzing the evaluation results collected for the RI sample points, the original 2012 population distribution was used to calculate case weights for each observation in the Rhode Island sample. These weights reflect the number of projects that each sample point represents and allow for the aggregation of results across strata. Since two sample sites were dropped from the study, the case weights are different than those in the original design. The case weights for this study are shown in the last column in Table 4-1.

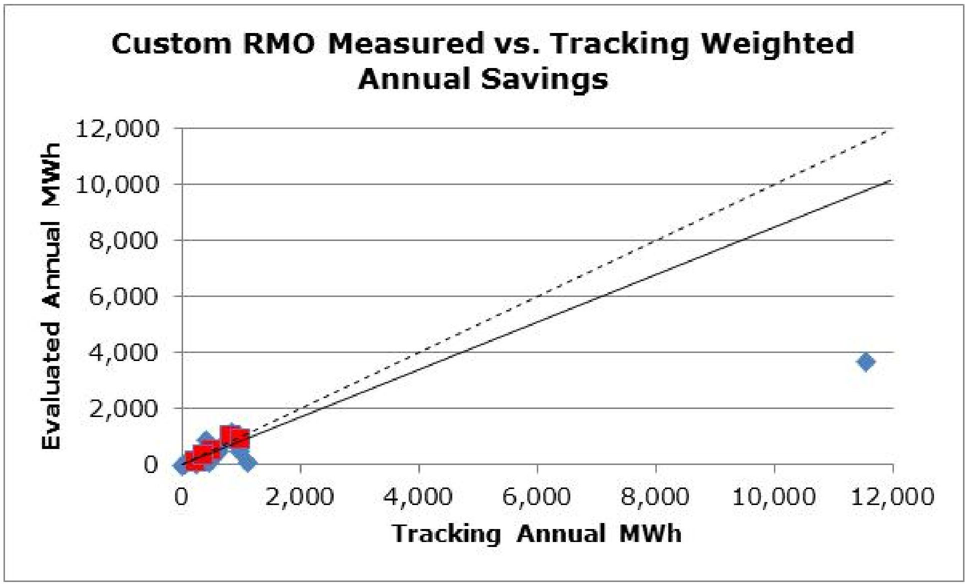
Table 4-1 RI Custom RMO Case Weights

State	Stratum	Maximum KWh Savings	Total Projects	Total Annual MWh	Projects in Sample	Case Weight
Rhode Island	1	224,085	17	1,162,229	4	4.25
Rhode Island	2	541,087	4	1,875,941	2	2

4.1 Major Findings and Observable Trends

Figure 4-1 presents a scatter plot of evaluation savings for the six Rhode Island sample points combined with the Massachusetts sample points. Each point has been weighted by the number of population projects that it represents. The dashed line represents a realization rate of one. The slope of the solid line in this graph is an indication of the realization rate, and can be seen to be less than one. However, the six Rhode Island sample points, as indicated by the six square points in the graph, were mostly close to one.

Figure 4-1 Scatter Plot of RI and MA Evaluation Results for Annual MWh Savings



4.2 Presentation of Results

Table 4-2 presents a summary of the site level results for this impact evaluation.

Table 4-2 RI Custom RMO Detailed Site Results

		Tracking Estimated Savings				Evaluation Savings			
Stratum	Site ID	kWh/yr	On-Peak %	On-Peak Summer kW	On-Peak Winter kW	kWh/yr	On-Peak %	On-Peak Summer kW	On-Peak Winter kW
1	824282	113,224	40%	19.2	1.5	117,651	54.4%	20.3	0.9
1	1438841	52,044	47%	5.9	5.9	30,289	46.4%	3.4	3.5
1	1794980	84,389	46%	10.9	8.6	76,958	46.8%	8.9	8.9
2	2099672	409,041	57%	67.1	67.6	530,778	47.1%	61.9	62.0
2	2202620	482,691	67%	79.2	79.8	446,462	72.5%	96.4	95.3
1	1310864	86,630	0%	0.0	0.0	76,719	45.3%	8.3	8.5

Table 4-3 summarizes the savings realization rates and primary reasons for discrepancies between the tracking and evaluation estimates of annual energy savings for the six RI sites. The site energy savings realization rates ranged from a low of 58% to a high of 130%.

Table 4-3 RI Custom RMO Realization Rates and Primary Site Discrepancies

Stratum	Site ID	Realization Rates kWh/Yr	On-Peak %	On-Peak Summer kW	On-Peak Winter kW	Primary Reasons for Discrepancies
1	824282	104%	136%	106%	65%	Annual fan operation was found to be 1,100 hours as compared to tracking estimate of 808 hours.
1	1438841	58%	99%	58%	58%	The reduction in savings is due to differences in wattage of the existing ECMs.
1	1794980	91%	102%	82%	103%	Savings variance due to differences in space temperatures, case temperatures and refrigeration compressor efficiency.
2	2099672	130%	83%	92%	92%	The increase in savings is due to extended annual operation and lower average operating kW.
2	2202620	92%	108%	122%	119%	The fan operates approximately 2,100 hours less than tracking estimates. Partially offset by lower average operating kW.
1	1310864	89%	N/A	N/A	N/A	Monitoring data found that the shutoff period is approximately 11% shorter than tracking estimates.

The site-level evaluation results for Rhode Island were aggregated using stratified ratio estimation. The Massachusetts results from separate Custom RMO samples were combined to determine a MA realization rate. Then the Rhode Island and Massachusetts realization rates were applied to their respective total tracking savings to estimate each state's total evaluated savings. The National Grid combined realization rate is the ratio of the total evaluated savings to the total tracking savings, each of which is calculated by summing across the two states. Table 4-4 summarizes the RI results and Table 4-5 shows the aggregation of the previously reported MA results to a combined Custom RMO category. Finally, Table 4-6 provides a summary of the aggregated National Grid results. Since the design criteria for the demand realization rates were different than those for the annual kWh (80% vs. 90% confidence levels), the precisions are reported only in the appropriate rows in these tables.

Table 4-4 Summary of RI Custom RMO Results

Rhode Island	Annual MWh	On-Peak MWh	% On-Peak kWh	On-Peak Summer kW	On-Peak Winter kW
Custom RMO					
Total Tracking Savings	3,038	1,382	51%	400	385
Total Measured Savings	3,028	1,587	71%	455	449
Realization Rate	100%	115%	139%	114%	117%
Relative Precision at 90% Confidence	11.0%	20.6%	-	N/A	N/A
Error Bound at 90% Confidence	332	327	-	N/A	N/A
Relative Precision at 80% Confidence	N/A	N/A	-	15.0%	16.5%
Error Bound at 80% Confidence	N/A	N/A	-	68	74
Error Ratio	0.20	0.33	-	0.31	0.34

Table 4-5 Summary of MA Custom RMO Results

Massachusetts	Annual MWh	On-Peak MWh	% On-Peak kWh	On-Peak Summer kW	On-Peak Winter kW
Custom RMO					
Total Tracking Savings	17,380	7,059	40%	2,329	2,009
Total Measured Savings	14,293	6,531	43%	2,056	1,727
Realization Rate	82%	93%	109%	88%	86%
Relative Precision at 90% Confidence	20.6%	19.8%	-	N/A	N/A
Error Bound at 90% Confidence	2,943	1,291	-	N/A	N/A
Relative Precision at 80% Confidence	N/A	N/A	-	18.7%	17.5%
Error Bound at 80% Confidence	N/A	N/A	-	385	302
Error Ratio	0.65	0.66	-	0.73	0.74

Table 4-6 Summary of Overall MA & RI National Grid Custom RMO Results

Massachusetts + Rhode Island	Annual MWh	On-Peak MWh	% On-Peak kWh	On-Peak Summer kW	On-Peak Winter kW
Custom RMO					
Total Tracking Savings	20,418	8,441	45%	2,728	2,393
Total Measured Savings	17,320	8,118	51%	2,511	2,176
Realization Rate	85%	96%	113%	92%	91%
Relative Precision at 90% Confidence	17.1%	16.4%	-	N/A	N/A
Error Bound at 90% Confidence	2,962	1,331	-	N/A	N/A
Relative Precision at 80% Confidence	N/A	N/A	-	15.6%	14.3%
Error Bound at 80% Confidence	N/A	N/A	-	391	311
Error Ratio	0.57	0.59	-	0.66	0.66

From the state-level results, we can observe that the Rhode Island realization rates are significantly higher than those estimated for Massachusetts for all savings variables analyzed. At 17.1%, the overall precision on the Annual KWh estimate is reasonable. All of the RI only precisions are better than expected due to the fact that error ratios were lower what was anticipated in the sample design.

4.3 Implications for Future Studies

From a statistical perspective, which is heavily dependent on Massachusetts results, it appears that the Custom RMO results are stable, and the variation across sample sites is about what was expected. The Rhode Island Custom RMO sites performed very well in comparison to MA. Unless the underlying causes of the variability change, future designs should assume similar error ratio values to determine sample size requirements.

5 CONCLUSIONS AND RECOMMENDATIONS

Despite the positive results of the Rhode Island sites, the National Grid Custom RMO custom measure category appears to be producing results that are lower than expected when combined with Massachusetts. Below are the DNV GL evaluation team findings and recommendations, which refer only to National Grid’s Rhode Island sites. Additional recommendations, based on National Grid’s Massachusetts sites, are available in the concurrent Massachusetts Custom RMO impact evaluation referenced previously.

- **Project Documentation.** The overall quality of the Rhode Island project files was very good. The measures studied included fans at an asphalt plant, VSDs on drying ovens, compressed air blow off, retrofitted refrigerated cases, and evaporator fan ECMs. There was no uniformity in the measure types, but the project documentation was very comprehensive, and provided all the details necessary to complete the site evaluations. Continue to collect and retain all relevant project files including applications, TA studies, analysis spreadsheets and specification sheets for all custom measures going forward.

- **Metering.** For some of the measures at the industrial facilities, it was found that production schedules and equipment operation were very diverse. For industrial type measures, it is sometimes difficult to assess the operational diversity with short term metering. DNV GL performed two distinct periods of metering at the asphalt plant since the first period did not appear long enough to assess the operational diversity. It is recommended that for measures which tend to have large production swings that National Grid considers doing some pre-installation metering, and also a minimum of 90 days of post-installation metering if evaluated. National Grid may also consider requesting a year of production records to aid in the development of tracking savings estimates.
- **Spreadsheet Tools.** National Grid utilizes spreadsheet tools for measures such as ECMs, which is intended to standardize the savings estimates of these types of high volume measures. However, these tools should incorporate the ability to adjust key saving assumptions if more specific information is available from the site. For example, site 1438841 was an ECM installation which used the spreadsheet tool to estimate tracking savings. However, a TA study had been done prior, which identified the actual wattages of the existing evaporator fan motors. The actual existing fan motors were of a lower wattage than the default wattages available in the spreadsheet tool, which resulted in lower evaluated savings estimates. If the spreadsheet tool were modified, the site wattages could have been used in place of the default wattages to arrive at a more accurate savings estimate.

6 APPENDIX A – SITE REPORTS

Application ID: 824282

Measure Category: Motor

Project Type: Retrofit

Summary

This site is a plant that provides custom asphalt for waiting customer vehicles. The existing bag-house fan is driven by two 200-HP motors. A 400-HP variable speed drive is installed in this measure to modulate the speed of the motors according to required static pressure set-points.

Table 1 below summarizes the energy and demand savings achieved by this project. The evaluation savings of 117,651 kWh is 4% greater than the tracking estimates. Summer on-peak demand savings are 6% more than the tracking estimates and winter on-peak demand savings are 35% less than anticipated.

Table 1: Summary of tracking and evaluation savings results

Savings Quantity	Tracking Estimate	Evaluation Estimate	Evaluation / Tracking
Annual Energy (kWh)	113,224	117,651	104%
% Energy Savings On-Peak	40.0%	54.4%	136%
Summer On-Peak Demand (kW)	19.16	20.35	106%
Winter On-Peak Demand (kW)	1.45	0.94	65%

Project Description

The plant uses a bag-house for air pollution control. It contains filters that trap particulate, shakers that drop the collected particles back to the load, and differential pressure sensors that determine the status of the bag house. It is not part of, or required for production. It responds to production. The bag house is also operated manually. It does not have to be on during production and it is often shut off between process runs and at times during process. The exhaust fan that serves the bag-house is driven by two 200-HP motors that operated at full speed. Existing dampers are manually modulated to keep suction pressures within allowable range. A 400-HP variable speed drive has been installed to modulate the speed of two 200-hp fan motors and automatically maintain the suction in the bag-house.

The asphalt plant operates all year, but heaviest operation is during the summer months with minimal operation during the winter. Asphalt is capable of being provided around the clock according to contractor need. Production can vary according to time-of-day or to weather conditions. However, bag-house fan operation isn't directly linked to production, but is an environmental requirement that is a result of production. For example less asphalt is produced during rainy periods, but fan operation may extend longer than usual during production due to additional moisture in the air.

Existing System

The existing system configuration consisted of dampers which were used to modulate airflow. The dampers were controlled manually by the plant operator and were typically heavily throttled back. The moisture content of the desired asphalt drove the exhaust airflow requirements. The fan motors ran at full speed throughout the process regardless of air flow requirements. The fans operated when asphalt was required by contractors. Fans would be started when trucks were in queue waiting for product. Annual existing system operation was based upon the actual tons of asphalt [147,885] produced in 2010, which represents an average production rate of 183 tons/hour. The tracking estimate was based on 808 annual hours of operation.

Proposed System

The exhaust fan is driven by two 200-hp motors. A 400-hp VFD was proposed to be installed to control the existing fan motors. The control dampers were to be locked at the 100% open position. The variable speed drives will maintain required suction pressure according to pressure set point in the bag-house. The fan will operate only as needed. The annual operating hours are assumed to be the same as the baseline estimate.

Tracking Analysis

Tracking Calculation Methodology

The operation of the existing fans with manual damper control was monitored [kW] by the TA and compared with tons of asphalt produced over the 28 day monitoring period. Table 2 provides the production and monitored power data.

Table 2: Baseline Production and Monitored Power

Monitored Baseline Production Data						
Date	Fan Operating Hours	Fan Energy kWh	Average kW Demand	Tons Produced	kWh Per Ton	Tons Per Hour
10/4/2011	4.0	659	165	89	7.4	22.3
10/5/2011	11.4	2,026	177	1,943	1.0	170.1
10/6/2011	10.3	1,893	185	119	15.9	11.6
10/7/2011	10.6	1,883	178	1,762	1.1	166.5
10/8/2011	***0.0***	***0***	***0***	***1,537***	***0.0***	***0.0***
10/9/2011	***0.0***	***0***	***0***	***708***	***0.0***	***0.0***
10/10/2011	***0.0***	***0***	***0***	***1,118***	***0.0***	***0.0***
10/11/2011	10.4	1,877	180	363	5.2	34.8
10/12/2011	9.5	1,654	174	3,019	0.5	317.8
10/13/2011	0.0	0	0	0	0.0	0.0
10/14/2011	3.5	627	179	517	1.2	147.7
10/15/2011	9.0	1,739	193	2,253	0.8	250.3
10/16/2011	7.1	1,297	183	0	0.0	0.0
10/17/2011	9.0	1,524	169	2,414	0.6	268.2
10/18/2011	13.6	2,467	182	2,220	1.1	163.5
10/19/2011	1.3	229	172	1,251	0.2	940.6
10/20/2011	18.2	3,365	185	3,277	1.0	180.4
10/21/2011	9.8	1,736	178	955	1.8	97.9
10/22/2011	5.8	986	169	1,582	0.6	271.4
10/23/2011	4.2	764	183	0	0.0	0.0
10/24/2011	16.6	2,995	181	2,243	1.3	135.3
10/25/2011	11.8	2,184	185	2,314	0.9	195.6
10/26/2011	15.8	2,966	188	4,334	0.7	275.2
10/27/2011	***0.0***	***0***	***0***	***678***	***0.0***	***0.0***
10/28/2011	14.5	2,722	188	1,389	2.0	95.8
10/29/2011	7.3	1,339	185	2,365	0.6	326.2
10/30/2011	0.0	0	0	0	0.0	0.0
10/31/2011	15.3	1,843	120	1,595	1.2	104.2
	218.8	38,775	177	40,045	0.97	183.0

Table 2 shows that the average demand over the monitoring period is 177 kW. This was the average demand for the period, but the hours of fan operation varied greatly with no direct correlation to tons produced due to manual operation of the fan. The kWh per ton value is a weighted average of operation and is used to estimate fan consumption.

Annual operating hours were based upon 2010 monthly production. Facility personnel estimated that average production is 183 tons per hour. Table 3 shows the monthly operating hours for baseline year 2010. Annual operation of 808 hours was calculated by dividing each month’s production output in tonnage by the hourly tons per hour production rate. However, as identified above in Table 2, fan operation isn’t directly linked to production due to their manual operation.

Table 3: Baseline Operating Hours

Monthly Production - 183.0 Tons per Hour			
Month	2010 Tons	2011 Tons	2010 Operating Hours
January	35	15	0
February	3	0	0
March	35	4	0
April	1,414	3,615	8
May	4,014	9,680	22
June	9,101	19,098	50
July	16,538	11,010	90
August	26,223	20,652	143
September	28,524	25,015	156
October	38,957	40,046	213
November	20,745		113
December	2,296		13
	147,885		808

Operation at the estimated average flow of 46,288 CFM at a static pressure slightly less than 2.0" was selected as the proposed condition. A fan curve provided by the manufacturer was used to identify the average brake horsepower [BHP] required after the installation of the variable speed drive which was determined to be 36.6 BHP. The proposed kW was calculated as:

$$kW_{proposed} = [BHP \times 0.7457] / [Eff] + VFD$$

Where:

$kW_{proposed}$ = Average fan kW with variable speed drive

BHP = Estimated brake horsepower from fan curve

0.7457 = BHP to kW conversion factor

Eff = motor efficiency

VFD = VFD efficiency burden

The VFD burden was calculated assuming a value of 3% of the full load kW at 385 BHP and was determined to be 8.6 kW.

Tracking savings were calculated by multiplying the 808 annual operating hours by the difference between the estimated existing 177.2 kW and the proposed 37.1 kW [Δ140.1 kW].

Discussion of Tracking Analysis

The tracking analysis uses a combination of monitored data and manufacturer's specifications to estimate the tracking savings. Monitoring the fan operation provides the average baseline kW usage. The installed kW value is based upon an operating kW based required for an average CFM and static pressure. The source or reasoning behind the CFM/static pressure selection is not identified.

