Impact Evaluation of Behavior Change in the Industrial Sector

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ABSTRACT

This paper will provide an in-depth look at the Northwest Energy Efficiency Alliance's (NEEA's) industrial behavior change program and the evaluation methods used to determine energy savings, as well as the implementation efforts required to ensure the effort leads to market transformation.

For many decades, leading manufacturers have relied on management systems to increase their employees' focus on operational variables, such as quality, safety, and environmental regulation. A management system is embedded at a company when:

1. Leadership sets a goal
2. Leadership allocates resources (e.g., staff, budget, and training) to achieve the goal
3. Staff regularly reports to leadership on progress toward the goal

Although these core concepts can readily be applied to energy management, they historically have not been, as energy management has been viewed by industry as a fixed cost similar to taxes.

The concept of NEEA's program, called the Continuous Energy Improvement (CEI) program, is to systematize energy management into the industry's traditional and familiar management structure. The CEI program adapts the familiar management system construct to energy and provides tools and services that enable companies to manage energy in the same way they manage other manufacturing variables.

Metrics and measurement are critical to both implementation and evaluation of systems-based energy management. The process of embedding a management system into operations drives staff to identify and report on key energy performance indicators. Consequently, staff become keenly aware not only of the goal, but also of measuring progress toward that goal.

Goals can be simple and easy to measure, such as "We will reduce our total energy consumption by 10% over 5 years." However, goals such as "We will reduce energy use per unit production (energy intensity) by 25% in 10 years," require knowledge of energy use and production output and the processes that drive them. Regardless of the complexity of the goal, its mere presence generally results not only in behavior change, but also in long-term change that drives persistent energy savings.

The challenge in quantifying energy savings from such efforts is that much of the energy savings is not attributable to specific capital improvements. Many of the savings result from actions such as scheduling, controls improvements, operations and maintenance procedures, and a generally heightened awareness of energy efficiency. To quantify savings, the impact evaluation must employ both a bottom-up and top-down methodology. The former uses traditional energy engineering techniques to quantify savings on a measure level.

A top-down statistical analysis is required to quantify savings resulting strictly from behavior change. In this type of analysis, evaluators examine indicators, such as kWh and Btu use, as well as key production statistics and other variables, such as weather, that allow for a normalization of energy with respect to the appropriate variables. When baseline energy use - minus capital improvement project savings - is compared with energy use after the company has embedded a management system, the data generally reveals that there are savings well beyond those attributable to specific projects that can be evaluated by a bottom-up methodology. These incremental savings can then be quantified and attributed to behavior-based changes.

This paper presents the methods, challenges, and results of an impact evaluation of an industrial initiative that targets energy savings and market transformation through behavior changes by embedding a management system for energy within a manufacturing firm's operations.

Introduction

Market transformation activities are often centered around mass market products or energy savings strategies. Typically quantifying savings from such efforts is done through a market research-based approach. However, the Northwest Energy Efficiency Alliance (NEEA) takes a unique approach to market transformation with their Continuous Energy Improvement (CEI) initiative. This initiative targets market transformation through behavior change in the large industrial sector. Specifically, this effort is targeted at large food processors. This is a grassroots effort that seeks to build market transformation from the bottom up by working directly with end users within the Northwest region. NEEA's long-term goal is to work toward the effort becoming self-sustaining, without the need for NEEA's involvement. With this in mind, their intervention with facilities focuses on building the organizational structure and systems to embed energy management into the company's daily operation and management. We'll refer to this as an "energy management system," which is different from the hardware and software that this term often refers to.

Market transformation efforts are historically targeted at upstream markets such as equipment manufacturers, distributors, and retailers. If market transformation efforts are geared towards end users, they will typically be on a mass scale through efforts such as advertising. The CEI effort, however, targets market transformation through individual interaction with end users. This is made possible by the nature of the target market: large food processors. The northwest region's major food processing is fairly consolidated to a community of large operations. Most are members of a trade organization (Northwest Food Processors Association), and the community is very communicative. Given this framework, it is reasonable to hypothesize that a market transformation program could seek to transform the behavior of a group of individual end users, and through demonstration of success within this group, affect the population of non-participants through communication amongst the community.

