Top-Down Analysis of Electric Savings in Food Processor Facilities: Taking a Step Back to Inform Forward-Reaching Industrial Strategies

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ABSTRACT

In 2005, the Northwest Energy Efficiency Alliance (NEEA) began working with food processors throughout the Northwest region to embed Strategic Energy Management (SEM) within their facilities. This manufacturing management system, known as Continuous Energy Improvement (CEI), has been implemented in 16 food processing facilities.

Long-term engagement with these facilities has enabled NEEA to aggregate a robust set of historical data, spanning energy, production, and key food processing business drivers. Analysis of this data provides insight into energy reduction trends over time and highlights not only successful energy efficiency interventions, but those that are less effective as well. Analysis and assessment of this long-term engagement yields a rich set of best practices that support the proliferation and diffusion of SEM throughout the Northwest region.

NEEA's Food Processing Initiative utilizes a top-down (whole facility) approach that relies on econometric models to isolate gross savings at each facility. This paper demonstrates the use of these models to establish estimates of electric energy efficiency improvements. Base period models consistent with the Evaluation Measurement and Verification (EM&V) protocols (IPMVP Method C) are presented and their application to estimate electric energy efficiency improvements at an industrial facility discussed.

NEEA is overlaying the results of the impact analysis with details of the multi-year engagement for insights on the effectiveness of interventions and their delivery for the greatest results. These interventions may include systems training, employee awareness, management coaching, recognition programs and industrial assessments. As a result, NEEA is better able to ensure the engagements are cost effective and can better predict spending across the span of the engagement.

Introduction

Since 2005, NEEA has worked in the food processing industry in the Northwest to create and implement a strategic energy management (SEM) system known as Continuous Energy Improvement (CEI). During the eight years of implementation, the CEI effort has evolved in response to changing market demands as well as release of ISO 50001 energy management system standard. Key challenges for NEEA have been acquisition of participant data – which is regarded as proprietary – and analysis of the data to enable reporting of savings to and by NEEA funders.

Working in partnership with participating food processors as well as its funders, NEEA has been able to collect both energy and production data and analyze the data using a combination of top-down and bottom-up analysis. Results of the analysis have proven to be invaluable for designing and enhancing annual CEI engagements to reflect lesson learned and best practices, and for understanding savings rate adoption trends to inform broader regional energy management efforts. At the individual facility level, implementers can predict the amount and type of resources required to ensure persistence of savings. For example, at predictable savings decline points, implementers can redesign the overall engagement to include quick-start efforts that re-engage top management and facility personnel in energy savings initiatives. More broadly, understanding adoption rates of populations of SEM participants can inform demand response planning at both the local utility and regional levels.

Analysis Plan

Since the inception of NEEA's CEI effort, 16 food processing plants have participated in the program. Monthly energy usage and production have been collected and reported in a consistent fashion for most of these plants. NEEA's primary interest is electricity usage and efficiency, but natural gas and other fuel use are also collected and reported. This paper reports on the use of this relatively long and consistent time series of energy usage and production to understand the nature of electric energy savings associated with these facilities and delineates best practices gleaned from annual review of engagement with each facility. The analysis was undertaken using facility specific modeling and analysis of the aggregate data.

Facility Level Analysis

NEEA estimates and tracks the savings at participating food processing plants using an econometric model for each facility based on whole facility energy usage over a base period. The model is then applied over the reporting period to estimate baseline energy usage given the actual level of production and other driver variables over the reporting period. Gross savings at each facility over each reporting period are then determined by subtracting actual energy usage from the estimated baseline predicted by the model.[1] Models are fuel specific. The results of the electric usage models are the focus of this paper. As will be seen in the results, an electric only analysis is confounded when fuel substitution occurs at a plant.

Econometric Model

Baseline models were developed for each facility that relate energy usage in month t to production, atmospheric variables such as degree days or mean temperature in month t and other driver variables as appropriate. The basic form of the baseline econometric models is shown below.[2] The error term has been omitted for simplicity of presentation.

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[1] This methodology is basically the methodology put forth as Method C in the IPMVP and BPA's MT&R Reference Guide.

[2] NEEA has also used econometric models that include an intervention term for each reporting period. This alternative approach required the re-estimation of the regression model following each reporting period so that the new intervention term could be estimated. NEEA began using the approach described in this paper after a comparison of the two approaches showed similar results.