Monitoring was performed for 28 days. Monitored data was collapsed into daily values and not hourly as shown in Table 2. The data in the bold italic font shows daily tons of production with no energy usage. This discrepancy is never mentioned or explained. It is not possible to have production without power usage. Table 4 shows that table with the impact of those production tons removed. Average kWh per ton increases to 1.08 from 0.97 kWh/ton

Table 4 Corrected Baseline Production and Monitored Power

Modified Monitored Baseline Production Data						
Date	Fan Operating Hours	Fan Energy kWh	Average kW Demand	Tons Produced	kWh Per Ton	Tons Per Hour
10/4/2011	4.0	659	165	89	7.4	22.3
10/5/2011	11.4	2,026	177	1,943	1.0	170.1
10/6/2011	10.3	1,893	185	119	15.9	11.6
10/7/2011	10.6	1,883	178	1,762	1.1	166.5
10/8/2011	***0.0***	***0***	***0***	***0***	***0.0***	***0.0***
10/9/2011	***0.0***	***0***	***0***	***0***	***0.0***	***0.0***
10/10/2011	***0.0***	***0***	***0***	***0***	***0.0***	***0.0***
10/11/2011	10.4	1,877	180	363	5.2	34.8
10/12/2011	9.5	1,654	174	3,019	0.5	317.8
10/13/2011	0.0	0	0	0	0.0	0.0
10/14/2011	3.5	627	179	517	1.2	147.7
10/15/2011	9.0	1,739	193	2,253	0.8	250.3
10/16/2011	7.1	1,297	183	0	0.0	0.0
10/17/2011	9.0	1,524	169	2,414	0.6	268.2
10/18/2011	13.6	2,467	182	2,220	1.1	163.5
10/19/2011	1.3	229	172	1,251	0.2	940.6
10/20/2011	18.2	3,365	185	3,277	1.0	180.4
10/21/2011	9.8	1,736	178	955	1.8	97.9
10/22/2011	5.8	986	169	1,582	0.6	271.4
10/23/2011	4.2	764	183	0	0.0	0.0
10/24/2011	16.6	2,995	181	2,243	1.3	135.3
10/25/2011	11.8	2,184	185	2,314	0.9	195.6
10/26/2011	15.8	2,966	188	4,334	0.7	275.2
10/27/2011	***0.0***	***0***	***0***	***0***	***0.0***	***0.0***
10/28/2011	14.5	2,722	188	1,389	2.0	95.8
10/29/2011	7.3	1,339	185	2,365	0.6	326.2
10/30/2011	0.0	0	0	0	0.0	0.0
10/31/2011	15.3	1,843	120	1,595	1.2	104.2
	218.8	38,775	177	36,004	1.08	164.6

Baseline Validity

The baseline is existing fan motor operation compared with the process output of the plant. This baseline is correct.

Evaluation Methodology

A comprehensive site visit was conducted. The installation of the variable speed drive was confirmed and the operation was observed. Facility personnel were interviewed. Baseline and post-installation production output was discussed. Monthly production tonnage was obtained for the year including the production that was concurrent with the evaluation monitoring period.

An Elite power logger was installed in the fan control panel. The logger was installed on the main power supply to the panel. The operation of both fans was monitored. The loggers were installed on June 24, 2013 and recorded average volts, amps, and kW every 15-minutes throughout the 121-day monitoring period.

Evaluation Data Collection

Monitored data from the Elite power logger was converted into average hourly kW values. These values are unique for each hour of the day based upon fan operation and production. Two site visits were made to obtain monitored data. The initial site visit occurred on 6/24/2013. The monitoring period lasted until 8/30/2013. The logger data showed varied operation and it was decided to return to the site to perform additional monitoring. The second round of monitoring occurred from 9/3/2013 to 10/16/2013. This provided a total of 121 monitored days of operation to capture production during prime seasonal periods. Monitored data was converted into hourly values for each month. Table 5 shows the fan monitoring data for the beginning of July.

Table 5: July 1-3 Monitored Fan Operation

90.7	Max kW	13,999	Total Monthly kWh

Hour of Year	Month	Day Number	Year	Hour	kW	% Max
4345	7	1	2013	1	0.0	0.0%
4346	7	1	2013	2	0.0	0.0%
4347	7	1	2013	3	0.0	0.0%
4348	7	1	2013	4	0.0	0.0%
4349	7	1	2013	5	0.0	0.0%
4350	7	1	2013	6	0.0	0.0%
4351	7	1	2013	7	23.5	25.9%
4352	7	1	2013	8	51.4	56.6%
4353	7	1	2013	9	0.0	0.0%
4354	7	1	2013	10	0.0	0.0%
4355	7	1	2013	11	0.0	0.0%
4356	7	1	2013	12	58.2	64.2%
4357	7	1	2013	13	25.0	27.6%
4358	7	1	2013	14	51.8	57.1%
4359	7	1	2013	15	17.5	19.3%
4360	7	1	2013	16	45.0	49.6%
4361	7	1	2013	17	0.0	0.0%
4362	7	1	2013	18	0.0	0.0%
4363	7	1	2013	19	0.0	0.0%
4364	7	1	2013	20	0.0	0.0%
4365	7	1	2013	21	0.0	0.0%
4366	7	1	2013	22	0.0	0.0%
4367	7	1	2013	23	0.0	0.0%
4368	7	1	2013	24	0.0	0.0%

Hour of Year	Month	Day Number	Year	Hour	kW	% Max
4369	7	2	2013	1	0.0	0.0%
4370	7	2	2013	2	0.0	0.0%
4371	7	2	2013	3	0.0	0.0%
4372	7	2	2013	4	0.0	0.0%
4373	7	2	2013	5	0.0	0.0%
4374	7	2	2013	6	36.7	40.5%
4375	7	2	2013	7	77.3	85.2%
4376	7	2	2013	8	83.6	92.2%
4377	7	2	2013	9	80.7	89.0%
4378	7	2	2013	10	82.9	91.5%
4379	7	2	2013	11	86.8	95.7%
4380	7	2	2013	12	86.5	95.4%
4381	7	2	2013	13	65.4	72.1%
4382	7	2	2013	14	0.0	0.0%
4383	7	2	2013	15	0.0	0.0%
4384	7	2	2013	16	0.0	0.0%
4385	7	2	2013	17	0.0	0.0%
4386	7	2	2013	18	0.0	0.0%
4387	7	2	2013	19	50.6	55.9%
4388	7	2	2013	20	67.8	74.8%
4389	7	2	2013	21	54.0	59.5%
4390	7	2	2013	22	0.0	0.0%
4391	7	2	2013	23	0.0	0.0%
4392	7	2	2013	24	0.0	0.0%

Hour of Year	Month	Day Number	Year	Hour	kW	% Max
4393	7	3	2013	1	0.0	0.0%
4394	7	3	2013	2	0.0	0.0%
4395	7	3	2013	3	0.0	0.0%
4396	7	3	2013	4	0.0	0.0%
4397	7	3	2013	5	0.0	0.0%
4398	7	3	2013	6	0.0	0.0%
4399	7	3	2013	7	0.0	0.0%
4400	7	3	2013	8	52.6	58.0%
4401	7	3	2013	9	0.0	0.0%
4402	7	3	2013	10	0.0	0.0%
4403	7	3	2013	11	0.0	0.0%
4404	7	3	2013	12	0.0	0.0%
4405	7	3	2013	13	0.0	0.0%
4406	7	3	2013	14	41.7	46.0%
4407	7	3	2013	15	46.0	50.7%
4408	7	3	2013	16	0.0	0.0%
4409	7	3	2013	17	0.0	0.0%
4410	7	3	2013	18	0.0	0.0%
4411	7	3	2013	19	0.0	0.0%
4412	7	3	2013	20	0.0	0.0%
4413	7	3	2013	21	0.0	0.0%
4414	7	3	2013	22	0.0	0.0%
4415	7	3	2013	23	0.0	0.0%
4416	7	3	2013	24	0.0	0.0%

Tons of asphalt produced was collected during the site visits. These are daily production totals for each month.

Evaluation Savings Analysis

There are three components that are used to analyze savings for this measure. These are production tonnage, pre-retrofit power requirement per ton from the pre-installation measurements, and installed power requirements per ton measured as part of this evaluation.

Production

Total monthly production was shown in Table 6 was provided by site personnel.

Table 6: 2012 – 2013 Monthly Production

2012 - 2013 PROCESS TONS BY MONTH	
Jan-13	0
Feb-13	880
Mar-13	177
Apr-13	3,831
May-13	4,866
Jun-13	29,809
Jul-13	***38,816***
Aug-13	***29,968***
Sep-13	***22,475***
Oct-12	10,959
Nov-12	8,422
Dec-12	1,808
Total	152,011

No precise hourly or daily production was provided that shows variation by product type, or other variables such as weather, or manual operation of the bag-house. These were also no comparable tracking data to compare that level of evaluation analysis with. Monitoring data showed hours when production occurs. Production is assumed to be uniform for each hour of monthly operation.

$$Tons_{hour\,i} = [Tons_{month} \times [kWh_{hour\,i}/kWh_{total\text{-}month}]]$$

Where:

$Tons_{hour\,i}$ = Tons of asphalt produced in $hour_i$ of operation

Tons = Total monthly tons of asphalt produced as provided by site

kWh_{houri} = Average hourly kWh from monitored power

$kWh_{total\text{-}month}$ = Sum of total monitored kWh for the month

The percentage of the monthly kWh in a given hour, kWh_{hour}/kWh_{total} is obtained from look-up tables that are generated from the monitored data. Table 5 above provides the fan operation for the first three days of July. Monthly schedules like Table 5 are generated for each month that monitoring occurred. An average weekly operating profile developed from this monthly data is used to estimate production during the non-monitoring period. Table 7 shows the average weekly operating profile. The percentages shown in this table is the percent of operation for each hour of the week and is the average operation from the monitoring data that is used to model the non-monitored months.

Table 7: Hourly Operating Percentages from Monitored Data

Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	0.8%	0.7%	0.8%	0.7%	0.8%	0.6%	0.8%
2	0.5%	0.0%	0.7%	0.8%	0.6%	0.0%	0.8%
3	0.8%	0.0%	0.7%	0.7%	0.8%	0.5%	0.6%
4	0.2%	0.0%	0.0%	0.6%	0.1%	0.0%	0.7%
5	0.2%	0.4%	0.1%	0.2%	0.4%	0.1%	0.2%
6	0.6%	0.5%	0.3%	0.3%	0.5%	0.3%	0.7%
7	1.0%	0.7%	0.7%	0.7%	0.7%	0.7%	0.9%
8	1.0%	0.8%	0.8%	0.8%	0.8%	0.9%	1.0%
9	0.7%	0.8%	0.8%	0.7%	0.8%	0.8%	1.0%
10	0.7%	0.7%	0.6%	0.6%	0.7%	0.9%	0.8%
11	0.3%	0.6%	0.7%	0.5%	0.9%	0.8%	0.9%
12	0.3%	0.6%	0.5%	0.4%	0.7%	0.7%	0.7%
13	0.4%	0.4%	0.4%	0.5%	0.7%	0.5%	0.4%
14	0.8%	0.6%	0.4%	0.5%	0.6%	0.5%	0.4%
15	0.0%	0.6%	0.5%	0.5%	0.4%	0.6%	0.6%
16	0.0%	0.5%	0.4%	0.4%	0.4%	0.5%	0.6%
17	0.0%	0.0%	0.0%	0.7%	0.7%	0.4%	0.6%
18	0.5%	0.6%	0.3%	0.8%	0.5%	0.5%	0.1%
19	0.8%	0.7%	0.7%	0.7%	0.6%	0.6%	0.5%
20	0.8%	0.8%	0.8%	0.7%	0.7%	0.6%	0.8%
21	0.7%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
22	0.7%	0.8%	0.8%	0.8%	0.8%	0.8%	0.7%
23	0.8%	0.8%	0.8%	0.7%	0.8%	0.8%	0.8%
24	0.8%	0.8%	0.8%	0.7%	0.8%	0.8%	0.7%
	100.0%	Sum of weekly operation					

Pre-Retrofit

The weighted average kWh/ton is used in the calculation. The weighted average is used because of the manual fan operation and lack of hourly production data discussed above. The kWh/ton value is obtained from **Error! Reference source not found.** above. This value is 1.08 kWh/ton. The existing kWh for each hour is created by multiplying the calculated tons produced by the 1.08 kWh/ton value.

Installed Power

The average weighted kWh/ton from the installed equipment is used to calculate the site evaluated power requirements per ton. This is obtained by dividing the total monitored kWh from our monitoring period by the tons of product produced over the same period. The site evaluated 0.336 kWh/ton power is multiplied by the tons created in step one. Table 8 shows production and fan operation for 3 full months of monitoring. The 91,259 tons are the sum of the bold italicized text in Table 6. The kWh is the sum of monitored kWh for July, August, and September. Table 5 shows the fan operating kWh for the first 3 days of July. The average kWh is the kWh divided by the tons.

Table 8: Production and Fan kWh for July, August, and September 2013

July, Aug, Sept	91,259	Tons
July, Aug, Sept	30,679	kWh
July, Aug, Sept	0.336	kWh/Ton

Annual savings are calculated using an 8,760 hour spreadsheet. The savings for the first day of July is shown in Table 9 below.

Table 9: Calculation Spreadsheet

						Avg	27.95	27.95	89.55	89.55	
						Max	100.3	100.3	333.1	333.1	232.7
						Min	0	0	0	0	0
Totals				192	152,011	Totals	53,390	53,390	171,041	171,041	117,651
							SITE KW		BASELINE KW		
Date	Month	Day	Day of Wk	Site Holiday	Tons	Hour	Baghouse Fan	Site Total kW	Baghouse Fan	Total Tracking kW	Total Houry kW Savings
7/1/2011	July	Fri	6	0	0	1	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	2	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	3	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	4	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	5	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	6	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	65	7	23.5	23.45	70.03	70.03	46.58
7/1/2011	July	Fri	6	0	142	8	51.4	51.36	153.37	153.37	102.01
7/1/2011	July	Fri	6	0	0	9	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	10	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	11	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	161	12	58.2	58.22	173.87	173.87	115.64
7/1/2011	July	Fri	6	0	69	13	25.0	25.00	74.65	74.65	49.65
7/1/2011	July	Fri	6	0	144	14	51.8	51.79	154.65	154.65	102.86
7/1/2011	July	Fri	6	0	49	15	17.5	17.49	52.24	52.24	34.74
7/1/2011	July	Fri	6	0	125	16	45.0	44.96	134.25	134.25	89.29
7/1/2011	July	Fri	6	0	0	17	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	18	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	19	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	20	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	21	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	22	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	23	0.0	0.00	0.00	0.00	0.00
7/1/2011	July	Fri	6	0	0	24	0.0	0.00	0.00	0.00	0.00

Tons are calculated proportionally according to hourly and monthly fan usage.

$Tons_{hour} = Tons_{month} X [kWh_{hour}/kWh_{month}]$

Where:

$Tons_{hour}$ = Tons of production for each hour

$Tons_{month}$ = Total production in tons for each month from Table 6

kWh_{hour} = Monitored kWh for each hour as exampled in Table 5.

kWh_{month} = The sum of monitored fan kWh for each month.

Verification of Equipment and Operating Parameters

Table 10 below provides a comparison of the data that contribute to the calculated energy savings.

Table 10: Data Comparison

Input	Tracking	Evaluation	Eval / Tracking
Fan Quantity	2	2	100%
Fan Motor HP	200	200	100%
Annual Tons Produced	147,885 [2010]	158,818 [October 2012 – September 2013]	107%
Average Existing kWh Per Ton	0.97	1.08	111%
Average Installed kWh Per Ton	0.20	0.34	165%
Annual Operating Hours	808	1,910	236%

Savings Analysis and Verification

The TA monitored fan operation for 28 days, but did not take the manual operation of the fan into consideration. The daily tons produced were divided by the total hours of fan operation for that day to create average tons per hour of production. However, there is no correlation between fan operation and production. The fan does not have to operate during production and fans can run without production. Table 2 shows a production range from 12 tons per hour to 941 tons per hour over the monitoring period with average production of 183 tons per hour. This average fan kW to tons approach resulted in a weighted average of 808 annual operating hours for the fan. The site evaluation found that annual operation was over 1,100 hours greater than the tracking estimate. The site analysis also performed a weighted analysis of production to fan usage using the monitored fan kWh and the production data.   Production for the site evaluation year is 7.0% greater than the tacking year. The tracking data was also adjusted to account for periods when bag-house fans operated with no production. This increased existing kWh per ton by 11%. The site evaluation also found that the installed kWh per ton was 65% greater than the tracking estimate.

Application ID: 1310864

Measure Category: Other

Project Type: Retrofit

Summary

Compressed air is provided to edge grinders continuously in this manufacturing facility. The compressed air is needed only when the grinders are operational. Automatic solenoid valves are installed at each grinder. These valves provide compressed air only when needed and reduce load at the plant's air compressors when the grinders are not in use.

Table 1 below summarizes the energy and demand savings achieved by this project. The evaluated savings of 76,719 kWh is 11% less than the tracking estimate of savings. Evaluated summer on-peak demand savings are 8.3 kW. Evaluated winter on-peak demand savings are 8.6 kW. Tracking demand savings for both periods was 0 kW.

Table 1: Summary of tracking and evaluation savings results

Savings Quantity	Tracking Estimate	Evaluation Estimate	Evaluation / Tracking
Annual Energy (kWh)	86,630	76,719	89%
% Energy Savings On-Peak	0%	45.6%	N/A
Summer On-Peak Demand (kW)	0.00	8.3	N/A
Winter On-Peak Demand (kW)	0.00	8.6	N/A

Project Description

Six edge grinders operate in the manufacturing process. These grinders have fine abrasive wheels that remove excess plastic from fabricated parts. Compressed air is used to "blow-off" the removed pieces to prevent the grit from damaging grinder bearings. The grinders do not operate continuously. Grinding operation depends upon production load. Grinding parameters have to be reprogrammed to match specifications required by the manufactured product. Blow-off air was provided continuously even when grinding was not occurring and the machine was off. A tap line was fed to the grinding surface of each machine to provide a continuous stream of 20 scfm of blow-off air.

Compressed air is provided to the facility from the central plant. This is a large manufacturing plant with multiple compressed air requirements. Typical process required as much as 3,000 scfm on a continuous basis. The grinder blow-off is only a small portion of total manufacturing compressed air loads. Table 2 shows air compressors operating in the central plant.