This is a phased approach that is not yet complete. NEEA has been working with individual end users for several years now and is working toward an exit strategy with those end users in hopes of maintained savings. Should savings be sustained after NEEA disengages with the end user, they will have achieved a transformation in behavior amongst the group of direct participants. Then, as this demonstrated success is communicated amongst the participants peer group, NEEA hopes to achieve market transformation. Future evaluations will be required to evaluate the persistence of energy savings after NEEA disengages end users, as well as adoption of these practices by the regions non-participants.

Unlike traditional incentive programs, CEI does not provide cash incentives. Instead, they offer assistance and expertise in setting up and integrating energy efficiency-focused management systems into the organization. CEI has identified, and intends to overcome, the market barriers identified below.

Market Barriers

- The food processing industry does not currently have a strategic energy management solution.
- Strategic energy management is not viewed as a priority for executives and industry leaders in meeting business objectives.
- The industry lacks training and understanding of how to implement strategic energy management.
- The market lacks practices, programs, qualified suppliers, and technologies to fulfill the industry's strategic energy management needs.

Strategies to Overcome Market Barriers

NEEA has identified and is implementing the following strategies to overcome the identified market barriers, thus transforming the market:

- Provide strategic energy management (SEM) tools and education to the industrial industry.
- Promote and encourage adoption of strategic energy management.
- Demonstrate the value of and train the market to deliver CEI, a framework developed by NEEA that embeds strategic energy management into business and manufacturing operations.
- Promote the value of ISO 50001.

This unique program approach also requires a unique evaluation approach. The savings analysis uses a combination of more traditional energy engineering approaches, as well as statistical, facility-level approaches. If done carefully, both approaches can be beneficial and do not have to be mutually exclusive.

Evaluation Methodology

As NEEA works with the program participants, they attempt to track all projects undertaken. Some projects may be capital based while others are simply operational measures. Savings are typically quantified and tracked through basic analysis done by the energy champion or other members of the energy team. Savings from these efforts are first tracked and evaluated on a project by project, or "bottom-up" basis. This methodology uses traditional energy engineering approaches including measurement of key parameters that impact the power use of the equipment. Then, traditional energy analytical approaches are used to quantify savings on a discrete project basis. These quantification approaches use tried and true methods of energy engineering, such as equipment load profile assessments, bin analysis, etc.

However, not all factors contributing to energy savings can be tracked as discrete projects. Much of the savings may come from more subtle behavior based changes that aren't tracked and quantified. To capture these savings, we use a facility-wide statistical approach that looks at energy use and contributing factors such as production, weather, etc. This is referred to as a "top-down" evaluation and is discussed in more detail in the Top Down Evaluation section below.

Bottom-Up Evaluation

Since discrete projects are tracked by participating facilities and NEEA, we are able to evaluate them using traditional energy engineering techniques. As measurement of equipment energy use and performance over time by evaluation engineers was not in the scope, we used the following modified approach to impact evaluation.