Baseline Model:

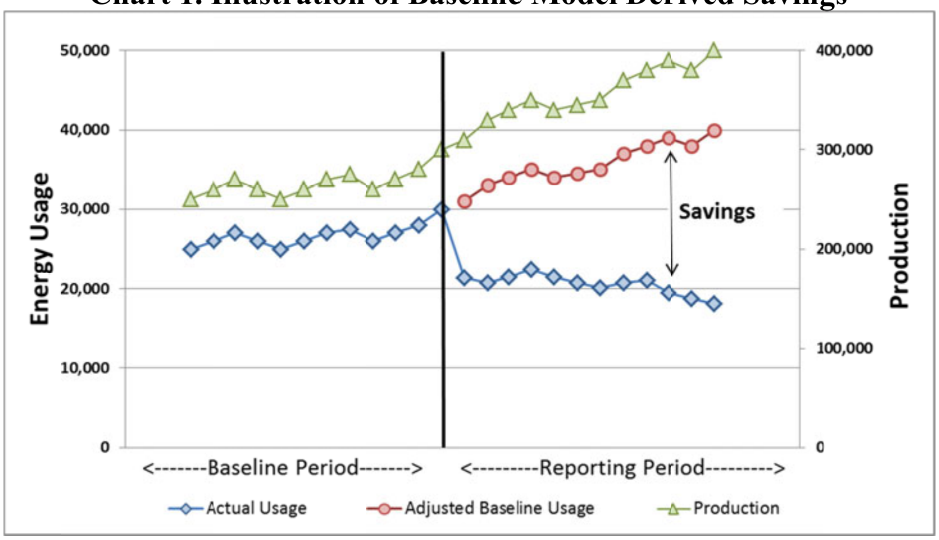
$$Energy_t = Intercept + B_1 \times Production_t + B_2 \times AtmosphericVariables_t + B_3 \times OtherDrivers_t$$

The baseline model is used to estimate the usage that would have taken place if not for changes at the plant since the base period. Actual usage is then subtracted from predicted usage to derive estimated savings.

Illustration of Approach

The chart below illustrates the application of the approach described above. The base and intervention periods are separated by the horizontal line. Model coefficients reflect the relationship between production and energy use during the base period. The model is then used to "predict" or simulate usage using actual production and weather. Gross savings is shown in Chart 1 as the difference between predicted (circle markers) and actual (diamond markers) energy usage.

Chart 1. Illustration of Baseline Model Derived Savings



Facility Level Results

Thirteen of the food processing plants have sufficient history for modeling, defined as at least one full year of monthly history, and produced regression models with correctly signed and significant driver variables. The percent gross savings of predicted baseline electric usage from these models is shown by plant and year in the table below. Plants owned by the same company are represented by a common first letter in the Plant ID column.

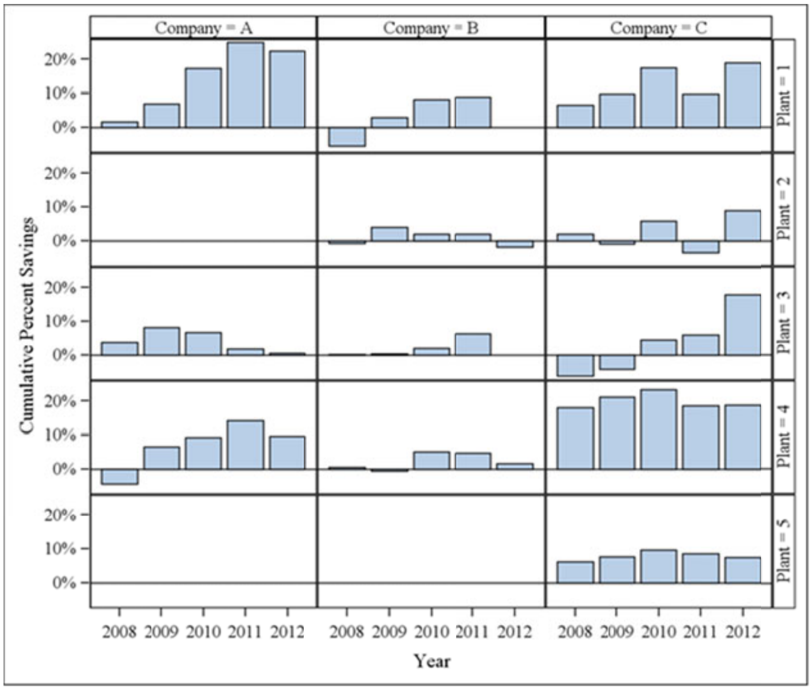
Table 1. Cumulative Savings by Plant and Year