Table 2 Air Compressors

Make	Model	Status	Quantity	HP	SCFM per Unit
Kobelco	KNW 1-E/H	Primary	5	150	653
Gardner Denver	KGDSNAA	Backup	2	125	536

All the compressors are oil-free water-cooled rotary screw units. The five Kobelco compressors are sufficient to meet most of the production loads. Four Kobelco compressors operate as base units. The fifth Kobelco compressor modulates and provides trim. The typical "minimum" compressed air usage is slightly under 2,700 CFM requiring all five compressors to operate. There are rare times when CFM requirement fall below 2,600 CFM which requires only 4 compressors. This is not scheduled or due to production fluctuations. This is more likely to occur when maintenance is required and equipment taken off-line. There is also a film process that comes on like, but rarely. A 6th compressor [one of the Garnder Denvers] is brought online to handle that load. Both these scenarios are very infrequent.

Baseline

The grinders are fed with a total of 120 scfm of compressed air at 125 psig. This is the equivalent of 18.4% of one of the 150-HP Kobelco compressors described above. Compressed air is provided continuously to the grinder as blow-off air. This blow-off operates 8,760 hours per year in the base case.

Installed

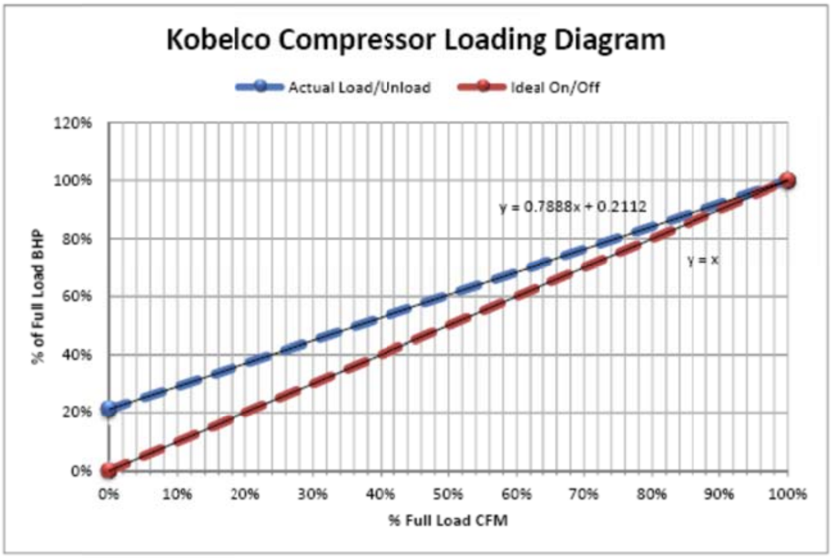
Automatic solenoid valves are installed on the blow-off lines feeding each of the six edge grinders. The new valves are linked to grinder start/stop controls. The solenoid valves close when the grinder is off and blow-off air is not required.

Tracking Analysis

<u>Tracking Calculation Methodology</u>

Edge grinder operation was monitored for 447 hours to identify baseline operating hours. The installed loggers monitored amperage only and showed when each of the grinders was used. This operating data was extrapolated to estimate annual operation. The six grinders operated for an average of 43.4% of the time during their monitoring period. This provides an annualized operation of 3,801(43.4% x 8,760) hours for the grinders. The electrical energy was calculated using a single 150-HP compressor. The total blow-off load provided to the six grinders is 120 CFM. This is 18.4% of total output for one of the Kobelco compressors. Figure 1 shows the manufacturer's operating curve for the plant's air compressors. This shows there is a linear function between full load CFM and full load BHP. These grinding machines remove the plastic edge burrs from production. The grinding creates a fine plastic particulate which must be removed from the grinding area. Compressed air was continuously provided to blow this particulate away. The blow-off was a fixed CFM per machine that was provided continuously for each of the 8,760 annual hours. This continuous load was part of the base load seen at the 4 fully loaded compressors.

Figure 1: Compressor Operating Curve



The engineering contractor worked with the grinding machine manufacturer to identify the required blow-off rate for the machines. Full load compressor kW is 117.0 kW from manufacturer's data. The percent operation is applied to the full load kW and multiplied by 8,760 hours to estimate baseline consumption. Baseline blow-off operation is calculated as:

$$kWh_{base} = CFM_{grinder}/CFM_{total} \times kW_{compressor} \times hours$$

Where:

kWh_{base} = Total annual baseline blow-off kWh

$CFM_{grinder}$ = Total blow-off CFM for all 6 grinders [120 CFM]

CFM_{total} = Total CFM of 150-HP compressor [653 CFM]

$kW_{compressor}$ = Full load compressor kW [117.0 kW]

Hours = Annual operating hours [8,760]

The proposed operation uses a similar approach. The monitoring data shows that average grinder operation is 3,801 hours per year. The grinders and the blow-off air will be off for 4,959 annual hours. The TA calculations include load/unload operation and some bleed-by of compressed air during the shutoff period [4.5 kW total]. The proposed operation is calculated using the following equation:

$$[kWh_{proposed} = CFM_{grinder}/CFM_{total} \times kW_{compressor} \times hours_{on}] + [kW_{bleed} \times hours_{off}]$$

Where:

$kWh_{proposed}$ = Total annual proposed blow-off kWh

$CFM_{grinder}$ = Total blow-off CFM for all 6 grinders [120 CFM]

CFM_{total} = Total CFM of 150-HP compressor [653 CFM]

$kW_{compressor}$ = Full load compressor kW [117.0 kW]

$hours_{on}$ = Annual operating hours [3,801]

kW_{bleed} = Average hourly bleed losses

$hours_{off}$ = Annual off hours [4,959]

Total annual savings are calculated by subtracting $kWh_{proposed}$ from kWh_{base}.

Discussion of Tracking Analysis

The calculations are based upon monitored amperage data, manufacturer's specifications, and facility compressed air requirements. Blow-off loads are based upon requirements set at the grinders and are accurately proportioned with the operating compressors.

Baseline Validity

The baseline is continuous blow-off air provided to the edge grinders. This is accurate and portrays actual baseline operation of the blow-off air. The proportional impact back to the compressors is also valid.

Evaluation Methodology

A comprehensive site visit was conducted. The new solenoid valves were identified and confirmed for all six edge grinders. Two grinders were off at the time of the site visit and no blow-off air was being provided. Facility personnel confirmed that the measure has been working well since it was completed. They also stated that, while production is variable, no major change in production has occurred. The compressed air plant is still comprised of the units listed in Table 2.

Six time-of-use loggers [TOU] were installed to monitor grinder operation. These loggers show when the grinders are turned on and off and provide the total duration of operation. This matches the baseline monitoring methodology used in the TA study. While the measures were installed at each grinder, the savings are achieved at the air compressors. The 120 scfm total load is a small fraction of total plant operation. Compressed air use is variable with multiple stations and end uses. It would not be possible to isolate just the blow-off operation by monitoring the air compressors.

Evaluation Data Collection

Monitored data from the TOU loggers was converted into average hourly operating percentages. These values are unique for each hour of the day and each day of the week. Production operates 24 hours per day and can occur on holidays. A "typical" weekly operating schedule was created from the data. Table 3 shows the average operating profile of all six grinders in total capacity.

Table 3: Average Grinder Hourly Operation

Site Average Hourly Percent Operation							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	0.51	0.53	0.46	0.53	0.55	0.57	0.47
2	0.42	0.42	0.49	0.44	0.51	0.58	0.54
3	0.44	0.48	0.56	0.47	0.48	0.64	0.50
4	0.53	0.51	0.42	0.37	0.50	0.52	0.47
5	0.50	0.49	0.32	0.44	0.58	0.45	0.49
6	0.51	0.48	0.40	0.50	0.56	0.46	0.41
7	0.52	0.55	0.44	0.55	0.63	0.61	0.35
8	0.49	0.52	0.38	0.49	0.69	0.57	0.43
9	0.60	0.50	0.34	0.53	0.55	0.52	0.42
10	0.59	0.52	0.33	0.54	0.45	0.48	0.47
11	0.52	0.44	0.37	0.50	0.56	0.56	0.37
12	0.55	0.52	0.40	0.48	0.67	0.49	0.50
13	0.44	0.62	0.43	0.53	0.60	0.49	0.49
14	0.58	0.55	0.38	0.53	0.71	0.47	0.57
15	0.47	0.43	0.30	0.60	0.66	0.60	0.44
16	0.60	0.42	0.40	0.58	0.66	0.49	0.40
17	0.61	0.56	0.43	0.57	0.50	0.50	0.45
18	0.51	0.61	0.45	0.54	0.44	0.56	0.40
19	0.45	0.63	0.33	0.52	0.46	0.53	0.36
20	0.51	0.61	0.38	0.51	0.56	0.41	0.42
21	0.50	0.52	0.42	0.64	0.46	0.43	0.42
22	0.50	0.44	0.38	0.54	0.47	0.44	0.47
23	0.52	0.35	0.41	0.48	0.48	0.41	0.47
24	0.54	0.45	0.46	0.49	0.52	0.48	0.44

The monitored data provides an average percentage of operation for each hour of the week. There are no seasonal variances in production. The weekly profiles generated for the grinders are considered "typical" of annual operation.

Evaluation Savings Analysis

Six TOU loggers were installed to obtain the operating and off hours of the grinders. This installation of the solenoid valves was confirmed. No blow-off air was being provided to the grinders units that were off. This was observed during both logger installation and retrieval.

The loggers were installed on 02/07/2014 and monitored on/off operation in 15-minute increments over the 48-day monitoring period. The logger monitoring grinder C31 failed after 1 day of operation. Facility personnel stated that it operates in tandem with C32 and using that data would be a good proxy for operation.

Annual savings are calculated using an 8,760 hour spreadsheet. The same equations used in the TA study were used to verify savings. Facility personnel confirmed that 120 CFM is used as blow-off for all 6 grinders. This is the lowest possible volume of air that can be used and still protect grinder bearings. This value will not change. The Kobelco air compressors are still the prime units and 4 units operate at base load with a 5th compressor providing trim. The compressor and blow-off values are used with the monitored operation to generate the hourly savings. The savings for the first operational day are provided in Table 4 below.

Table 4: Calculation Spreadsheet

				Avg	11.06	2.28	13.34	21.82	21.82	
				Max	15.8	3.1	17.1	21.8	21.8	11.8
				Min	6.9	1.3	10.00	22	22	5
Totals				Totals	96,899	19,964	116,863	191,144	191,144	74,281
				SITE KW				BASELINE KW		
Date	Month	Day	Day of Wk	Hour	Grinders On	Grinders Off	Site Total kW	Grinders C31 to C52	Total Tracking kW	Total Houry kW Savings
1/1/2011	Jan	Sat	7	1	10.5	2.4	12.90	21.82	21.82	8.92
1/1/2011	Jan	Sat	7	2	12.0	2.1	14.07	21.82	21.82	7.75
1/1/2011	Jan	Sat	7	3	11.3	2.2	13.51	21.82	21.82	8.31
1/1/2011	Jan	Sat	7	4	10.6	2.4	12.97	21.82	21.82	8.85
1/1/2011	Jan	Sat	7	5	10.9	2.3	13.22	21.82	21.82	8.60
1/1/2011	Jan	Sat	7	6	9.3	2.6	11.94	21.82	21.82	9.88
1/1/2011	Jan	Sat	7	7	8.0	2.9	10.93	21.82	21.82	10.89
1/1/2011	Jan	Sat	7	8	9.8	2.5	12.32	21.82	21.82	9.50
1/1/2011	Jan	Sat	7	9	9.5	2.6	12.11	21.82	21.82	9.71
1/1/2011	Jan	Sat	7	10	10.5	2.4	12.87	21.82	21.82	8.95
1/1/2011	Jan	Sat	7	11	8.4	2.8	11.24	21.82	21.82	10.58
1/1/2011	Jan	Sat	7	12	11.2	2.2	13.48	21.82	21.82	8.34
1/1/2011	Jan	Sat	7	13	11.0	2.3	13.33	21.82	21.82	8.49
1/1/2011	Jan	Sat	7	14	12.8	1.9	14.72	21.82	21.82	7.10
1/1/2011	Jan	Sat	7	15	9.9	2.5	12.45	21.82	21.82	9.37
1/1/2011	Jan	Sat	7	16	9.0	2.7	11.74	21.82	21.82	10.08
1/1/2011	Jan	Sat	7	17	10.2	2.5	12.67	21.82	21.82	9.15
1/1/2011	Jan	Sat	7	18	9.0	2.7	11.72	21.82	21.82	10.10
1/1/2011	Jan	Sat	7	19	8.1	2.9	11.01	21.82	21.82	10.81
1/1/2011	Jan	Sat	7	20	9.4	2.6	12.05	21.82	21.82	9.77
1/1/2011	Jan	Sat	7	21	9.4	2.6	12.03	21.82	21.82	9.79
1/1/2011	Jan	Sat	7	22	10.6	2.4	13.00	21.82	21.82	8.82
1/1/2011	Jan	Sat	7	23	10.5	2.4	12.88	21.82	21.82	8.94
1/1/2011	Jan	Sat	7	24	10.0	2.5	12.47	21.82	21.82	9.35

Verification of Equipment and Operating Parameters

Table 5 below provides a comparison of the data that contribute to the calculated energy savings.

Table 5: Data Comparison

Input	Tracking	Evaluation	Eval / Tracking
Grinder Quantity	6	6	100%
Blow-Off CFM	120	120	100%
Total Compressor CFM	653	653	100%
Compressor Full Load kW	117.0	117.0	100%
Bleed kW	4.5	4.5	100%
Average Baseline Hours	8,760	8,760	100%
Average Grinder Shutoff Hours	4,959	4,435	89.4%

Savings Analysis and Verification

The reason for the savings difference is that the evaluation monitoring found that the shutoff period is approximately 11% shorter than the tracking estimates. Facility personnel stated that no major changes to production were made or new product introduced. Production is variable. The tracking savings are based upon 447 monitoring hours and ended on December 20th. While production occurs around the clock and there are no holiday shutdowns, tracking monitoring may have captured a slight holiday reduction which was translated into lower annualized hours. Evaluation monitoring occurred for 1,156 hours which is over 2.5 times longer than the TA study.

Application ID: 1438841

Measure Category: Refrigeration, Motors and Other

Project Type: Retrofit

Summary

Standard efficiency shaded pole evaporator fan motors are replaced with 58 electrically commutated motors [ECM] in this 50,000 ft2 supermarket. The ECM's are installed in walk-in coolers and freezers. No fan controls are installed.

Table 1 below summarizes the energy and demand savings achieved by this project. The evaluation savings of 30,289 kWh is 42% less than the tracking estimates. The reduction in tracking savings is due to changes in existing ECM Wattages. Summer on-peak demand savings are 42% less than the tracking estimates and winter on-peak demand savings are 42% less than anticipated.

Table 1: Summary of tracking and evaluation savings results

Savings Quantity	Tracking Estimate	Evaluation Estimate	Evaluation / Tracking
Annual Energy (kWh)	52,044	30,289	58%
% Energy Savings On-Peak	47.0%	46.4%	99%
Summer On-Peak Demand (kW)	5.94	3.43	58%
Winter On-Peak Demand (kW)	5.94	3.46	58%

Project Description

Evaporator fans are located inside refrigerated cases and freezers to circulate air to maintain required temperatures. The existing evaporator fans are replaced with efficient electrically commutated motors [ECM's] in this retrofit project. Fifty eight total shaded pole evaporator fan motors are replaced with ECMs in this project. Fifty four of the motors are installed in medium temperature coolers [dairy, produce, packaged meat]. Four ECMs are installed in low temperature freezers. Table 2 shows where the ECMs were installed and the quantities of the fan motors.

Table 2 Refrigeration Units and Electrically Commutated Motors

Location	Quantity	Location	Quantity	Location	Quantity
Deli Cooler 1	4	Produce Prep	4	Frozen Foods	2
Bakery Cooler	2	Bakery Freezer	6	Dairy Cooler	10
Meat Prep	8	Produce Cooler	6	Meat Cooler	12
Deli Cooler 2	2	Ice Cream Freezer	2		

Baseline

Forty eight of the existing evaporator fan motors were 1/30 horse power [HP] shaded pole units and six motors are 1/20 HP units. The four remaining motors were 1/3 HP shaded pole units. These four fans are located in the ice cream and frozen foods freezers. All of the existing motors operated 8,760 hours. Table 3 shows the quantities and Wattages of the existing and installed motors.

Table 3: Motor Quantities and Wattages

Existing			Installed
HP	Total	Watts/Motor	Watts/Motor
1/30	48	75.4	44
1/20	6	97.0	44
1/3	4	397.0	202

Installed

The fifty four existing 1/30 HP and 1/20 HP shaded pole motors were replaced with fifty four 44 Watt electrically commutated motors. The four existing 1/3 HP motors were replaced with four 202 Watt ECMs. All of these installed fan motors operate 8,760 hours per year. No additional motor controls are installed in this project.

Tracking Analysis

Tracking Calculation Methodology

Two sets of savings calculations were included in the tracking documentation. Tracking savings were calculated using the 2009 version of the Energy Initiative Custom Express spreadsheet. Tracking savings are generated by adding together the direct Watt saving per ECM motor with the indirect Watts per ECM. No existing or installed motor wattages were included in the Energy Initiative Custom Express spreadsheet.

A second spreadsheet generated by the engineering vendor who installed the motors provides a inventory of the cases and boxes where the ECMs were installed. The quantities match the Energy Initiative Custom Express spreadsheet data. The second spreadsheet provides the existing motor horsepower and Wattages along with corresponding installed motor Wattages.

Direct savings refer to the difference in Watts of the shaded pole motors and the electrically commutated motors. Indirect savings are the interactive refrigeration savings. The motors are located within the refrigerated units. Heat is generated by the motors as they operate the fans. The efficient ECMs generate less heat per hour. This reduces the load at the compressors and is the source of the interactive refrigeration savings.

The sum of the direct and indirect per motor savings is multiplied by the quantity of motors installed to create the total savings. The baseline and installed motor Wattages are included in the TA spreadsheet but are not directly used in the savings equations.

The direct savings are calculated using a fixed savings Wattage from the motor Energy Initiative Custom Express spreadsheet[4]. Savings for the 1/3 HP motors are fixed at 69 Watts per motor. Savings for the 1/30 HP and 1/20 HP motors are fixed at 75 Watts per motor. The cooler fans and freezer fans are analyzed the same way and are calculated as follows:

$$kWh_{motors} = (kW_i + kW_d) \times Qty_{motors} \times 8{,}760$$

Where:

kWh_{motors} = Total ECM kWh Savings

kW_i = Indirect kW per ECM

kW_d = Direct Watt Saving per ECM [69 Watts for 1/3 HP and 75Watts for 1/30 & 1/20 HP]

Qty_{motors} = Quantity of Motors

8,760 = Annual Operating Hours

The indirect kW per ECM is calculated as follows:

$kW_i = (kW_d \ X\ 3{,}413)/12{,}000 \times Reff$

Where:

kW_i = Indirect kW per ECM

kW_d = Direct Watt Saving per ECM

3,413 = BTU/kWh conversion

12,000 = kW/Ton conversion

Reff = Refrigeration Efficiency

Discussion of Tracking Analysis

The source of the direct saving factors in the Custom Express Tool was not provided in the tracking documentation.