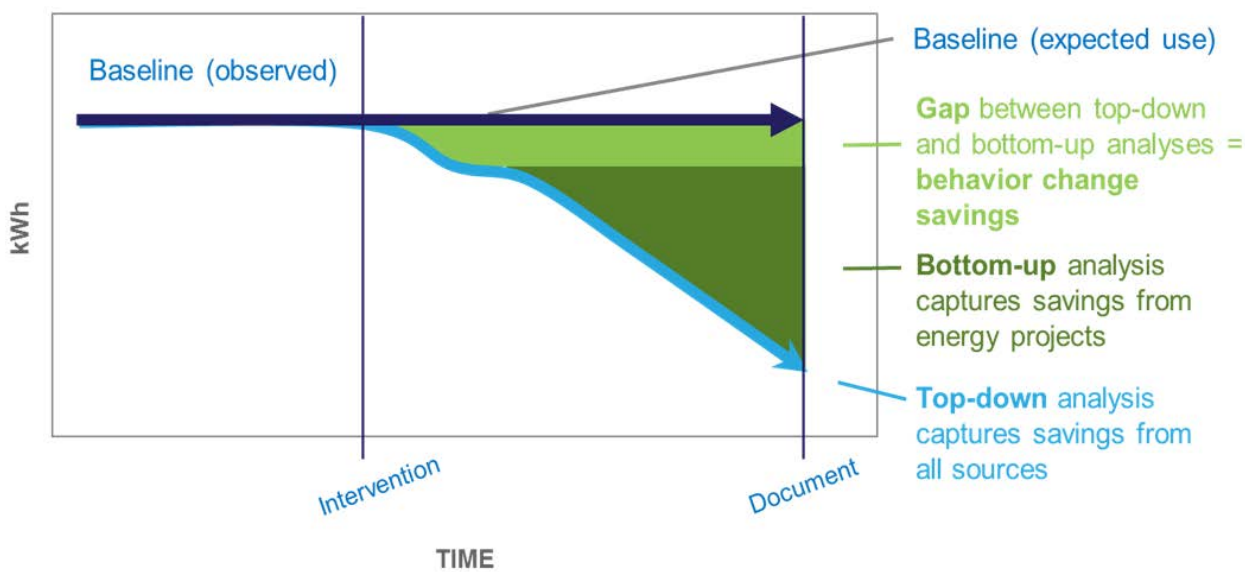
- **Engineering Review** – We reviewed the file documentation, ex-ante savings estimate, and calculation approach used to determine savings. This often led to modifications in methodologies, assumptions, etc. to form draft ex-post evaluation results.
- **Site Visits** – Since the population of participating facilities was a relatively small number of large facilities (forty- five projects across thirteen facilities), a sample-based approach was not an option. Based on this limitation, we conducted site visits at 100% of the participating facilities. The site visits included facility staff interviews, data collection, facility tours, inspection of affected equipment, and spot measurements of key values. Without the logger-based instrumentation, the facility staff interviews, data collection, and spot measurements were of particular importance. The spot measurements included values such as equipment power, temperatures, pressures, flow rates, VFD speeds, boiler efficiencies, etc.
    - **Data Collection** – The specific data collected varies by measure, but most often includes power curves, design specifications such as pump pressure and flow, fan rpm, cfm, compressor hp, control types, etc. Often, design drawings include a schedule of equipment that contains much of this key data.
    - **Spot Measurements** – The spot measurements helped avoid the need for assumptions that introduce uncertainty into the analysis. For example, motor calculations often use an assumed load factor to account for the difference between motor sizing and actual shaft power. A power measurement can replace this assumed load factor with measured power, eliminating that uncertainty. Similarly, measuring values such as temperatures, pressures, flow or boiler combustion efficiency allow for a better understanding of the actual operating conditions of equipment, allowing for a reduction in assumptions and a more accurate and defensible analysis.
- **Final Analysis** – Following the site visits, we used the data collected to modify our draft evaluations and determine the final ex-post savings. This analysis was conducted using the data collected and measured during the site visits, along with generally accepted energy engineering practices. The goal of the final analysis is to use measured or collected data, wherever reasonable to replace assumptions that may have been made in the ex-ante analysis.
- **Realization Rate Determination** – Evaluating 100% of the participating sites made the determination of realization rate simple and reliable. We simply determined a discrete realization rate for electric and gas savings for each project. Then, weighted by savings, we rolled the realization rates up to the facility level, and finally, program level. NEEA will now use these realization rates to apply to future ex-ante savings estimates.

Additional corollary data was tracked along with the bottom-up results to allow for further categorization of the results. This included tracking whether the project was capital or O&M, and if it was capital, whether it received funding from another program administrator.

Top-Down Evaluation

Not all measures can be tracked discretely. For example, at a staff meeting, a manager may declare: “We have a corporate goal to reduce our energy use by 5% this year; I want everyone to be conscientious about energy use.” This may lead to a series of subtle changes across multiple staff members that cannot be tracked as discrete projects. It may be as small as shutting off the lights when they leave their office or as significant as shutting off major process lines when not in use or rerouting the product flow to be more efficient. These actions may never hit the radar of the energy champion and will therefore be impossible to track as discrete efforts. However, in aggregate, these actions may result in significant energy reductions in addition to those stemming from projects identified and tracked by the energy champion. To capture them requires a top-down analysis of the facility’s energy use and the factors affecting it. Figure 1 illustrates this concept.

Figure 1. Bottom-Up and Top-Down Interaction



The top-down evaluation is a regression analysis of monthly electric and natural gas consumption for each facility. The analysis provides an estimate of energy savings for the entire CEI program engagement. The regression models use relevant variables, such as monthly average temperature and production output. The regression results produce an intervention parameter coefficient, which is an indication of monthly energy savings.

A top-down evaluation was conducted for each facility. To ensure enough data availability, we collected data (utility, production, weather, etc.) for 36 months prior to participation to ensure a proper baseline could be developed. Next, we collected data for the entire participation period, typically 2006 or 2007 through 2010. This resulted in a fairly robust data set, spanning 7 to 8 years.