Plant ID	2007	2008	2009	2010	2011	2012
A1	NA	1.6%	6.8%	17.3%	25.0%	22.3%
A2	NA	-23.3%	52.4%	0.3%	53.2%	73.2%
A3	NA	3.7%	8.2%	6.6%	1.8%	0.5%
A4	NA	-4.5%	6.6%	9.2%	14.1%	9.7%
B1	NA	-5.5%	2.8%	8.1%	8.9%	NA
B2	NA	-0.8%	3.9%	1.9%	1.9%	-1.9%
B3	-3.2%	0.2%	0.3%	1.9%	6.3%	NA
B4	NA	0.5%	-0.7%	5.1%	4.6%	1.5%
C1	3.9%	6.4%	9.7%	17.4%	9.9%	18.9%
C2	NA	1.9%	-0.9%	5.8%	-3.4%	8.8%
C3	NA	-6.3%	-4.2%	4.5%	6.0%	17.8%
C4	-4.2%	18.1%	21.1%	23.3%	18.6%	18.7%
C5	1.1%	6.2%	7.6%	9.6%	8.5%	7.5%

Some characteristics in the pattern of savings shown in Table 1 are worth considering. First of all, one of the plants (A2) shows large swings in gross savings due to fuel substitution that could not be adequately modeled in the baseline equation for that plant. Next, ignoring A2, it appears that savings in the first reporting year are low. Half of the plants actually showed higher electric use than their modeled baseline during the first reporting year.

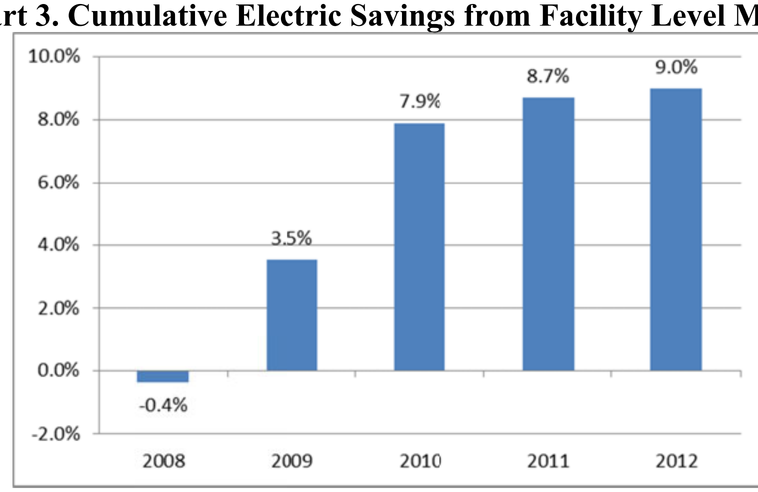
The data from Table 1 is charted graphically in Chart 2 with plant A2 values omitted for clarity of presentation. Chart 2 makes it easier to see that three of the four plants with double digit savings in 2012 belong to the same food processing company. Although there are many possible explanations for this result that are not related to the CEI program, in the view of program implementers, this company has maintained a consistently high focus on CEI.

Chart 2. Cumulative Electric Savings by Company-Plant Grid



The overall pattern of savings is more easily depicted in the chart below, which shows the average percentage savings for all facilities (excluding Plant A2) weighted by electric usage.

Chart 3. Cumulative Electric Savings from Facility Level Models



Overall, usage actually increased over the baseline during 2008, early in the CEI engagement. Savings increased by about four percentage points in years two and three, followed by a much more modest increase in 2011 and 2012. One possible explanation for the slow start in year one is the time it takes for an industrial facility to incorporate CEI into periodic reporting and review activities and to take energy savings actions in light of the reporting. The small increase in savings observed over the last couple of years is consistent with a mature CEI effort.