A detailed inventory of existing and installed motors is provided in the TA savings. The location and motor quantities listed in that document matches the evaporator units addressed in this project. Monitoring was performed on all 4 of the 1/3 HP motors and on 33 of the smaller ECMs. The monitored Wattages closely match the installed wattages of the TA report. Table 4 shows the Wattage comparison.

[4] It should be noted that the Custom Express Tool developed to calculate savings for this measure was based on averages from previous projects to make a a more streamlined analysis that required fewer data inputs. It was appropriate to use this tool for this application.

Table 4: Monitoring Watts/Motor Compared With TA Installed Watts/Motor

202.0	TA Installed Watts/Motor - Replacement for 1/3 HP Freezer Motors
200.2	Monitored Watts/Motor - All 4 Motors Monitored - Average kW Over Monitoring Period
207.3	Monitored Watts/Motor - All 4 Motors Monitored - Maximum kW Over Monitoring Period
44.0	TA Installed Watts/Motor - Replacement for 1/30 & 1/20 HP Case Motors
46.7	Monitored Watts/Motor - 33 Motors Monitored - Average kW Over Monitoring Period
47.5	Monitored Watts/Motor - 33 Motors Monitored - Maximum kW Over Monitoring Period

Tracking savings are based upon fixed per-motor savings factors based upon the size of the unit. This is a prescriptive approach. The existing motor Wattages from the TA study were used to calculate savings in the site evaluation.

Evaluation Methodology

A comprehensive site visit was conducted. The evaluation included an inventory of the installed fan motors. This was compared to the tracking data. Store personnel were interviewed. There were no reported problems with the installation and the fans are fully operational. The make and model of the refrigeration rack system was also noted

Two Elite power loggers were installed to monitor evaporator fan operation. One logger monitored the operation of the 4 freezer boxes which each have one fan. This is 100% of the installed freezer fans. The second logger monitored the operation of 33 cooler evaporator fans or 61% of the remaining units.

Evaluation Data Collection

Elite power logger monitored the cooler and freezer ECM operation. The loggers were installed on July 24, 2013. The Elite logger recorded average volts, amps, and kW every 15-minutes throughout the 42-day monitoring period. Instantaneous power readings were taken to help identify the proper circuit and to provide an estimated fan load in case the monitoring failed.

Monitored data from the Elite power loggers was converted into average hourly kW values. These values are unique for each hour of the day and each day of the week. A "typical" weekly operating schedule was created from the data for the electrically commutated motors. Table 5 shows the average operating profile of a typical cooler operating fan. The values are the total monitored kW divided by the total number of fans monitored [33].

Table 5: Weekly Cooler ECM Power

Site Average Hourly kW - Cooler Per Motor							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	0.0470	0.0466	0.0467	0.0468	0.0467	0.0467	0.0468
2	0.0469	0.0466	0.0466	0.0467	0.0466	0.0467	0.0468
3	0.0467	0.0469	0.0466	0.0466	0.0467	0.0466	0.0466
4	0.0466	0.0468	0.0466	0.0466	0.0467	0.0466	0.0467
5	0.0459	0.0460	0.0455	0.0457	0.0458	0.0458	0.0459
6	0.0470	0.0470	0.0468	0.0469	0.0469	0.0468	0.0470
7	0.0470	0.0469	0.0467	0.0468	0.0468	0.0467	0.0469
8	0.0470	0.0468	0.0467	0.0468	0.0469	0.0467	0.0468
9	0.0469	0.0467	0.0467	0.0467	0.0467	0.0466	0.0467
10	0.0470	0.0468	0.0467	0.0468	0.0468	0.0467	0.0467
11	0.0469	0.0468	0.0466	0.0468	0.0468	0.0467	0.0466
12	0.0468	0.0467	0.0466	0.0468	0.0468	0.0467	0.0467
13	0.0468	0.0467	0.0466	0.0467	0.0466	0.0465	0.0466
14	0.0469	0.0468	0.0467	0.0468	0.0467	0.0466	0.0467
15	0.0469	0.0467	0.0467	0.0466	0.0468	0.0467	0.0466
16	0.0467	0.0465	0.0465	0.0464	0.0465	0.0465	0.0465
17	0.0460	0.0455	0.0457	0.0456	0.0457	0.0457	0.0456
18	0.0469	0.0467	0.0467	0.0466	0.0468	0.0466	0.0467
19	0.0468	0.0465	0.0467	0.0467	0.0467	0.0466	0.0466
20	0.0468	0.0466	0.0468	0.0467	0.0468	0.0467	0.0466
21	0.0468	0.0466	0.0467	0.0467	0.0468	0.0467	0.0467
22	0.0470	0.0467	0.0469	0.0469	0.0469	0.0468	0.0468
23	0.0470	0.0466	0.0468	0.0468	0.0468	0.0467	0.0467
24	0.0470	0.0466	0.0468	0.0468	0.0468	0.0467	0.0468

Savings were also attributed to the replacement of the 4 freezer fans. Table 6 shows average weekly operating profile for the typical freezer fan. The values are the monitored kW divided by the number of fans monitored [4].

Table 6: Weekly Freezer ECM Power

Site Average Hourly kW							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	0.203	0.201	0.200	0.201	0.200	0.200	0.200
2	0.204	0.203	0.203	0.203	0.202	0.202	0.201
3	0.192	0.194	0.192	0.193	0.193	0.193	0.194
4	0.202	0.203	0.202	0.203	0.203	0.202	0.203
5	0.203	0.203	0.202	0.203	0.202	0.202	0.203
6	0.202	0.202	0.202	0.203	0.202	0.201	0.203
7	0.202	0.202	0.201	0.202	0.201	0.201	0.202
8	0.202	0.202	0.201	0.201	0.201	0.201	0.201
9	0.200	0.202	0.202	0.202	0.202	0.202	0.200
10	0.199	0.201	0.201	0.201	0.201	0.201	0.199
11	0.199	0.200	0.200	0.201	0.200	0.200	0.200
12	0.199	0.200	0.200	0.200	0.200	0.200	0.199
13	0.199	0.200	0.200	0.200	0.200	0.201	0.199
14	0.199	0.200	0.201	0.200	0.200	0.200	0.200
15	0.191	0.190	0.191	0.190	0.191	0.192	0.190
16	0.199	0.200	0.200	0.199	0.200	0.200	0.199
17	0.200	0.201	0.201	0.201	0.202	0.201	0.199
18	0.200	0.201	0.201	0.201	0.202	0.201	0.199
19	0.200	0.201	0.201	0.201	0.201	0.201	0.200
20	0.200	0.200	0.200	0.200	0.201	0.200	0.199
21	0.201	0.200	0.200	0.201	0.201	0.200	0.199
22	0.203	0.201	0.202	0.202	0.202	0.201	0.200
23	0.204	0.202	0.202	0.202	0.202	0.202	0.201
24	0.203	0.200	0.200	0.201	0.200	0.200	0.200

Evaluation Savings Analysis

The Elite logger showed minor fluctuations in voltage and power from hour to hour. These fluctuations were calculated for each hour as a percentage of the average hourly power divided by the maximum weekly power. These percentages were used to adjust the hourly baseline fan power.

Annual savings are calculated using an 8,760 hour spreadsheet. The evaluation baseline fan usage is based upon vendor analysis, not the Custom Express Tool used in savings tracking. This substitution was made because the exact baseline motor horsepower’s were not specified in the tool. Cooler, freezer and interactive refrigeration savings are calculated separately. The hourly fan motor savings are converted into equivalent refrigeration load for additional savings at the compressors. Summer and winter demand savings were calculated for the hours in those periods. The savings for day one are provided in Table 7 below.

Table 7: Calculation Spreadsheet

						Avg	0.801	2.519	3.320	1.558	4.149	1.072	6.778	
						Max	0.816	2.540	3.353	1.588	4.182	1.083	6.849	3.5
						Min	0.758	2.458	3.259	1.475	4.048	1.053	6.657	3
Totals						Totals	7,015	22,069	29,084	13,645	36,341	9,387	59,373	30,289
				TMY 3 Temps		SITE KW				BASELINE KW				
Date	Month	Day	Day of Wk	OWB Temp	ODB Temp	Hour	Freezers	Coolers	Site Total kW	Freezers	Coolers	Interactive Refrigeration	Total Tracking kW	Total Houry kW Savings
1/1/2011	Jan	Sat	7	16	17	1	0.798	2.528	3.33	1.553	4.162	1.073	6.79	3.46
1/1/2011	Jan	Sat	7	15	16	2	0.803	2.529	3.33	1.562	4.165	1.075	6.80	3.47
1/1/2011	Jan	Sat	7	14	15	3	0.775	2.519	3.29	1.508	4.148	1.061	6.72	3.42
1/1/2011	Jan	Sat	7	13	14	4	0.812	2.521	3.33	1.580	4.151	1.077	6.81	3.47
1/1/2011	Jan	Sat	7	14	15	5	0.812	2.477	3.29	1.580	4.079	1.064	6.72	3.43
1/1/2011	Jan	Sat	7	14	15	6	0.810	2.537	3.35	1.576	4.178	1.081	6.83	3.49
1/1/2011	Jan	Sat	7	14	15	7	0.809	2.532	3.34	1.574	4.170	1.079	6.82	3.48
1/1/2011	Jan	Sat	7	14	15	8	0.804	2.530	3.33	1.563	4.166	1.076	6.80	3.47
1/1/2011	Jan	Sat	7	16	18	9	0.799	2.524	3.32	1.554	4.157	1.072	6.78	3.46
1/1/2011	Jan	Sat	7	20	22	10	0.798	2.524	3.32	1.551	4.156	1.071	6.78	3.46
1/1/2011	Jan	Sat	7	23	26	11	0.798	2.518	3.32	1.553	4.146	1.070	6.77	3.45
1/1/2011	Jan	Sat	7	26	30	12	0.795	2.521	3.32	1.547	4.152	1.070	6.77	3.45
1/1/2011	Jan	Sat	7	25	31	13	0.796	2.518	3.31	1.548	4.147	1.069	6.76	3.45
1/1/2011	Jan	Sat	7	26	32	14	0.799	2.521	3.32	1.554	4.151	1.071	6.78	3.46
1/1/2011	Jan	Sat	7	26	33	15	0.758	2.518	3.28	1.475	4.146	1.053	6.67	3.40
1/1/2011	Jan	Sat	7	26	33	16	0.795	2.512	3.31	1.547	4.136	1.067	6.75	3.44
1/1/2011	Jan	Sat	7	25	31	17	0.795	2.464	3.26	1.546	4.057	1.053	6.66	3.40
1/1/2011	Jan	Sat	7	24	29	18	0.796	2.520	3.32	1.549	4.150	1.070	6.77	3.45
1/1/2011	Jan	Sat	7	25	30	19	0.799	2.514	3.31	1.553	4.140	1.069	6.76	3.45
1/1/2011	Jan	Sat	7	25	30	20	0.796	2.517	3.31	1.548	4.144	1.069	6.76	3.45
1/1/2011	Jan	Sat	7	25	30	21	0.796	2.521	3.32	1.549	4.152	1.070	6.77	3.45
1/1/2011	Jan	Sat	7	25	30	22	0.802	2.528	3.33	1.559	4.163	1.075	6.80	3.47
1/1/2011	Jan	Sat	7	25	30	23	0.806	2.522	3.33	1.567	4.154	1.075	6.80	3.47
1/1/2011	Jan	Sat	7	25	29	24	0.802	2.526	3.33	1.559	4.160	1.074	6.79	3.47

Freezer and cooler ECM savings are calculated using the following equation:

$$kWh_{fans} = \Sigma_{hours}[[kW_{base} \times Percent_{adj}] - kW_{installed}]$$

Where:

kWh_{fans} = ECM fan kWh savings

kW_{base} = Total kW of baseline fans

$Percent_{adj}$ = Adjustment factor for monitored power fluctuations

$kW_{installed}$ = Total kW of installed fans

The new electrically commutated motors generate less waste heat than the baseline shaded pole motors. This waste heat represents a reduced load at the compressors and provides additional savings. The equation for these savings is:

$$kWh_{ltheat} = \Sigma_{hours}[[[kW_{base} - kW_{installed}] \times 3.413]/12{,}000] \times Eff$$

Where:

kWh_{ltheat} = Annual kWh energy savings from reduction in fan waste heat

kW_{base} = Baseline fan kW adjusted for power fluctuations

$kW_{installed}$ = Total kW of installed fans

3.412 = kW to BTUH conversion factor

12,000 = BTUH to tons conversion factor

Eff = Refrigeration system efficiency in kW/ton

Figure 1 below shows the daily operating profiles and average hourly power usage for the freezer ECM fans.

Figure 1: Freezer Fan Operating Profile

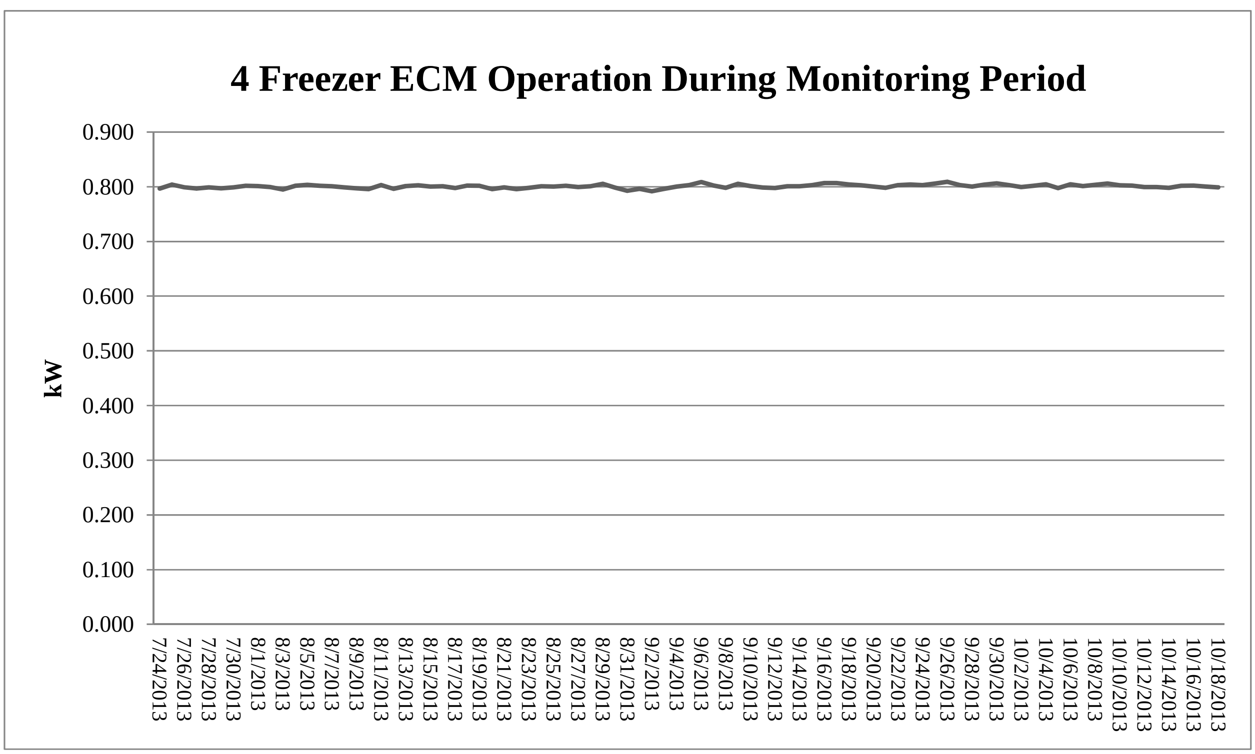
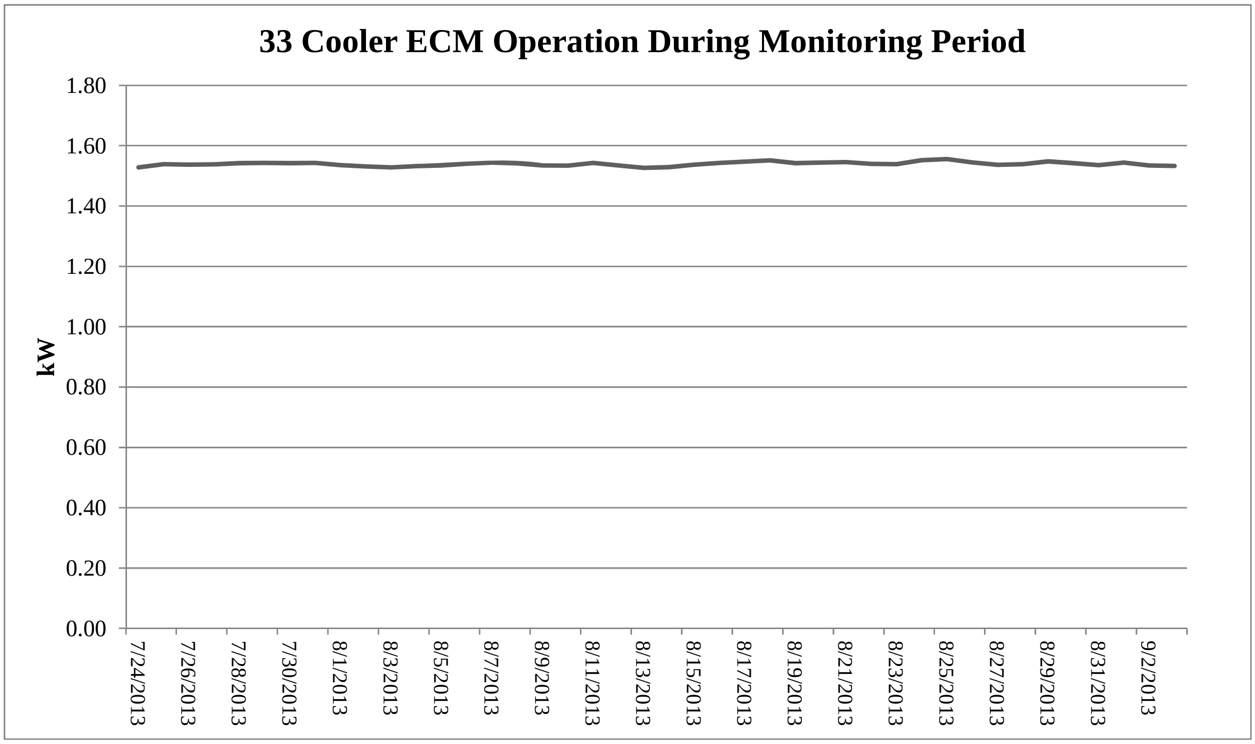


Figure 2 shows the same data for the monitored cooler fans.