When conducting billing-based analysis, especially in these economic times, one should consider the potential impact associated with the economic turndown. Since food sales are less impacted by the economy, these facilities are affected less by the economic turndown than those producing more discretionary products. However, one should not rule out the potential for the economy to impact even the food processing industry. The predominant dependent variable in a production environment is product throughput (lbs, tons, number of widgets, etc.). The extent to which these facilities are affected by the economy will be directly reflected in the product throughput. Since this is our largest dependent variable, any impact of the economic turndown is captured as a function of production in our regression analysis. In effect, this normalizes the energy use (and savings) for production, which will reflect any impact of a changing economy. Privacy issues surrounding production data prevented the inclusion of non-participants for comparison.

Below is an example of a top-down analysis equation. Some plants had additional variables included such as shutdown periods, process changes, etc. Once the variables are identified, the data dictates the coefficients in the equation below that best fit a data regression.

$$kWh_i = \beta_0 + \beta_1 Intervention_i + \beta_2 Temp_i + \beta_3 Output_i + \varepsilon_i$$
$$Therms_i = \beta_0 + \beta_1 Intervention_i + \beta_2 Temp_i + \beta_3 Output_i + \varepsilon_i$$

$$\begin{aligned}
&Where:\\
kWh &= Total\ monthly\ electricity\ use\\
Therms &= Total\ monthly\ natural\ gas\ use\\
Intervention &= Indicator\ for\ the\ NEEA\ initiative\\
Temp &= Average\ monthly\ external\ temperature\ in\ degrees\ F.\\
Output &= Total\ monthly\ production\ in\ pounds\\
i &= Index\ for\ month\ of\ production\\
\varepsilon &= Error\ term\ asumed\ normally\ distributed\\
\beta &= Coefficients\ to\ be\ estimated
\end{aligned}$$

To determine the statistical significance of the model, we must review the analysis of variance (ANOVA) table. Figure 2 illustrates example analysis results for one facility. The data reveals two key findings. The first is that the regression model is statistically significant. Note the high R squared value of .97 indicates a high level of correlation between energy use and the dependent variables identified. The next finding from the coefficients is that the program had a statistically significant impact on energy consumption. In the example below, we see a decrease in gas use by nearly 6,000 therms per month, as indicated by the intervention coefficient titled CEI2006-10.

Figure 2: Indicators of Regression Fit for One Facility's Top-Down Billing Data Analysis

Summary of Fit

RSquare	0.971803
RSquare Adj	0.970375
Root Mean Square Error	11074.11
Mean of Response	51757.53
Observations (or Sum Wgts)	84

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	3.335e+11	1.667e+11	1338.273
Error	81	1.0093e+10	124599962	Prob > F
C. Total	83	3.4359e+11		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	11225.015	2468.904	4.55	<.0001*
CEI2006-10	-5939.29	2698.433	-2.20	0.0306*
Brooks lbs	0.0052756	0.000102	51.55	<.0001*

Statistically significant CEI intervention 2006-2010

The regression results from this example model for natural gas consumption resulted in an excellent overall fit of the model. The intervention parameter is statistically different from zero and negative indicating energy savings.

A separate analysis was conducted for each facility for gas and electric discretely. These top down results for each facility are then tracked separately from the bottom up described earlier.

Determination of Results

Using both the bottom-up and top-down methodologies, it is important to take care to ensure that the two methodologies complement each other, without overlap.

We track and report the savings in several categories and subcategories. First, we report discrete project savings using the bottom-up methodology. These are further subcategorized by O&M projects, capital projects funded in-house, and capital projects receiving incentives from other program administrators. Next, to eliminate overlap, we net out the total bottom-up savings from the top-down savings to determine top-down savings in excess of the bottom-up. The results are later presented by these categories in Tables 3 and 4. Lastly, the total savings is the sum of the bottom-up and top-down savings in excess of the bottom-up. Essentially, this is the same as the top-down savings. However, conducting both the bottom-up and top-down analysis improves the data tracking and defensibility of savings. Tracking the bottom-up savings allows us to better understand the actions being taken that yield the energy savings. It also allows us to better understand the extent to which these actions receive funding from other program administrators.

Presentation and Discussion of Results

The evaluation showed that data supports the theory that measurable energy savings can be demonstrated through a carefully planned initiative to target behavior changes in the industrial sector.

Bottom-Up Results

The bottom-up analysis showed overall positive results, with an electric realization rate of 99%, albeit with variations on a project and facility level and a gas realization rate of 74%. See Figures 3 and 4 for facility-level ex-ante and ex-post results. Table 1 provides a closer look at facility-level bottom-up results. Table 1 columns refer to pending and validated savings, which can be translated to ex-ante and ex-post savings, respectively. Note that the electric savings are measured in average MW (aMW). This unit of measurement is often used in the northwest region and is intended to represent the average MW reduction during the course of a year. Mathematically, this is simply:

$$aMW = MWh/yr \, / \, 8{,}760 \; hr/yr$$

All of our calculations, methodologies, measurements, and data collection were documented and included in a report for transparency and defensibility.

Figure 3. Facility Level Gas Savings

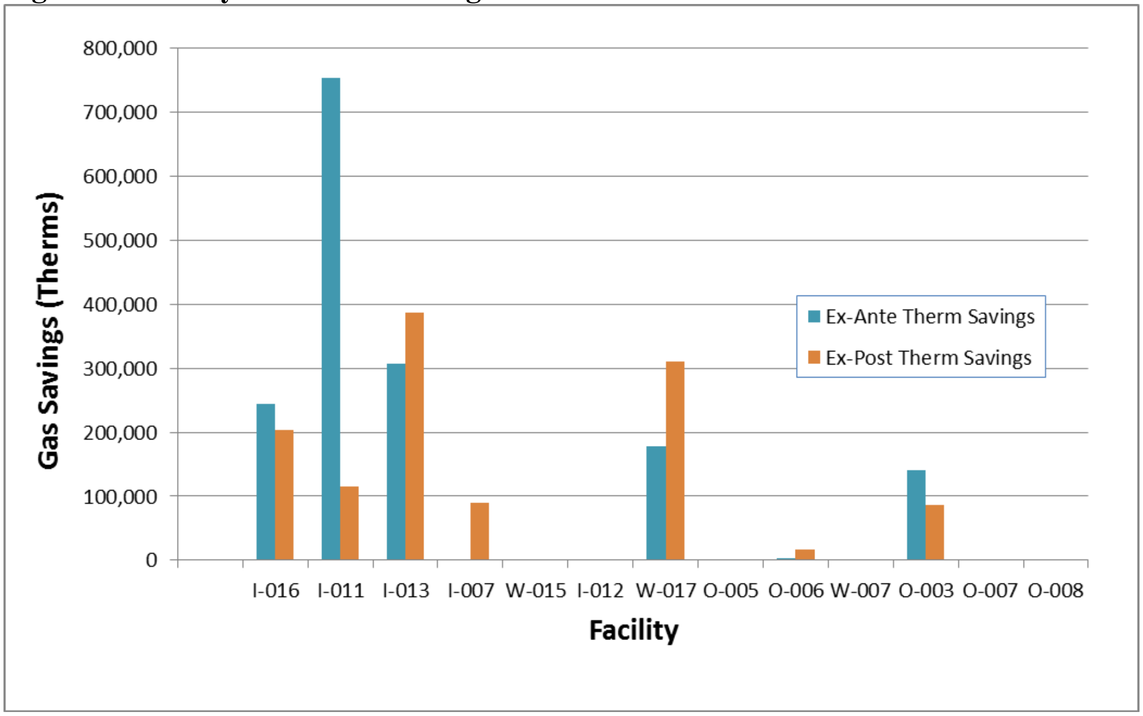


Figure 4. Facility Level Electric Savings

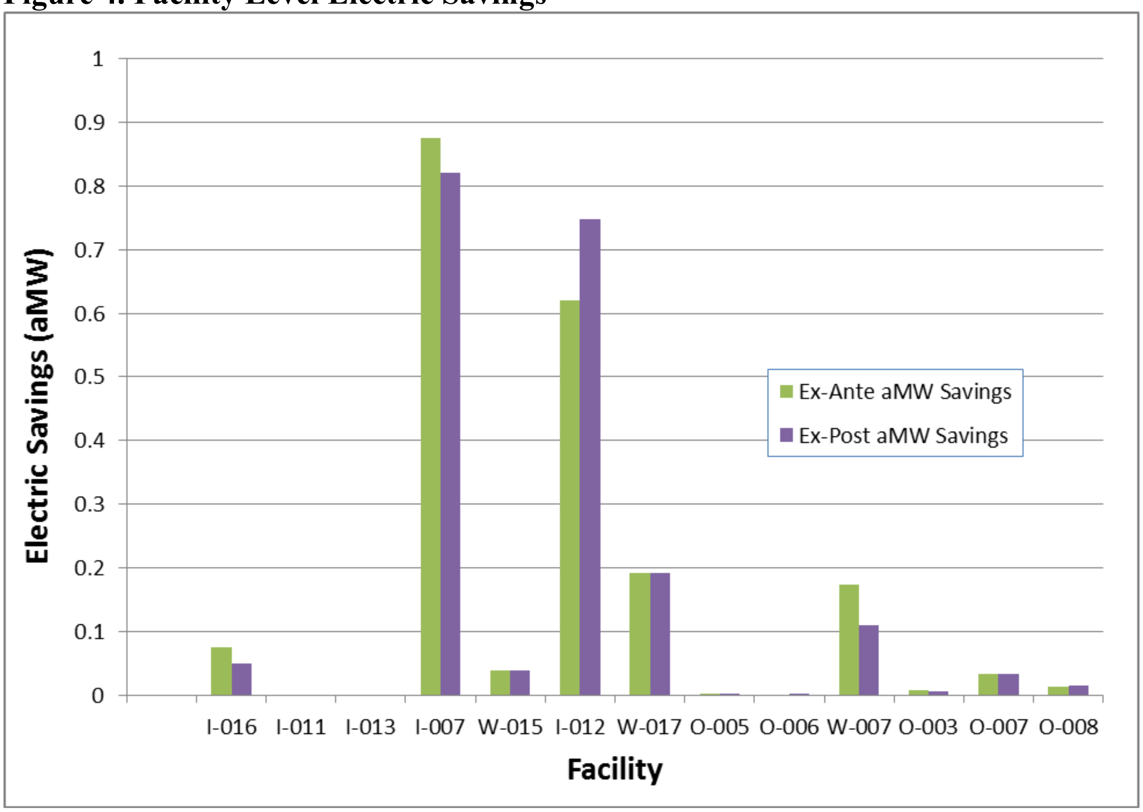


Table 1. Bottom-Up Analysis Results

Facility Code	Pending Measure Qty	Validated Measure Qty	Pending aMW Savings	Validated aMW Savings	Pending Therm Savings	Validated Therm Savings	Electric Realization Rate	Gas Realization Rate