Figure 2: Cooler Fan Operating Profile



Verification of Equipment and Operating Parameters

Table 8 below provides a comparison of the data that contribute to the calculated energy savings.

Table 8: Data Comparison

Input	Tracking	Evaluation	Eval/Tracking
Freezer ECM Quantity	4	4	100%
Freezer Existing Watts/Motor	271	***397***	146%
Freezer Installed Watts/Motor	***202***	***200***	99%
Freezer Average Existing kW	1.08	***1.59***	146%
Freezer Average Installed kW	***0.81***	0.80	99%
Freezer Annual Operating Hours	8,760	8,760	100%
Cooler ECM Quantity	54	54	100%
Cooler Existing Watts/Motor	119	***78***	65%
Cooler Average Existing kW	6.43	***4.20***	65%
Cooler Installed Watts/Motor	***44***	47	106%
Cooler Average Installed kW	***2.38***	2.52	106%
Annual ECM Operating Hours	8,760	8,760	100%
Interactive Refrigeration kW/ton	1.50	1.58	105%
Interactive Refrigeration kWh	14,261	9,387	66%
Motor Savings kWh	37,783	20,902	55%

Savings Analysis and Verification

The annual savings for the new electrically commutated motors are 21,755 kWh less than the tracking estimates. The tracking savings were calculated using a prescriptive format. A per-motor savings factor was applied to each fan size which did not include site specific information on the pre installation motors. The existing and installed motor Wattages were not provided in the savings used in the tracking estimate. Specific motor size information was available from another study included with the documentation. That study contained specific motor quantities, existing motor Wattages, and installed motor Wattages. The motor quantities and locations in that additional study also matched the quantities and locations identified in the project. The primary difference between the tracking estimate used and the evaluated values is the Wattages of the existing motors. ECM operation is 8,760 hours in both the tracking and site evaluations. There is also a 2,300 kWh reduction in interactive savings because of the reduction in the direct motor savings.

Application ID: 1794980

Measure Category: Refrigeration

Project Type: Retrofit

Summary

This super market contains open refrigerated dairy and deli cases. New glass doors and frames are added to these open cases. Existing fluorescent case lighting is replaced with LED strip fixtures.

Table 1 below summarizes the energy and demand savings achieved by this project. The evaluation savings of 76,958 kWh is 9% less than the tracking estimates. The savings variance is due to fewer refrigeration savings linked with the installed doors. Differences in space temperatures, case temperatures, and refrigeration compressor efficiency are the factors in the difference. Summer on-peak demand savings are 18% less than the tracking estimates and winter on-peak demand savings are 3% greater than anticipated.

Table 1: Summary of tracking and evaluation savings results

Savings Quantity	Tracking Estimate	Evaluation Estimate	Evaluation / Tracking
Annual Energy (kWh)	84,389	76,958	91%
% Energy Savings On-Peak	46.0%	46.8%	102%
Summer On-Peak Demand (kW)	10.94	8.95	82%
Winter On-Peak Demand (kW)	8.63	8.90	103%

Project Description

Existing dairy and deli cases in this store were multi-shelf reach-in units without night curtains. The open case design permits refrigerated air to escape the case enclosure and enter the sales floor. This refrigerated air is not recirculated through the case fans and store temperature replacement air is drawn into the units. This replacement air must be cooled to the 33°F discharge air temperature required to maintain product temperature and quality. Fifty two doors were added to these cases to contain the refrigerated air within the showcases. These door systems, including mounting frames were installed on 8’ and 12’ showcases. Table 2 shows the savings for each component of the measure. Table 3 shows the refrigerated showcases that are part of this project.

Table 2: Savings by Component

Savings	kWh	% of Total
Lighting	6,535	8.5%
Doors	67,703	88.0%
Interactive Refrigeration	2,720	3.5%
Totals	76,958	100.0%

Table 3 Refrigeration Showcases

Type	Make	Model	Quantity	Total Doors Added
Deli 8 Foot	Hill	05DM	1	3
Deli 12 Foot	Hill	05DM	2	8
Dairy 8 Foot	Hussmann	D5X-LEP	3	9
Dairy 12 Foot	Hussmann	D5X-LEP	8	32

New showcase lighting was installed with the new doors. Existing fluorescent fixtures were removed and LED strip lighting installed in each of the showcases.

Baseline

The 14 existing units are open reach-in cases that contain dairy and packaged deli products. These cases were equipped with T-8 fluorescent lamps and ballasts. The lighting in the 8′ dairy cases were rated at 112 Watts per case and the deli 8′ cases at 118 Watts. The lighting in the 12′ dairy cases were rated at 168 Watts per case and the deli 12′ cases at 170 Watts. Tracking assumes that the case lights are turned off two hours per day during four 30-minute defrost periods.

Installed

Fifty two 2-pane argon filled doors with reflective coatings are installed with mounting frames to cover the case openings. No anti-condensate heaters were installed on these new doors. All existing T-8 fluorescent lamps and ballasts are removed and LED strip lighting was installed on door frames. All 8′ cases have a lighting load of 84 Watts per case. The 12′ cases have a lighting load of 11 2Watts per case. The installed case lights operate with the baseline schedule. No additional lighting controls are installed with this measure.

Tracking Analysis

Tracking Calculation Methodology

Energy savings and demand reduction estimates were calculated using an Excel spreadsheet analysis. Assumptions and savings calculations in the tracking analysis were produced using case manufacturer refrigeration load and LED specifications. The make and model of the refrigerated cases were identified. The design lighting specifications for each of the case types was used to calculate the baseline lighting load. The design specifications also include an estimate of BTUH in refrigeration requirements per linear foot of open case. This was used to calculate savings linked to the installation of the new doors.

The TA spreadsheet utilizes macros to calculate the energy and demand savings. The baseline and installed lighting specifications are defined along with the lighting operating hours. Lighting savings are calculated as:

$$kWh_{lights} = [kW_{base} - kW_{installed}] \times hours_{day} \times days_{year}$$

Where:

kWh_{lights} = Annual lighting energy savings

kW_{base} = Sum of the connected kW lighting load of baseline fixtures

$kW_{installed}$ = Sum of the connected kW lighting load of installed fixtures

$hours_{day}$ = Hours per day of lighting usage

$days_{year}$ = Days per year of lighting usage

The difference in lighting kW is multiplied by 3.412 BTUs per kW to convert lighting savings to a reduction in MBTUs of heat to be removed. Another macro then converts the total BTUs to kWh. The BTUs are multiplied by a conversion factor in the macro to generate the final kWh savings. The kW/ton efficiency is not specified in the macro. However, total BTUs provided can be converted to tons. Dividing the kW saved by these tons yields an average 1.29 kW/ton efficiency.

The installation of the doors creates a barrier between the sales area and the interior of the cases. Refrigerated air that was escaping to the sales floor is now contained in the showcases. The tracking calculations use a macro that contains a BTU/hour per door savings value. The source of that value is not defined. However, refrigeration savings attributed to the new doors is 751 BTUs per hour per door. The savings formula is:

$$kWh_{doors} = [[BTUH_{door} \times Quantity_{doors} \times Hours]/12{,}000] \times Ref_{eff}$$

Where:

kWh_{doors} = Total electrical saving for the installed doors

BTUH = BTUs saved per hour per door

$Quantity_{doors}$ = Number of doors installed

Hours = Annual showcase operating hours

12,000 = BTUs/ton conversion factor

Ref_{eff} = Refrigeration efficiency in kW/ton

Tracking savings for the doors are generated by multiplying the savings value per door times the linear feet of the showcases. This is then multiplied by 8,760 annual hours.

Discussion of Tracking Analysis

Tracking energy savings is based upon the manufacturers' lighting and refrigeration load design specifications of existing cases. LED lighting manufacturer's specifications are used for the installed lighting systems. Continuous lighting operation was assumed except for two hour per day during defrost cycles. The fixture wattages are appropriate. Lighting operation is generally not linked with defrost cycles as this would result in dark showcases for 30 minute blocks when the store is open. Lighting operation should have been 8.760 hours.

It is more difficult to assess the savings for the new doors. BTUH specifications are provided for the existing 8' and 12' open showcases. These rating are per linear foot of showcase and include the evaporator fan heat as cooling load, conduction loads, and infiltration loads. Total amperage is also provided for the showcases. The electrical loads include lights and fans. Cut sheets are also provided for the new doors. The cut sheets include the dimensions of the doors and amperage for frame heaters [0.29 amps]. Door heater amperage is 0 amps. Additional data sheets provide a BTU per door load that are based upon a 75°F ambient store temperature and 38°F case temperature. The BTU/door value also includes door rail heaters, frame heaters, and lights. The TA spreadsheet uses a 0.0867 BTUH savings per linear foot per hour for each door type. That value is some interactive product of the baseline open refrigerated case load and load attributed to the new doors. The value cannot be replicated.

The TA vendor has provided calculations for several other refrigeration projects. While the macro values are undefined, past experience with the TAs work has shown that analysis to be accurate. The savings are based upon detailed specifications from the manufacturers' which contribute to accuracy.

Baseline Validity

Tracking savings are based upon the TA's specifications for the pre-existing and retrofitted cases. This represents the actual power requirements for the cases. The baseline specifications used for this measure are valid. Table 4 shows the total baseline power specification of the existing cases. Figure 1 shows the design refrigeration specifications for an existing showcase. The refrigeration requirements are typical loads under design conditions. This value is affected in the field by traffic at the cases, product load and temperature, evaporator fan CFM, sales floor and cooler temperature and humidity, and other factors.

Table 4: Baseline Power Specifications

ECM	Base-Case						
		Ancillary Loads					
	Suct	Fans		Lights		ACH	
	Temp	watts	hrs	watts	hrs	watts	Cont
Dairy	20	2,170	22	1,680	22.0	0	N
Deli	15	396	22	458	22.0	0	N

Figure 1: Showcase Specification Cutsheet

Existing conditons

O5DM Multi-Deck Merchandiser

4', 6', 8' & 12' (Beverage / Dairy / Deli / Produce)

Electrical Data

Case Length	Fans Per Case	Standard Fans 120 Volts Amps	Standard Fans 120 Volts Watts	High Efficiency Fans 120 Volts Amps	High Efficiency Fans 120 Volts Watts	Anti-Condensate Heaters 120 Volts Amps	Anti-Condensate Heaters 120 Volts Watts	Defrost Heaters 208 Volts Amps	Defrost Heaters 208 Volts Watts	Defrost Heaters 240 Volts Amps	Defrost Heaters 240 Volts Watts
4'	2	1.00	60	0.47	28	- - -[1]	- - -	1.92	400	2.22	532
6'	2	1.00	60	0.47	28	- - -	- - -	2.88	600	3.33	798
8'	3	1.50	90	0.70	42	- - -	- - -	3.85	800	4.44	1065
12'	4	2.00	120	0.93	56	- - -	- - -	5.77	1200	6.67	1600

Lighting Data

Case Length	Lights Per Row	Light Length	Fluorescent Lighting (Per Light Row) 120 Volts Amps	Fluorescent Lighting (Per Light Row) 120 Volts Watts	Clearvoyant LED Lighting (Per Light Row) Standard Power (Cornice or Shelf) 120 Volts Amps	Standard Power 120 Volts Watts	High Power (Cornice) 120 Volts Amps	High Power (Cornice) 120 Volts Watts
4'	1	4'	0.23	28	0.10	11.9	0.22	26.2
6'	2	3'	0.37	44	0.14	16.6	0.30	35.8
8'	2	4'	0.47	56	0.20	23.8	0.44	52.4
12'	3	4'	0.70	84	0.30	35.7	0.66	78.6

Existing conditions:
8ft: 2 x 56W = 112W
12ft: 2 x 84W = 168W

Existing conditions:
8ft: 8 x 1319 = 10552 Btu/hr
12ft: 12 x 1319W = 15828 Btu/hr

Guidelines & Control Settings

Application	Front Sill Heights	[2]BTUH/ft Conventional	[2]BTUH/ft Parallel	Superheat Set Point @ Bulb (°F)	Evaporator (°F)	Discharge Air (°F)	Discharge[3] Air Velocity (FPM)
Deli	2.5" Ext.	1600	1458	6 - 8	22	30	270
	5" Ext.	1556	1418	6 - 8	22	30	270
	7.5" Ext.	1523	1388	6 - 8	22	30	270
Dairy Cut Produce	Std. Dairy	1490	1358	6 - 8	26	34	270
	2.5" Ext.	1448	1319	6 - 8	26	34	270
	5" Ext.	1415	1289	6 - 8	26	34	270
	7.5" Ext.	1381	1258	6 - 8	26	34	270
Beverage Bulk Produce	Std. Dairy	1512	1378	6 - 8	29	36	270
	2.5" Ext.	1469	1338	6 - 8	29	36	270
	5" Ext.	1436	1308	6 - 8	29	36	270
	7.5" Ext.	1403	1278	6 - 8	29	36	270

Defrost Controls

Defrosts Per Day	Run-Off Time (min)	Electric Defrost Fail-Safe (min)	Electric Defrost Termination Temp (°F)	Timed-Off Defrost Fail-Safe (min)	Timed-Off Defrost Termination Temp (°F)	Hot Gas Defrost Fail-Safe (min)	Hot Gas Defrost Termination Temp (°F)	Reverse Air Defrost Fail-Safe (min)	Reverse Air Defrost Termination Temp (°F)
4	6 - 8	32	47	42	47	26	45	42	45

1 NOTE: "- - -" indicates that feature is not an option on this case model.

2 BTUH/ft notes:

- Listed BTUH/ft indicate unlighted shelves. For T8 lighted shelves and 3rd row lighting, add 80 BTUH per 4' lighted shelf and 60 BTUH per 3' lighted shelf to determine Total Lighting BTUH Load, then divide the Total Lighting BTUH Load by the length of the case. For LED lighting, add 36 BTUH per 4' lighted shelf and 27 BTUH per 3' lighted shelf to determine Total Lighting BTUH Load, then divide the Total Lighting BTUH Load by the length of the case.
- Standard fans increase refrigeration load by 96 BTUH/fan.

3 Average discharge air velocity at peak of defrost.

Medium Temperature Defrost Schedule	
Defrost per Day	Time
1	12 midnight
2	12am - 12pm
3	6am - 2pm - 10pm
4	12am - 6am - 12pm - 6pm

HILL PHOENIX EXCELLENCE

168 All measurements are taken per ASHRAE - 72 - 2005 specifications. 05/11

Evaluation Methodology

A comprehensive site visit was conducted. The evaluation included a complete inventory of the number doors installed, dimensions of the showcases and installed doors, store ambient temperature, refrigerated showcase temperature, and quantity of installed lighting fixtures. The make and model of the refrigeration rack system was also noted.

Store personnel were interviewed to discuss the operation of the refrigeration systems and the facility. According to these contact, the LED lighting systems are working without problem. Showcase lighting is not turned off. Restocking and cleaning occurs when the store is closed [midnight to 6 am]. Most store lighting is off during that time and the showcase lighting is used for illumination in these areas. There are no reported problems with the new doors.

An Elite power logger was installed to monitor the operation of the LED lighting circuits. All of the lighting circuits were located in the same electrical center and it was possible to monitor 100% of the installed lighting. Temperature loggers were installed to monitor the hourly ambient store temperature and hourly showcase temperature.

The door manufacturer was contacted for additional specifications and information. The engineering department provided an average U-value for the new doors. That data is not included in general specifications and cut sheets. Performance usually includes fan/lighting/heating loads to estimate total refrigeration loads. A net search was made on the compressor information obtained at the site to identify the refrigeration efficiency.

Evaluation Data Collection

Monitored data from the Elite power logger was converted into average hourly kW values. These values are unique for each hour of the day and each day of the week. A "typical" weekly operating schedule was created from the data for the LED lighting. That schedule is provided in the Table 5 below.

Table 5: Weekly LED Lighting Power

Site Average Hourly Lighting kW							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	1.34	1.34	1.34	1.35	1.34	1.34	1.34
2	1.34	1.34	1.34	1.34	1.34	1.34	1.34
3	1.34	1.34	1.34	1.34	1.34	1.34	1.34
4	1.34	1.34	1.34	1.34	1.34	1.33	1.34
5	1.34	1.34	1.34	1.34	1.34	1.33	1.34
6	1.35	1.34	1.22	1.34	1.34	1.33	1.34
7	1.35	1.35	1.34	1.36	1.35	1.34	1.35
8	1.34	1.35	1.35	1.36	1.34	1.34	1.34
9	1.34	1.35	1.35	1.37	1.35	1.35	1.34
10	1.34	1.35	1.35	1.36	1.35	1.34	1.34
11	1.34	1.35	1.35	1.36	1.34	1.34	1.34
12	1.34	1.35	1.35	1.36	1.35	1.34	1.34
13	1.34	1.34	1.36	1.34	1.35	1.34	1.34
14	1.33	1.34	1.35	1.34	1.35	1.34	1.34
15	1.33	1.34	1.35	1.34	1.35	1.34	1.33
16	1.33	1.35	1.35	1.34	1.35	1.34	1.34
17	1.34	1.35	1.36	1.35	1.35	1.34	1.34
18	1.34	1.36	1.37	1.35	1.35	1.35	1.35
19	1.35	1.36	1.38	1.36	1.36	1.36	1.35
20	1.34	1.36	1.37	1.36	1.36	1.36	1.35
21	1.35	1.35	1.36	1.35	1.35	1.34	1.34
22	1.35	1.35	1.36	1.35	1.35	1.34	1.34
23	1.34	1.34	1.34	1.34	1.34	1.34	1.34
24	1.34	1.34	1.34	1.34	1.34	1.34	1.34

Savings for the installation of the new doors is based upon the spillover air from the refrigerated cases to the sales floor. Store ambient temperature and showcase temperature was monitored. The store heating and cooling set point temperatures are both 70°F. Table 6 shows average weekly store temperature profile. The average weekly showcase temperatures are provided in Table 7.

The loggers were installed on June 26, 2013. The Elite logger recorded average volts, amps, and kW every 15-minutes throughout the 58-day monitoring period. The instantaneous power readings were taken to help identify the proper circuit and to provide an estimated lighting power load in case the monitoring failed. The temperature loggers were installed on the same date and recorded temperatures hourly in degree Fahrenheit.