I-016	5	5	0.074	0.048	244,821	203,761	65%	83%
I-011	3	3	0.000	0.000	753,095	115,872	N/A	15%
I-013	2	2	0.000	0.000	306,676	386,639	N/A	126%
I-007	7	7	0.876	0.820	0	89,280	94%	N/A
W-015	2	2	0.038	0.038	0	0	100%	N/A
I-012	6	6	0.619	0.748	0	0	121%	N/A
W-017	2	2	0.192	0.192	178,214	310,303	100%	174%
O-005	3	3	0.001	0.001	0	0	65%	N/A
O-006	1	4	0.000	0.000	3,280	17,343	N/A	529%
W-007	4	4	0.173	0.110	0	0	64%	N/A
O-003	2	2	0.007	0.006	141,477	86,400	89%	61%
O-007	2	2	0.033	0.033	1,551	1,552	100%	100%
O-008	3	3	0.014	0.015	0	0	111%	N/A
Total	**42**	**45**	**2.027**	**2.012**	**1,629,114**	**1,211,150**	**99%**	**74%**

Top-Down Results

The top-down analysis generally showed savings in addition to the bottom-up quantified savings. This supports the theory that an energy management structure, including goals, measurement, and tracking, etc. will yield not only discrete energy efficiency projects, but also behavioral changes that result in savings in addition to those projects. Table 2 shows the total top down savings results as well as the "Top-Down Savings In Excess of Bottom-Up" results. Top-Down Savings In Excess of Bottom-Up represents the total top-down savings, minus the bottom-up savings. This ensures that no results are double counted by the two methods.

Table 2. Top-Down Analysis Results

Year	Total Top-Down Savings (aMW)	Top-Down Savings In Excess of Bottom-Up (aMW)	Total Top-Down Savings (therms)	Top-Down Savings In Excess of Bottom-Up (therms)
2006	0.242	0.22	73,666	73,666
2007	0.672	0.461	131,378	131,378
2008	0.913	0.563	967,701	967,701
2009	0.816	0.564	1,879,095	1,875,815
2010	1.194	1.138	2,235,366	1,658,478
Total	**3.837**	**2.946**	**5,287,206**	**4,707,038**

Program Life-to-Date Results

The program has been active for several years and has seen great success. It has saved the Northwest region over 10.8 aMW, which translates to nearly 100 million kWh. Additionally, the program has seen significant natural gas savings, although the tracking of gas savings was light in the early years of the program, likely making the reported savings conservative. To date, the program has resulted in savings of nearly 7 million therms. See Tables 3 and 4 for a detailed reporting of the program's annual gas and electric energy savings. Note that the savings are delineated between top down and bottom up, as well as whether the measures were capital improvements and whether they were funded by utility programs. The O&M, Incented Capital, and Unincented Capital columns are all results of the bottom-up analysis. The Net Top Down column is simply the top-down results minus the bottom-up results. This avoids any overlap or double counting between the two methods.

NEEA has been engaged with the participating facilities for several years and is working toward building self-sustaining management systems within each facility so that the energy savings can be sustained in future years without the need for NEEA's intervention.

Table 3. Program Annual and Life-to-Date Electric Savings

Year	Validated Electric Savings (aMW)				
	O&M	Incented Capital	Unincented Capital	Top-Down In Excess of Bottom-Up	Total Electric Savings
2006	0.161	0.489	0	0.22	0.869
2007	0.329	0.227	0.285	0.461	1.303
2008	1.079	1.306	0.617	0.563	3.565
2009	1.263	0.559	0.059	0.564	2.446
2010	0.005	1.371	0.129	1.138	2.642
TOTAL	**2.837**	**3.953**	**1.090**	**2.946**	**10.825**

Table 4. Program Annual and Life-to-Date Gas Savings

Year	Validated Gas Savings (therms)				
	O&M	Incented Capital	Unincented Capital	Top-Down In Excess of Bottom Up	Total Gas Savings
2006	N/A	N/A	N/A	73,666	73,666
2007	N/A	N/A	N/A	131,378	131,378
2008	68,750	0	988,664	967,701	2,025,115
2009	3,280	0	20,600	1,875,815	1,899,695
2010	146,592	1,552	1,059,726	1,658,478	2,866,348
TOTAL	**218,622**	**1,552**	**2,068,990**	**4,707,038**	**6,996,202**

These program results measure the impact of the program solely on direct program participants. If the program transforms the industrial food processing market as the program designers intend, future evaluation cycles will need to measure the influence on non-participants in the Pacific Northwest industrial food processing community, and perhaps an out-of-region non-participant group to serve as a baseline to assess broader market trends.

Keys to Success

Through interviews with program management and with each of the participating facilities, we believe we have identified some key features contributing to the success of the effort. Below is a compilation of these features.

- **Management Commitment** – It is critical that this be a top-down-driven priority. All other key features to a successful program will ultimately depend on this one. If this is not obtained early on, it is unlikely that the effort will be a success.
- **Formation of Energy Team** – This includes a dedicated energy champion, as well as members from affected departments and management.
- **Establishment of Goals** – Goals are important in driving the energy team toward achieving the desired outcome, which is a specific, quantifiable energy reduction.
- **Allocation of Resources** – Many of the opportunities identified by the energy team will require capital and/or staff investments. It is important that management make these resources available, provided that they pass an economic screening (payback period, ROI, etc.).
- **Measurement of Progress** – In order for goals to be effective, it is critical that progress toward these goals be measured and tracked.
- **Reporting of Progress** – It is important that management receive information and provide feedback to the energy team. Only with this accountability will the goals, tracking, and reporting be effective.

Conclusion

The program has successfully changed behavior to address energy conservation at a number of the region's largest food manufacturers. More importantly, it has served as a proof of concept to be adopted by other utility programs. The Energy Trust of Oregon and Bonneville Power Administration (BPA) have both adopted the principles of CEI to form their own continuous energy management programs targeted at the industrial sector. These programs have had their own success, and the concept will likely be adopted by a number of other program administrators in the coming years. As this moves more from NEEA's proof of concept to implementation by the regions program administrators, they will have begun to achieve their goal of market transformation.

The evaluation has shown that a well-planned engagement of the industrial sector to initiate behavior changes can produce meaningful, measurable, cost-effective energy savings. The savings analysis, while data intensive, does show statistically significant energy savings. Provided proper energy use and production data is made available, program administrators should be able to quantify and claim savings for their efforts, should they adopt similar programs.