Table 6: Weekly Store Temperature °F

Site Average Hourly Store Temperature							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	67.08	67.21	67.00	66.91	66.66	67.08	67.39
2	67.01	67.39	67.27	66.96	67.34	67.29	67.51
3	67.43	67.30	67.60	67.26	67.42	67.83	67.47
4	67.68	67.52	67.56	67.48	67.59	67.53	67.50
5	67.50	67.21	67.48	67.72	67.35	67.28	67.40
6	68.20	67.98	67.81	68.17	68.15	67.99	68.08
7	68.27	68.50	68.17	68.23	68.29	68.28	68.12
8	69.57	69.28	69.89	69.81	69.91	69.62	69.86
9	69.76	69.70	69.61	69.56	69.31	69.68	69.47
10	69.67	69.30	69.87	69.47	69.40	69.31	69.63
11	69.99	70.18	70.12	69.82	69.84	70.31	70.10
12	70.16	69.99	69.96	70.32	70.20	70.01	70.02
13	70.32	70.26	70.53	70.48	70.07	70.42	70.78
14	70.30	70.44	70.08	70.13	70.31	70.23	70.21
15	71.19	71.16	70.99	70.87	71.08	71.13	71.22
16	69.73	69.99	69.79	70.30	70.00	70.10	70.07
17	68.91	69.30	69.12	69.06	69.28	69.40	69.12
18	69.83	70.31	69.97	70.06	70.37	69.92	70.19
19	69.33	69.76	69.52	69.36	69.47	69.58	69.49
20	69.01	69.06	69.09	68.83	68.82	69.36	69.01
21	67.77	67.94	68.21	68.28	68.03	68.01	67.54
22	67.43	68.02	67.53	67.81	67.46	67.39	67.36
23	67.13	66.99	66.80	67.11	66.91	67.12	66.92
24	67.14	67.73	67.60	67.53	67.37	67.61	67.47

Table 7: Weekly Showcase Temperature °F

Site Average Hourly Cooler Temperature							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	36.48	36.59	36.97	36.13	36.41	36.56	36.51
2	36.68	36.61	36.39	36.76	36.70	36.71	36.31
3	35.91	36.58	36.34	36.52	36.63	36.52	36.57
4	36.79	36.29	36.57	36.24	36.41	36.70	36.78
5	36.28	36.62	36.43	36.58	36.89	36.34	36.91
6	36.79	36.46	36.36	36.20	36.45	36.36	36.29
7	36.73	36.19	36.51	36.29	36.35	36.63	36.30
8	36.87	36.64	36.68	36.63	36.73	36.72	36.61
9	36.88	36.56	36.72	36.79	36.61	36.27	36.10
10	36.22	36.48	36.53	36.68	36.63	36.62	36.23
11	36.34	36.70	36.34	36.30	36.49	36.32	36.37
12	36.12	36.63	36.82	36.56	36.76	36.52	36.30
13	36.43	36.44	36.17	36.54	36.67	36.32	36.51
14	36.90	36.43	36.66	36.61	36.89	36.64	36.28
15	36.43	36.38	36.67	36.61	36.58	36.69	36.77
16	36.20	36.68	36.46	36.44	36.68	37.06	36.54
17	36.62	36.53	36.76	36.42	36.87	36.60	36.86
18	36.61	36.37	36.44	36.21	36.49	36.82	36.36
19	36.46	36.72	36.72	36.54	36.34	36.68	36.19
20	36.18	36.72	36.64	36.31	36.63	36.60	36.70
21	36.87	36.61	36.41	36.64	36.49	36.57	36.16
22	36.46	36.44	36.54	36.72	36.52	36.28	36.63
23	36.40	36.19	36.38	36.69	36.56	36.81	36.63
24	36.38	36.66	36.40	36.20	36.70	36.57	36.31

Evaluation Savings Analysis

LED Lighting

The Elite power logger monitored the LED lighting circuits. The circuits were located in the same electrical panel and it was possible to monitor 100% of the installed LED fixtures. The logger provided the average hourly power usage and the lighting operating schedule. The average monitored power was compared with the tracking lighting power obtained from the tracking specifications. The installed lighting was expected to draw 1.46 kW in the TA study. Monitoring data showed that average lighting power was 1.34 kW. The Elite logger showed minor fluctuations in voltage and power from hour to hour. These fluctuations were calculated for each hour as a percentage of the average hourly power divided by the maximum weekly power. These percentages were used to adjust the hourly baseline power.

New Refrigerated Case Doors

Savings are derived from eliminating refrigerated air spillover onto the sales floor. The difference between the store and showcase temperatures is used with total door area and u-value to calculate conduction losses through the new doors. This is compared to the refrigerated load created from manufacturers' specifications for the open cases.

Annual savings are calculated using an 8,760 hour spreadsheet. Lighting and door savings are calculated separately. The hourly lighting savings are converted into equivalent refrigeration load for additional savings at the compressors. Summer and winter demand savings were calculated for the hours in those periods. The savings for day one are provided in Table 8 below.

Table 8: Calculation Spreadsheet

						Avg	1.344	0.715	2.059	2.090	8.444	0.310	10.845	
						Max	1.375	0.770	2.117	2.138	8.796	0.318	11.180	9.1
						Min	1.218	0.665	1.915	1.894	8.121	0.281	10.456	8
Totals						Totals	11,777	6,264	18,041	18,311	73,967	2,720	94,998	76,958
				TMY 3 Temps		**SITE KW**				**BASELINE KW**				
Date	Month	Day	Day of Wk	OWB Temp	ODB Temp	Hour	Lighting	Doors	Site Total kW	Lighting	Open Case	Lighting Refrigeration	Total Tracking kW	Total Houry kW Savings
1/1/2011	Jan	Sat	7	16	17	1	1.341	0.684	2.02	2.084	8.265	0.310	10.66	8.63
1/1/2011	Jan	Sat	7	15	16	2	1.337	0.691	2.03	2.078	8.235	0.309	10.62	8.59
1/1/2011	Jan	Sat	7	14	15	3	1.339	0.684	2.02	2.081	8.287	0.309	10.68	8.65
1/1/2011	Jan	Sat	7	13	14	4	1.338	0.680	2.02	2.081	8.339	0.309	10.73	8.71
1/1/2011	Jan	Sat	7	14	15	5	1.340	0.675	2.02	2.084	8.357	0.310	10.75	8.73
1/1/2011	Jan	Sat	7	14	15	6	1.343	0.704	2.05	2.088	8.299	0.310	10.70	8.65
1/1/2011	Jan	Sat	7	14	15	7	1.346	0.705	2.05	2.093	8.307	0.311	10.71	8.66
1/1/2011	Jan	Sat	7	14	15	8	1.341	0.736	2.08	2.085	8.591	0.310	10.99	8.91
1/1/2011	Jan	Sat	7	16	18	9	1.345	0.739	2.08	2.091	8.424	0.311	10.83	8.74
1/1/2011	Jan	Sat	7	20	22	10	1.343	0.740	2.08	2.089	8.475	0.310	10.87	8.79
1/1/2011	Jan	Sat	7	23	26	11	1.339	0.747	2.09	2.082	8.563	0.309	10.95	8.87
1/1/2011	Jan	Sat	7	26	30	12	1.338	0.747	2.08	2.080	8.538	0.309	10.93	8.84
1/1/2011	Jan	Sat	7	25	31	13	1.340	0.759	2.10	2.083	8.681	0.309	11.07	8.97
1/1/2011	Jan	Sat	7	26	32	14	1.336	0.752	2.09	2.078	8.556	0.309	10.94	8.85
1/1/2011	Jan	Sat	7	26	33	15	1.335	0.763	2.10	2.076	8.796	0.308	11.18	9.08
1/1/2011	Jan	Sat	7	26	33	16	1.339	0.742	2.08	2.082	8.601	0.309	10.99	8.91
1/1/2011	Jan	Sat	7	25	31	17	1.343	0.715	2.06	2.088	8.557	0.310	10.96	8.90
1/1/2011	Jan	Sat	7	24	29	18	1.348	0.749	2.10	2.095	8.572	0.311	10.98	8.88
1/1/2011	Jan	Sat	7	25	30	19	1.353	0.737	2.09	2.104	8.447	0.312	10.86	8.77
1/1/2011	Jan	Sat	7	25	30	20	1.352	0.716	2.07	2.103	8.508	0.312	10.92	8.85
1/1/2011	Jan	Sat	7	25	30	21	1.340	0.695	2.04	2.084	8.203	0.310	10.60	8.56
1/1/2011	Jan	Sat	7	25	30	22	1.342	0.680	2.02	2.086	8.288	0.310	10.68	8.66
1/1/2011	Jan	Sat	7	25	30	23	1.339	0.671	2.01	2.082	8.235	0.309	10.63	8.62

The formulas for each of the calculated columns are listed below.

Lighting savings (difference in the "lighting" columns in Table 8 above) are calculated using the following equation:

$$kWh_{lights} = \Sigma_{hours}[[kW_{base} \times Percent_{adj}] - kW_{installed}]$$

Where:

kWh_{lights} = lighting kWh savings

kW_{base} = Total kW of baseline fixtures

$Percent_{adj}$ = Adjustment factor for monitored power fluctuations

$kW_{installed}$ = Total kW of installed fixtures

The new LED lighting system generates less waste hear than the baseline fluorescent fixtures. This waste heat represents a reduced load at the compressors and provides additional savings. The equation for these savings is:

$$kWh_{light\ refrig} = \Sigma_{hours}[[[kW_{base} - kW_{installed}] \times 3.413]/12{,}000] \times Eff$$

Where:

$kWh_{lght\ refrig}$ = Annual kWh refrigeration energy savings from reduction in lighting waste heat

kW_{base} = Baseline lighting adjusted for power fluctuations

$kW_{installed}$ = Total kW of installed fixtures

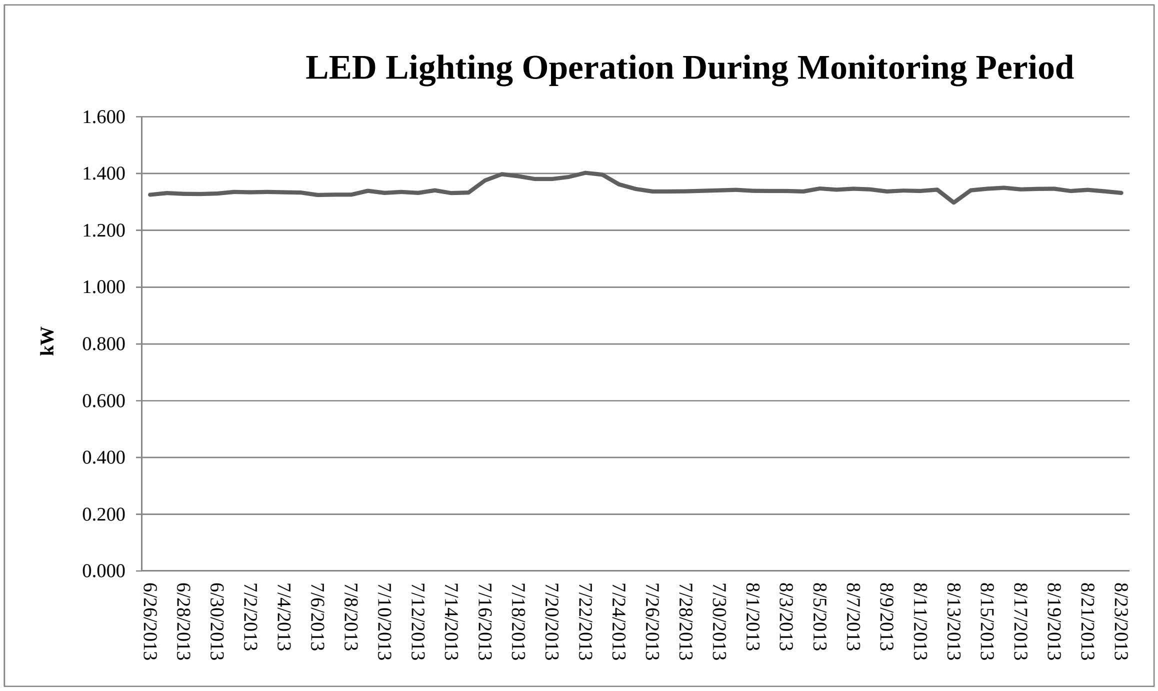
3.412 = kW to BTUH conversion factor

12,000 = BTUH to tons conversion factor

Eff = Refrigeration system efficiency in kW/ton

Figure 2 below shows the daily operating profiles and average hourly power usage for the LED lighting systems.

Figure 2: LED Lighting Operating Profile



The energy loss through the new doors is calculated as conduction losses using the total door area, U-value of the installed doors, and the differential between the ambient store temperature and the showcase temperature.

$$kWh_{doors} = \Sigma_{hours}[[U \times Area \times [Temp_{store} - Temp_{case}]/12{,}000] \times Eff$$

Where:

kWh_{doors} = Conduction energy usage for the new doors

U = U-value of installed doors BTU/FT^2/°F

Area = Total door area in square feet

$Temp_{store}$ = Average monitored store temperature °F

$Temp_{case}$ = Average monitored case temperature °F

12,000 = BTUH to tons conversion factor

Eff = Refrigeration system efficiency in kW/ton

The energy usage for the open showcases is calculated using the manufacturers' data per linear foot of showcase. The BTU per linear foot values in the tracking documentation includes gains from efficient evaporator fans. Fan power is provided in the specification sheets. The fan kW was converted to BTUs and subtracted from the listed linear foot value. Store and case temperatures had only minor fluctuation over the monitoring period. Similar adjustments for temperature fluctuations to the lighting power adjustments were made in calculating open case energy usage.

$kWh_{open\ case} = \Sigma_{hours}[[[LF \times Loss]/12{,}000] \times Eff \times Ambient_{adj} \times Case_{adj}$

Where:

$kWh_{open\ case}$ = Energy usage from open case spillover

LF = Linear feet of showcase

Loss = Manufacturers' open case design load in BTU/linear foot minus evaporator fan load

12,000 = BTUH to tons conversion factor

Eff = Refrigeration system efficiency in kW/ton

$Ambient_{adj}$ = Store temperature fluctuation factor

$Case_{adj}$ = Showcase temperature fluctuation factor

Door savings are calculated by subtracting kWh_{doors} from $kWh_{open\ case}$.

Verification of Equipment and Operating Parameters

Table 9 below provides a comparison of the data that contribute to the calculated energy savings.

Table 9: Data Comparison

Input	Tracking	Evaluation	Eval / Tracking
Baseline Lighting kW	2.138	2.090	98%
Installed Lighting kW	1.456	1.344	92%
Annual Lighting Operating Hours	8,030	8,760	109%
Number of Doors	52	52	100%
Door Area	635.62	635.62	100%
Refrigeration Efficiency kW/ton	1.29	1.48	115%

Savings Analysis and Verification

Monitoring shows that the installed lighting draws 8% less power than estimated while the baseline usage draws 2% less than estimated when compensated for voltage fluctuations. The showcase lighting operates continuously according to monitored data and confirmed by store personnel. Tracking savings assume that lighting is turned off 4 times per day for a total of two hours during defrost cycles. This shut-off period is often associated with evaporator fans and not relevant with showcase lighting. The difference in power and increased operation adds 1,057 kWh to annual savings. This is 19% greater than the estimated tracking savings.

This increase in savings is offset by reduced savings for the new showcase doors. The tracking spreadsheet uses many macros to generate savings. These include a fixed 751 BTUH per door savings factor. How that factor was created is not known. However, the tracking data does include product specifications for the open showcases. This data includes refrigeration load per linear foot of open case. No corresponding load data is provided for the installed doors. The evaluation calculates savings for the doors by subtracting the conduction losses from the spillover losses from the open cases. Refrigerated cases recirculate air across the product from high discharge ports at the evaporator fans to return intakes at the bottom of the cases. This creates an air curtain that separates the refrigerated space from the sales floor. This air curtain is breached when product is added and removed. The air curtain is also affected by agitation from customer traffic in the aisle. Spillover also occurs when product blocks return grating. This can be due to over stocking shelves or product dropped on the shelves. The refrigerated air then spills to the sales floor and must be replaces and cooled to the required discharge air temperature.

Spillover is one of several variables that make up the refrigerated case load. Other variables include the mass and temperature of new product stocked into the cases. This product must be brought to case temperature and represents additional load. This can slightly increase case temperatures. Traffic is another component. The refrigerated air flow in each open case generates an air curtain that separates the store air from air in the showcase. That air curtain is disrupted when people pass by the showcases and when they reach into the case to obtain product. This again can contribute to case temperature differential with the space. Other variable include the actual CFM of the evaporator fans compared with design CFM requirements. Evaporator fan CFM was not monitored for this evaluation.

The installation of the new doors eliminates the spillover losses from the front of the case and reduces the traffic losses. Traffic losses occur only when doors are open to get product. The new doors are saving 9,019 kWh less than the tracking estimates. Temperature differential between the case interior and the sales floor is a common product for spillover and traffic losses. The averaged monitored showcase temperature [36.5°F] is 2.5°F greater than the 34°F design case temperature. This slightly higher operating temperature means that less energy is required to fulfill the spillover and traffic losses.

The installed LED lighting is saving 19% more energy than anticipated as discussed above. The interactive refrigeration savings for the lighting are 24% greater than tracking savings due to the increased lighting operating hours and higher refrigeration kW/ton. The savings for the new doors are 12% less than anticipated. Table 10 below breaks out the total savings by measure type.

Table 10: Summary of Savings by Measure

Measure	Evaluation	Tracking	Eval/Track
LED Lighting	6,535	5,476	119%
Interactive Lighting	2,720	2,191	124%
New Doors	67,703	76,722	88%
Totals	76,958	84,389	91%

Application ID: 2099672

Measure Category: Refrigeration, Motor, and Other

Project Type: Retrofit

Summary

This is a 330,000 square foot textile plant that is comprised of low bay and high bay manufacturing areas, warehouse space, offices, and a laboratory wing. Manufacturing process includes tenter frames that provide continuous drying to textile lines. This measure installs variable speed drives on each of the 10 dryer fans and one exhaust fan on tenter frame #7. The new drives are tied into the plant's existing PLC system.

Table 1 below summarizes the energy and demand savings achieved by this project. The evaluation savings of 530,778 kWh is 30% greater than the tracking estimates. The increase in savings is due to extended annual operation of the tenter frame over tracking estimates and lower average operating kW. Summer on-peak demand savings are 8% less than the tracking estimates and winter on-peak demand savings are 8% less than anticipated.

Table 1: Summary of tracking and evaluation savings results

Savings Quantity	Tracking Estimate	Evaluation Estimate	Evaluation / Tracking
Annual Energy (kWh)	409,041	530,778	130%
% Energy Savings On-Peak	57.0%	47.1%	83%
Summer On-Peak Demand (kW)	67.10	61.93	92%
Winter On-Peak Demand (kW)	67.60	61.97	92%

Project Description

The tenter frame heats air via the combustion of propane. The heated air is circulated over the fabric. The fabric passes through several individually temperature controlled zones. The machine uses a total of ten 15 HP fans to recirculate heated air within the heating zones. There is also one 15 HP exhaust fan that provides continuous exhaust from the heating zone chambers. Variable speed drives are installed on each on the recirculation fans and on the exhaust fan. The PLC system will monitor the temperature and moisture of the fabric passing through production. The variable speed drive speeds will be modulated according to the type of fabric and moisture/temperature requirements. Table 2 shows the tenter frame fan data.

Table 2 Tenter Frame #7 Fan Data

Tenter Fan	HP	Motor Efficiency	Full Load kW	Percent Runtime	Percent Load
Recirculation #1	15.0	92.4%	12.1	81%	79%
Recirculation #2	15.0	92.4%	12.1	81%	82%
Recirculation #3	15.0	92.4%	12.1	81%	79%
Recirculation #4	15.0	92.4%	12.1	81%	78%
Recirculation #5	15.0	92.4%	12.1	81%	79%
Recirculation #6	15.0	92.4%	12.1	81%	85%
Recirculation #7	15.0	92.4%	12.1	81%	79%
Recirculation #8	15.0	92.4%	12.1	81%	83%
Recirculation #9	15.0	92.4%	12.1	81%	76%
Recirculation #10	15.0	92.4%	12.1	81%	73%
Exhaust #1	15.0	92.4%	12.1	81%	79%

Baseline

In each of the heating zones within the tenter frame there is a set of motorized dampers on the inlet to each recirculation fan. These dampers were installed to control the rate of air recirculation within the zone, based on the particular type and weight of fabric and the required finish. In particular, the fabric weight has the most impact on the airflow rate required for proper drying and finishing. The tenter frame is used to process fabrics of about 20 different denier weights. Denier refers to the size of the individual stands or fabric filament. The weights range from 70 denier to 1,000 denier.

Under current operation, the zone dampers for the recirculation air fans and the exhaust fan are not modulated in response to the weight of the fabric being processed. Each fan is operated continuously whenever the tenter frame is in operation. The inlet dampers on each fan are either fully open or fully closed. Under normal operation with the line running, the dampers are all fully open. There is an interlock that closes all of the dampers whenever the machine is stopped with the fabric not moving. This is done to protect the fabric from burning. Under current operation all temperature control of the heating within each zone is done via modulation of the gas burner for the zone with the airflow quantity fixed.

Installed

The variable speed drives control the fan speed for each of the ten existing recirculation fans and the exhaust fan. All existing motors are premium efficiency units and are not replaced in this measure. The new

VFDs would be connected to the machine's PLC system. Each fan speed is modulated by the production specifications of type and weight of fabric processed.

With the installation of the variable speed drives, the inlet dampers will remain in place but will be fully open under normal operation. The existing interlock will remain in place to close each inlet damper when the fabric rolls are stopped to protect the fabric. Annual operation is estimated at 7,096 hours for both the baseline and installed scenarios.

Tracking Analysis

Tracking Calculation Methodology

The annual energy consumption of each recirculation fan is calculated in an Excel spreadsheet based on motor nameplate horsepower, nameplate efficiency, percent load, and percent runtime. Amperage was monitored for 6 of the baseline fans for a 24 hour period. Average amperage was used to estimate percent load. No working copy of the spreadsheet was available. Calculations were recreated for the baseline operation from input values provided in the PDF version of the spreadsheet. The tracking savings were recreated using the values provided in the PDF version. The recalculated saving matched the tracking values. Average baseline fan operation is calculated as:

$$kWh_{base} = \Sigma_{fans} \text{ [HP x Load]/Eff x 7,096}$$

Where:

kWh_{base} = Total annual baseline tenter frame fan kWh

HP = Fan motor HP

Load = Percent motor load

Eff = Motor efficiency

7,096 = Annual operating hours

The calculation of usage of the proposed operation uses a similar approach. The calculation includes estimates of operation at three different anticipated production loads. Based upon projected throughput, the drives are expected to operate at 50% load for 20% of the time, at 65% load for 50% of the time, and at 75% load for 30% of the time. The percent load profiles were estimates provided by facility personnel based upon their production experience. Energy saving is the difference between energy use of the baseline and the proposed system. The calculations also assume a 3% VFD burden. Motor efficiency is estimated at 74% at low load. It was not possible to replicate the savings exactly. The recreated savings were 0.85% greater than the tracking savings. This difference may be due to rounding or additional factors not included in the input values. Average fan motor kW with drives ranges from 4.0 kW to 4.7 kW. Total average operating kW with the variable speed drives is calculated to be 47.8 kW.

Discussion of Tracking Analysis

The calculations are based upon nameplate and monitored amperage data. Baseline operation is appropriately calculated as constant speed during production operation. The proposed operation estimates usage at 50%, 65%, and 75% load bins. A ^2.5 affinity power is used in load calculations. Operating hours are assigned to each load bin. The calculations are comprehensive and accurate.

Baseline Validity

The baseline is existing motors operating at fixed constant speed. This is accurate and portrays actual baseline operation of the tenter ovens.

Evaluation Methodology

A comprehensive site visit was conducted. The tenter oven was identified and the variable speed drives were installed. Facility personnel stated that the new drives were working without problem since they were installed. The fans are located inside the tenter frame and it was not possible to obtain nameplate data as the unit was operating. Motor sizes were confirmed from motor maintenance records at the facility.

An Elite power logger was installed in the tenter frame motor control panel. The logger was installed on the main power supply to the panel. This enabled the monitoring of all ten recirculation fans and the exhaust fan.

Evaluation Data Collection

Elite power logger monitored total recirculation and exhaust fan operation. The loggers were installed on August 26, 2013. The Elite logger recorded average volts, amps, and kW every 15-minutes throughout the 60-day monitoring period.

Monitored data from the Elite power loggers was converted into average hourly kW values. These values are unique for each hour of the day and each day of the week. A "typical" weekly operating schedule was created from the data for the tenter frame fan motors. Table 3 shows the average operating profile of the tenter frame fans.

Table 3: Tenter Frame #7 Fan Power

Site Average Hourly kW							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	42.21	40.69	41.96	42.34	42.88	42.64	42.18
2	42.03	40.76	41.72	42.41	42.80	42.27	42.31
3	41.97	42.22	42.08	42.56	42.78	42.43	42.27
4	42.11	42.85	42.07	42.14	43.46	42.05	42.07
5	41.97	43.12	41.82	42.66	44.19	41.90	42.29
6	42.79	41.83	42.10	42.18	43.77	41.99	41.70
7	43.52	42.89	42.47	42.78	43.68	42.57	42.52
8	42.19	45.03	42.45	42.31	43.56	42.09	42.79
9	41.70	44.94	42.42	42.50	43.78	41.72	42.82
10	41.47	43.44	42.02	42.50	44.18	42.52	41.86
11	41.91	41.62	42.55	42.44	43.47	43.24	42.38
12	42.27	41.94	42.57	42.10	43.64	42.22	42.54
13	42.61	42.04	42.60	42.53	44.45	42.39	42.11
14	42.31	41.54	42.28	42.04	43.85	42.53	42.36
15	43.86	41.93	42.34	42.91	42.28	42.31	42.33
16	42.46	42.08	43.71	41.94	42.35	42.20	42.97
17	43.09	41.54	43.02	42.88	42.38	42.06	42.60
18	42.40	41.30	42.22	42.35	42.48	41.81	42.91
19	41.97	41.75	42.12	42.62	42.44	42.21	42.97
20	42.23	41.63	42.14	42.41	42.35	41.94	42.30
21	42.18	41.14	42.18	42.61	42.12	41.87	42.21
22	42.04	41.33	41.99	42.24	42.22	42.07	42.29
23	42.25	41.43	42.41	42.62	42.11	41.70	43.66
24	41.65	41.34	42.56	42.58	42.30	42.25	42.80

The monitored data provides an average kW for each operating hour of the week. The monitoring data shows that this unit is used extensively and operated for 98% of the monitoring period. The tenter frame operated for 1,414 hours of the 1,441 monitoring hours. Site personnel confirmed that this is the lead unit and is dedicated to the product line that is the bulk of their production output. This product line has consistent operation throughout the year according to facility production histories.

Evaluation Savings Analysis

Annual savings are calculated using an 8,760 hour spreadsheet. The baseline fan usage is obtained from the value recreated from the tracking data. Savings are generated by subtracting the monitored hourly kW from the baseline kW. Summer and winter demand savings were calculated for the hours in those periods. The savings for the first operational day are provided in Table 4 below.

Table 4: Calculation Spreadsheet

								Avg	41.68	41.68	103.63	103.63	
								Max	45.0	45.0	105.46	105.5	64.8
								Min	0	0	0	0	0
Totals				192	8,420			Totals	357,155	357,155	887,933	887,933	530,778
						TMY 3 Temps			SITE KW		BASELINE KW		
Date	Month	Day	Day of Wk	Site Holiday	Operating Hours	OWB Temp	ODB Temp	Hour	Tenter Frame	Site Total kW	Tenter Frame	Total Tracking kW	Total Houry kW Savings
1/2/2011	Jan	Sun	1	0	1.0	25	29	1	42.2	42.21	105.46	105.46	63.25
1/2/2011	Jan	Sun	1	0	1.0	25	29	2	42.0	42.03	105.46	105.46	63.42
1/2/2011	Jan	Sun	1	0	1.0	26	29	3	42.0	41.97	105.46	105.46	63.49
1/2/2011	Jan	Sun	1	0	1.0	25	29	4	42.1	42.11	105.46	105.46	63.35
1/2/2011	Jan	Sun	1	0	1.0	25	29	5	42.0	41.97	105.46	105.46	63.49
1/2/2011	Jan	Sun	1	0	1.0	25	27	6	42.8	42.79	105.46	105.46	62.67
1/2/2011	Jan	Sun	1	0	1.0	24	26	7	43.5	43.52	105.46	105.46	61.94
1/2/2011	Jan	Sun	1	0	1.0	23	25	8	42.2	42.19	105.46	105.46	63.27
1/2/2011	Jan	Sun	1	0	1.0	24	27	9	41.7	41.70	105.46	105.46	63.76
1/2/2011	Jan	Sun	1	0	1.0	23	27	10	41.5	41.47	105.46	105.46	63.99
1/2/2011	Jan	Sun	1	0	1.0	24	28	11	41.9	41.91	105.46	105.46	63.55
1/2/2011	Jan	Sun	1	0	1.0	23	25	12	42.3	42.27	105.46	105.46	63.19
1/2/2011	Jan	Sun	1	0	1.0	23	24	13	42.6	42.61	105.46	105.46	62.85
1/2/2011	Jan	Sun	1	0	1.0	25	26	14	42.3	42.31	105.46	105.46	63.15
1/2/2011	Jan	Sun	1	0	1.0	25	27	15	43.9	43.86	105.46	105.46	61.60
1/2/2011	Jan	Sun	1	0	1.0	26	27	16	42.5	42.46	105.46	105.46	62.99
1/2/2011	Jan	Sun	1	0	1.0	25	26	17	43.1	43.09	105.46	105.46	62.37
1/2/2011	Jan	Sun	1	0	1.0	26	27	18	42.4	42.40	105.46	105.46	63.06
1/2/2011	Jan	Sun	1	0	1.0	27	27	19	42.0	41.97	105.46	105.46	63.48
1/2/2011	Jan	Sun	1	0	1.0	27	27	20	42.2	42.23	105.46	105.46	63.23
1/2/2011	Jan	Sun	1	0	1.0	26	26	21	42.2	42.18	105.46	105.46	63.28
1/2/2011	Jan	Sun	1	0	1.0	25	25	22	42.0	42.04	105.46	105.46	63.42
1/2/2011	Jan	Sun	1	0	1.0	23	24	23	42.3	42.25	105.46	105.46	63.20
1/2/2011	Jan	Sun	1	0	1.0	22	23	24	41.6	41.65	105.46	105.46	63.81

Tenter fan savings are calculated using the following equation:

$$kWh_{fans} = \Sigma_{hours} [kW_{base} - kW_{installed}]$$

Where:

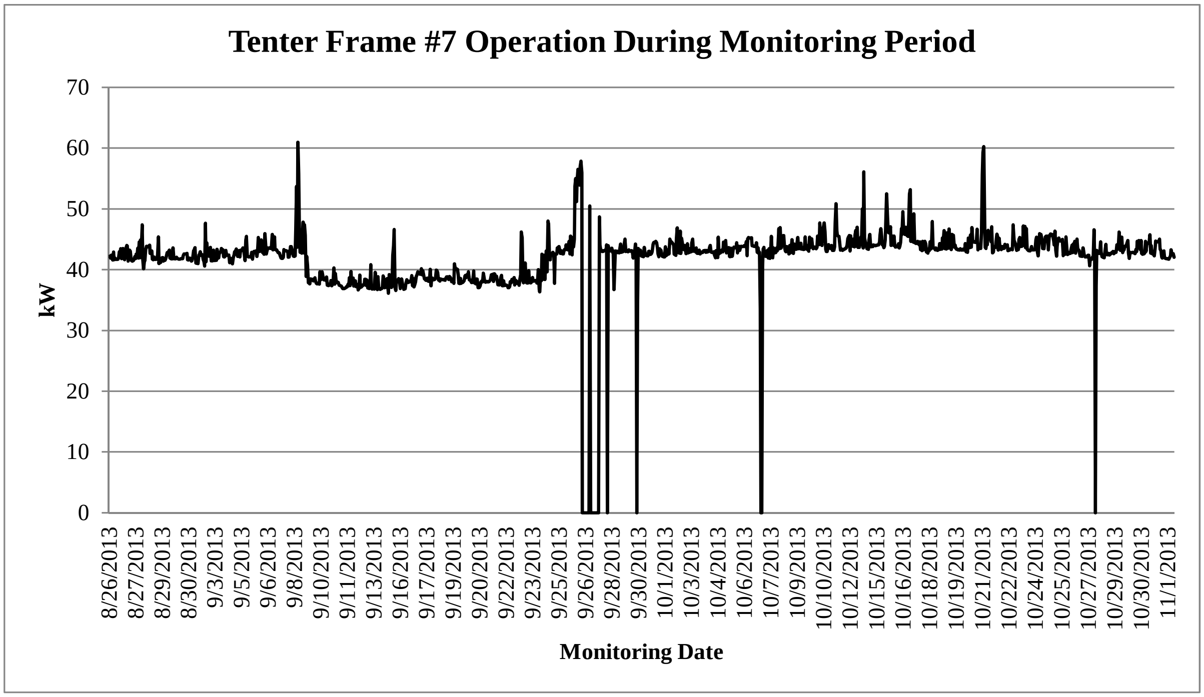
kWh_{fans} = Recirculating and exhaust fan kWh savings

kW_{base} = Total kW of baseline fans

$kW_{installed}$ = Total monitored kW of variable speed driven fans

Figure 1 below shows the daily operating profiles and average hourly power usage for the 10 tenter frame recirculation fans and exhaust fan.

Figure 1: Tenter Frame #7 Fan Operating Profile



Verification of Equipment and Operating Parameters

Table 5 below provides a comparison of the data that contribute to the calculated energy savings.

Table 5: Data Comparison

Input	Tracking	Evaluation	Eval / Tracking
Fan Quantity	11	11	100%
Fan Motor HP	15	15	100%
Annual Operating Hours	7,096	8,420	119%
Average Baseline Operating kW	105.5	105.5	100%
Average Installed Operating kW	47.8	41.7	87%

Savings Analysis and Verification

This is the lead process unit on the plant floor and is dedicated to the most important product line. The increase in savings is due to the tenter frame operating 19% longer than tracking estimates. The average operating kW for all the fans controlled by drives is also 13% less than estimated. The operation of the tenter frame fans operated with less variation in speed than the tracking calculations. The monitored fan power in Table 3 shows the uniformity in fan operation across the hours per week. Tracking savings conservatively estimated a wider range of operation, which was not needed due to the consistent nature of product throughput and required production temperatures. This tighter level of fan operation resulted in the lower than anticipated fan kW. All 11 existing fans were monitored for this evaluation. Tracking savings were estimated using pre-installation monitoring data on 6 of the fans that were extrapolated out to the remaining fans for the pre-case and based on estimates of post installation kW using engineering models of drive performance.

Application ID: 2202620

Measure Category: Refrigeration, Motors, Other

Project Type: Retrofit

Summary

This is a 330,000 square foot textile plant that is comprised of low bay and high bay manufacturing areas, warehouse space, offices, and a laboratory wing. Manufacturing process includes tenter frames. A tenter frame moves fabric through oven sections to heat set the fabric or keep it from shrinking during drying. Each oven section is equipped with a fan that circulates drying air. This measure installs variable speed drives on each of tenter frame #10's 12 dryer recirculating fans and two exhaust fan. The new drives are tied into the plant's existing PLC system.

Table 1 below summarizes the energy and demand savings achieved by this project. The evaluation savings of 446,462 kWh is 7% less than the tracking estimates. The primary reason for the reduction in savings is that the tenter frame operates nearly 2,100 less hours than tracking estimates. The impact from the operational adjustment is partially offset by the fans operating a total of 22.0 kW less than predicted. Summer on-peak demand savings are 22% greater than the tracking estimates and winter on-peak demand savings are 19% more than anticipated.

Table 1: Summary of tracking and evaluation savings results

Savings Quantity	Tracking Estimate	Evaluation Estimate	Evaluation / Tracking
Annual Energy (kWh)	482,691	446,462	93%
% Energy Savings On-Peak	67.0%	72.2%	108%
Summer On-Peak Demand (kW)	79.20	96.44	122%
Winter On-Peak Demand (kW)	79.80	95.32	119%

Project Description

Tenter frame #10 is used to treat specialty product in the process line and provide additional capacity for product that normally is treated by tenter frame #7. The unit has less operation than the other units at this site. Specialty products require lower heating temperatures.

The enter frame heats air via the combustion of propane. The heated air is circulated over the fabric. The fabric passes through several individually temperature controlled zones. The machine uses a total of twelve 15 HP fans to recirculate heated air within the heating zones. There are also two 7.5 HP exhaust fans that provides continuous exhaust from the heating zone chambers. Variable speed drives are installed on each on the recirculation fans and on the exhaust fans. The PLC system will monitor the temperature and moisture of the fabric passing through production. The variable speed drive speeds will be modulated according to the type of fabric and moisture/temperature requirements. Table 2 shows the tenter frame fan data.

Table 2 Tenter Fan Data

Tenter Fan	HP	Motor Efficiency	Full Load kW	Percent Runtime	Percent Load
Recirculation #1	15.0	92.4%	12.1	81%	79%
Recirculation #2	15.0	92.4%	12.1	81%	79%
Recirculation #3	15.0	92.4%	12.1	81%	79%
Recirculation #4	15.0	92.4%	12.1	81%	79%
Recirculation #5	15.0	92.4%	12.1	81%	79%
Recirculation #6	15.0	92.4%	12.1	81%	79%
Recirculation #7	15.0	92.4%	12.1	81%	79%
Recirculation #8	15.0	92.4%	12.1	81%	79%
Recirculation #9	15.0	92.4%	12.1	81%	79%
Recirculation #10	15.0	92.4%	12.1	81%	79%
Recirculation #11	15.0	92.4%	12.1	81%	79%
Recirculation #12	15.0	92.4%	12.1	81%	79%
Exhaust #1	7.5	91.7%	12.1	81%	79%
Exhaust #1	7.5	91.7%	12.1	81%	79%

Existing

In each of the heating zones within the tenter frame there is a set of motorized dampers on the inlet to each recirculation fan. These dampers were proposed to control the rate of air recirculation within the zone, based on the particular type and weight of fabric and the required finish. In particular the fabric weight has the most impact on the airflow rate required for proper drying and finishing. The tenter frame is used to process fabrics of about 20 different weights. The weights range from 70 denier to 1,000 denier.

Under current operation, the zone dampers for the recirculation air fans and the exhaust fan are not modulated in response to the weight of the fabric being processed. Each fan is operated continuously whenever the tenter frame is in operation. The inlet dampers on each fan are either fully open or fully closed. Under normal operation with the line running, the dampers are all fully open. There is an interlock that closes all of the dampers whenever the machine is stopped with the fabric not moving. This is done to protect the fabric from burning. Under current operation all temperature control of the heating within each zone is done via modulation of the gas burner for the zone with the airflow quantity fixed.

Proposed

The variable speed drives control the fan speed for each of the twelve existing recirculation fans and the two exhaust fans. All existing motors are premium efficiency units and are not replaced in this measure. The new VFDs would be connected to the machine's PLC system. Each fan speed is modulated by the production specifications of type and weight of fabric processed.

With the installation of the variable speed drives, the inlet dampers will remain in place but will be fully open under normal operation. The existing interlock will remain in place to close each inlet damper when the fabric rolls are stopped to protect the fabric. Annual operation is estimated at 7,096 hours for both the existing and proposed scenarios.

Tracking Analysis

Tracking Calculation Methodology

The annual energy consumption of each recirculation fan is calculated in an Excel spreadsheet based on motor nameplate horsepower, nameplate efficiency, percent load, and percent runtime. No monitoring was done on tenter frame #10's fans. Variable speed drives were proposed on a second tenter frame in the facility. Amperage was monitored on six fans for a 24-hour period on that tenter frame. Average fan data was estimated for tenter frame #10 based on those measurements. No working copy of the spreadsheet was available. Calculations were recreated for the existing operation from input values provided in the PDF version of the spreadsheet. Average existing fan operation is calculated as:

$$kWh_{base} = \Sigma_{fans} [HP \times Load]/Eff \times 7{,}096$$

Where:

kWh_{base} = Total annual existing tenter frame fan kWh

HP = Fan motor HP

Load = Percent motor load

Eff = Motor efficiency

7,096 = Annual operating hours

The calculation of usage of the proposed operation uses a similar approach. The calculation includes estimates of operation at three different anticipated production loads. Based upon projected throughput, the dives are expected to operate at 50% load for 20% of the time, at 65% load for 50% of the time, and at 75% load for 30% of the time. Energy saving is the difference between energy use of the existing and the proposed system. The calculations also assume a 3% VFD burden. Motor efficiency is estimated at 74% at low load. It was not possible to replicate the savings exactly. The recreated savings were 4,400 kWh greater than the tracking which is slightly less than a 1.0% difference. This may be due to rounding or additional factors not included in the input values. The average fan motor kW is 4.3 kW with drives for the recirculating fans and 2.2 kW for each of the exhaust fans. Total average operating kW with the variable speed drives is estimated at 56.4 kW.

Discussion of Tracking Analysis

The calculations are based upon nameplate and monitored amperage data. Existing operation is appropriately calculated as constant speed operation. The proposed operation estimates usage at 50%, 65%, and 75% load bins. A ^2.5 affinity power is used in load calculations. Operating hours are assigned to each load bin. The calculations are comprehensive and accurate.

Baseline Validity

The existing motors operated at fixed constant speed. This is accurate and portrays actual existing operation of the tenter ovens.

Evaluation Methodology

A comprehensive site visit was conducted. The tenter oven was identified and the installation of the variable speed drives was verified. Facility personnel stated that the new drives were working without problem since they were installed. The fans are located inside the tenter frame and it was not possible to obtain nameplate data as the unit was operating. Motor sizes were confirmed from motor maintenance records at the facility.

An Elite power logger was installed in the tenter frame motor control panel. The logger was installed on the main power supply to the panel. This enabled the monitoring of all twelve recirculation fans and the two exhaust fans.

Evaluation Data Collection

Elite power logger monitored total recirculation and exhaust fan operation. The loggers were proposed on August 26, 2013. The Elite logger recorded average volts, amps, and kW every 15-minutes throughout the 56-day monitoring period. Monitored data from the Elite power logger was converted into average hourly kW values. These values are unique for each hour of the day and each day of the week. A "typical" weekly operating schedule was created from the data for the tenter frame fan motors. Table 3 shows the average operating profile of the tenter frame fans. Table 4 shows the hourly operating percentages.

Table 3: Tenter Frame #10 Fan Power

Site Average Hourly kW							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	0.00	0.00	33.52	32.73	24.15	26.42	25.69
2	0.00	0.00	35.66	42.06	21.83	27.68	24.40
3	0.00	0.00	45.17	35.61	24.14	26.17	27.03
4	0.00	0.00	27.26	40.37	22.76	25.38	23.22
5	0.00	0.00	0.00	44.30	17.33	20.45	0.00
6	0.00	0.00	0.00	37.71	12.01	0.00	0.00
7	0.00	0.00	0.00	0.00	12.02	0.00	0.00
8	24.31	0.00	0.00	0.00	12.06	12.80	0.00
9	23.10	0.00	18.80	0.00	12.10	27.20	0.00
10	30.84	0.00	23.41	0.00	12.03	25.89	0.00
11	29.49	16.68	24.03	0.00	11.96	27.21	17.95
12	29.51	23.61	26.47	24.73	21.72	24.58	25.28
13	29.48	26.95	29.08	31.27	24.85	28.84	27.04
14	28.81	25.62	28.66	31.40	25.07	28.86	28.57
15	30.21	26.28	29.79	29.56	24.48	28.26	27.87
16	0.00	26.25	30.42	26.26	27.26	26.46	24.30
17	0.00	27.83	31.79	27.08	29.27	28.03	25.38
18	0.00	28.77	28.81	28.78	29.31	28.26	19.85
19	0.00	30.70	30.55	28.05	29.83	27.87	21.35
20	0.00	28.46	28.59	24.97	29.62	28.33	24.13
21	0.00	29.39	26.81	26.21	27.94	27.23	25.56
22	0.00	27.73	29.87	26.37	30.50	26.50	25.08
23	0.00	31.54	32.32	26.11	30.23	26.92	23.06
24	0.00	29.53	33.40	25.44	24.70	25.46	0.00

Table 4: Tenter Frame #10 Hourly Operating Percentages

Monitoring Percent of Operating Hours							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	0.0%	0.0%	28.1%	20.0%	35.0%	37.5%	30.6%
2	0.0%	0.0%	21.9%	10.0%	22.5%	22.5%	13.9%
3	0.0%	0.0%	12.5%	10.0%	20.0%	17.5%	11.1%
4	0.0%	0.0%	6.3%	10.0%	20.0%	10.0%	8.3%
5	0.0%	0.0%	0.0%	10.0%	20.0%	5.0%	0.0%
6	0.0%	0.0%	0.0%	7.5%	20.0%	0.0%	0.0%
7	0.0%	0.0%	0.0%	0.0%	20.0%	0.0%	0.0%
8	18.8%	0.0%	0.0%	0.0%	20.0%	5.0%	0.0%
9	25.0%	0.0%	9.4%	0.0%	20.0%	10.0%	0.0%
10	25.0%	0.0%	12.5%	0.0%	20.0%	10.0%	0.0%
11	25.0%	46.7%	12.5%	0.0%	20.0%	10.0%	11.1%
12	25.0%	54.5%	63.9%	57.5%	60.0%	60.0%	22.2%
13	25.0%	57.7%	70.0%	50.0%	70.0%	60.0%	22.2%
14	25.0%	75.0%	62.5%	44.4%	70.0%	60.0%	22.2%
15	25.0%	75.0%	60.0%	50.0%	70.0%	55.6%	22.2%
16	0.0%	87.5%	65.0%	77.8%	87.5%	63.9%	33.3%
17	0.0%	81.3%	70.0%	77.8%	90.0%	55.6%	33.3%
18	0.0%	75.0%	62.5%	77.8%	82.5%	55.6%	33.3%
19	0.0%	75.0%	50.0%	75.7%	80.0%	55.6%	29.4%
20	0.0%	75.0%	50.0%	65.0%	80.0%	55.6%	15.6%
21	0.0%	75.0%	42.5%	50.0%	80.0%	55.6%	12.5%
22	0.0%	65.6%	20.0%	40.0%	60.0%	36.1%	13.8%
23	0.0%	40.6%	20.0%	40.0%	60.0%	33.3%	10.0%
24	0.0%	37.5%	20.0%	40.0%	52.5%	33.3%	0.0%

The monitored data provides an average kW for each operating hour of the week. The monitoring data shows that this unit operated for 34% of the monitoring period. Annualized, current operation is 2,618 annual hours. Site personnel stated the monitoring period coincided with a lull in production for tenter frame #10. They stated that future orders will extend the use of this unit and that production will extend to at least 5,000 annual hours. This is an increase of 2,382 hours over the monitoring period. Table 5 shows the weekly schedule with the 5,000 hour annual operation. Priority was given to extend first shift operation on Mondays through Fridays to get to the 5,000 hour level.

Table 5: Adjusted Operating Hours

Process Adjusted Process Operating Hours							
Hour	Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	0.0%	0.0%	53.7%	38.2%	66.8%	71.6%	58.4%
2	0.0%	0.0%	41.8%	19.1%	43.0%	43.0%	26.5%
3	0.0%	0.0%	23.9%	19.1%	38.2%	33.4%	21.2%
4	0.0%	0.0%	11.9%	19.1%	38.2%	19.1%	15.9%
5	0.0%	0.0%	0.0%	19.1%	38.2%	9.5%	0.0%
6	0.0%	0.0%	0.0%	14.3%	38.2%	0.0%	0.0%
7	0.0%	40.0%	40.0%	40.0%	40.0%	40.0%	0.0%
8	35.8%	50.0%	50.0%	50.0%	50.0%	50.0%	0.0%
9	47.7%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%
10	47.7%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%
11	47.7%	100.0%	100.0%	100.0%	100.0%	100.0%	21.2%
12	47.7%	100.0%	100.0%	100.0%	100.0%	100.0%	42.4%
13	47.7%	100.0%	100.0%	100.0%	100.0%	100.0%	42.4%
14	47.7%	100.0%	100.0%	100.0%	100.0%	100.0%	42.4%
15	47.7%	100.0%	100.0%	100.0%	100.0%	100.0%	42.4%
16	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	63.7%
17	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	63.7%
18	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	63.7%
19	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	56.2%
20	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	29.8%
21	0.0%	100.0%	100.0%	95.5%	100.0%	100.0%	23.9%
22	0.0%	100.0%	38.2%	76.4%	100.0%	69.0%	26.3%
23	0.0%	77.6%	38.2%	76.4%	100.0%	63.7%	19.1%
24	0.0%	71.6%	38.2%	76.4%	100.0%	63.7%	0.0%

Evaluation Savings Analysis

Annual savings are calculated using an 8,760 hour spreadsheet. The existing fan usage is obtained from the value recreated from the tracking data. Savings are generated by subtracting the monitored hourly kW from the existing kW. Annual operating hours were adjusted to match the anticipated 5,000 projected operating hours. Summer and winter demand savings were calculated for the hours in those periods. The savings for the first operational day are provided in Table 6 below.

Table 6: Calculation Spreadsheet

								Avg	24.40	19.21	90.10	90.10	
								Max	31.8	31.8	124.4	124.4	112.4
								Min	0	0	0	0	0
Totals				192	5,000			Totals	121,765	121,765	571,043	571,043	449,277
						TMY3 Temps		SITE KW			BASELINE KW		
Date	Month	Day	Day of Wk	Site Holiday	Process Adjusted Operating Hours	OWB Temp	ODB Temp	Hour	Tenter Frame	Site Total kW	Tenter Frame	Total Tracking kW	Total Houry kW Savings
1/2/2011	Jan	Sun	1	0	0.00	25	29	1	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	25	29	2	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	26	29	3	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	25	29	4	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	25	29	5	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	25	27	6	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	24	26	7	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.37	23	25	8	8.9	8.90	45.55	45.55	36.65
1/2/2011	Jan	Sun	1	0	0.49	24	27	9	11.3	11.28	60.73	60.73	49.45
1/2/2011	Jan	Sun	1	0	0.49	23	27	10	15.1	15.06	60.73	60.73	45.67
1/2/2011	Jan	Sun	1	0	0.49	24	28	11	14.4	14.40	60.73	60.73	46.33
1/2/2011	Jan	Sun	1	0	0.49	23	25	12	14.4	14.41	60.73	60.73	46.32
1/2/2011	Jan	Sun	1	0	0.49	23	24	13	14.4	14.39	60.73	60.73	46.34
1/2/2011	Jan	Sun	1	0	0.49	25	26	14	14.1	14.06	60.73	60.73	46.66
1/2/2011	Jan	Sun	1	0	0.49	25	27	15	14.7	14.75	60.73	60.73	45.98
1/2/2011	Jan	Sun	1	0	0.00	26	27	16	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	25	26	17	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	26	27	18	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	27	27	19	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	27	27	20	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	26	26	21	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	25	25	22	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	23	24	23	0.0	0.00	0.00	0.00	0.00
1/2/2011	Jan	Sun	1	0	0.00	22	23	24	0.0	0.00	0.00	0.00	0.00

Tenter fan savings are calculated using the following equation:

$$kWh_{fans} = \Sigma_{hours} [kW_{base} - kW_{proposed}]$$

where

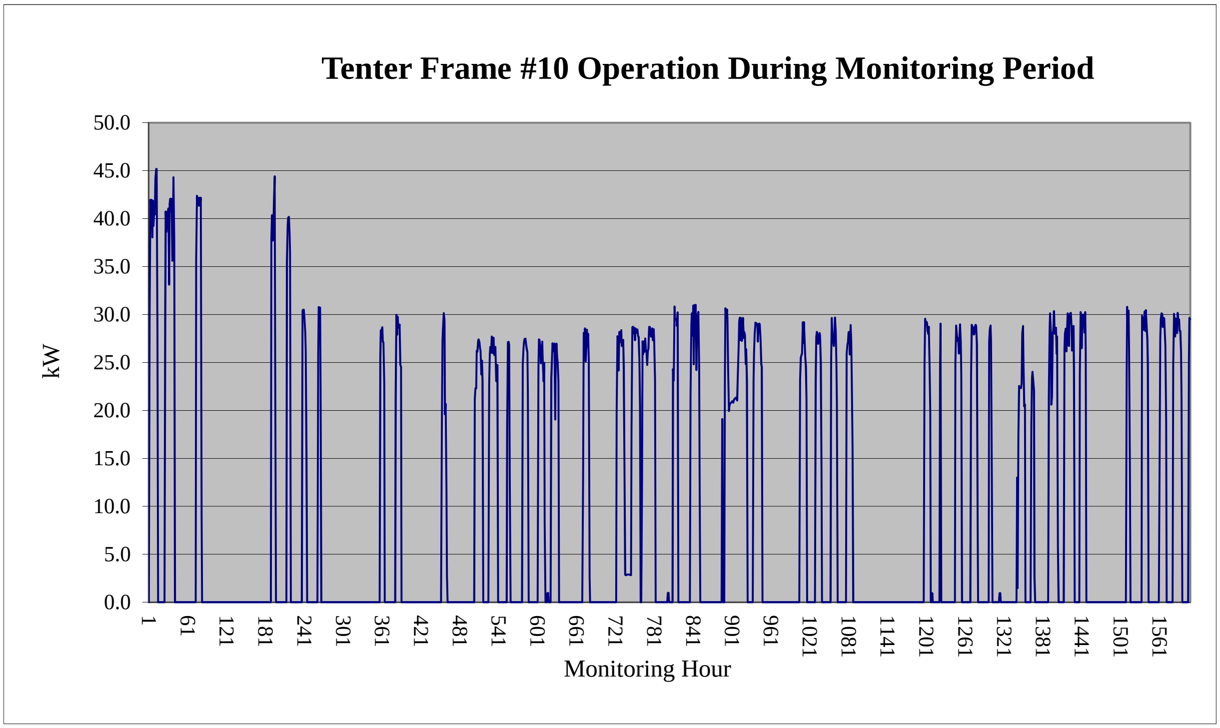
kWh_{fans} = Recirculating and exhaust fan kWh savings

kW_{base} = Total kW of existing fans

$kW_{proposed}$ = Total monitored kW of variable speed driven fans

Figure 1 below shows the daily operating profiles and average hourly power usage for the 12 tenter frame recirculation fans and two exhaust fans.

Figure 1: Tenter Frame Fan #10 Operating Profile



Verification of Equipment and Operating Parameters

Table 7 below provides a comparison of the data that contribute to the calculated energy savings.

Table 7: Data Comparison

Input	Tracking	Evaluation	Eval / Tracking
Recirculating Fan Quantity	12	12	100%
Recirculating Fan Motor HP	15	15	100%
Exhaust Fan Quantity	2	2	100%
Exhaust Fan Motor HP	7.5	7.5	100%
Annual Operating Hours	7,096	5,000	70%
Average Existing Operating kW	124.4	124.4	100%
Average Proposed Operating kW	56.4	24.4	43%

Savings Analysis and Verification

This is unit is used for specialty products and for overflow production when tenter frame #7 is at full capacity. Tenter frame #10 operated for 34% of the monitoring period. Site personnel stated that monitoring coincided with a lull in production and annual operation is expected to be a minimum of 5,000 hours. Tenter frame operation was increased to 5,000 hours of operation in the evaluation calculations. This is 70% of estimated tracking operation.

The impact of the reduced operating hours is partially offset by the lower average fan kW required by the tenter frame fans. Average summer demand savings are 22% greater than tracking values and 19% greater than winter estimates.

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.