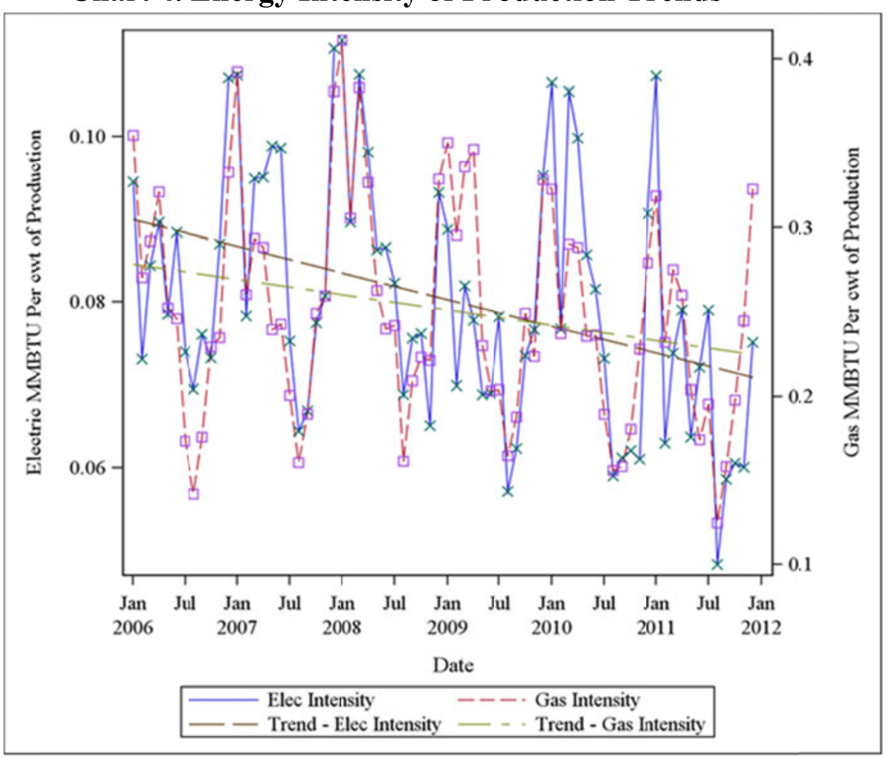
Aggregate Level Analysis

The facility level analysis is useful for observing how the gross savings after implementing CEI compares among facilities and among the three companies in the analysis. Facility data was also aggregated and the aggregate electric usage and production analyzed for efficiency trends and relationships of interest including the relationship between energy usage, capital energy savings investments and trending efficiency levels.

Aggregate data from 2006 through 2011 was available for analysis. This data includes electric and gas consumption, total production, CEI production, estimated savings from capital projects and climate variables. CEI production refers to the amount of production from plants that have implanted CEI. CEI production begins at zero in 2006 and reaches total production by January 2008.

By plotting energy usage per unit of production over time, it is possible to see how energy intensity has changed throughout the course of CEI engagement. Electric and natural gas usage per hundred weight (cwt) of production are shown in Chart 4. Trend lines have also been fitted to the data and are also shown in the chart for illustrative rather than statistical purposes.

Chart 4. Energy Intensity of Production Trends



It is clear from the data in Chart 4 that energy intensity has declined over time for both electric and gas. Although the trend lines were estimated over the entire 2006 through 2012 period, a close inspection of the data shows that the real decline in energy intensity began somewhere around 2007 or 2008. If the trend lines are refit beginning in 2008 they become steeper.[3] This finding is consistent with the timing of CEI engagement and the lag between engagement and observed savings found from the facility level analysis.

Econometric Model

As with the facility analysis, an econometric model was specified to better understand the relationships in the aggregate data. The general specification of the model is shown below.

$$Energy_t = f(Output_t, CEI\_Output_t, Weather_t, Trend_t, Other_t)$$

Energy usage in month t is a function of total output (production), CEI Output (production), weather or atmospheric variables, general trend and other variables. The percentage of total output from facilities engaged in CEI begins at zero in 2006, prior to CEI adoption at any of the facilities. CEI percentage of output rises through 2007 and is at 100 percent by January 2008 with engagement at all facilities in the analysis. Two "other" variables available in the aggregate data set, and of particular interest in this analysis, are the expected energy savings from capital and operating and maintenance (O&M) projects. Similar models were developed for both electric and natural gas. Because NEEA's focus is electricity, the electric model results are presented and discussed below.

Electric Model Results

Several combinations of variables including various specifications of trend and climate variables were assessed using regression analysis to fit the model. The results of the model selected for best fit is shown in the table on the following page.

[3] The trend lines are shown for illustrative purposes rather than statistical assessment of trend. It is worth noting however that both trend lines shown in the chart are statistically significant at the alpha equal 0.10 level of testing. The electric trend line is also significant at the alpha equal 0.05 level of testing. When estimated beginning in 2008, both trend lines are significant at the alpha equal 0.05 level of testing.

Table 2. Regression Results for Aggregate Electric Model

R-Square	0.76
Adj R-Sq	0.75
Durbin-Watson D	1.82

Variable	Label	Parameter Estimate	t Value	Pr > $\lvert t \rvert$	Variance Inflation
Intercept	Intercept	-396409	-2.10	0.0399	0
Output	Total production (cwt)	0.03851	10.08	<.0001	1.84
CEI_Output	Total Production Under SEM	-0.00669	-1.71	0.0923	4.98
CapElec_Monthly	Elec savings from capital projects	-6.963	-4.52	<.0001	17.05
Trend	Simple trend variable	27.939	2.56	0.0127	26.01

Overall, the model explains 76 percent of the variation in monthly electric usage. All variables in the model are significant at the 10 percent level of significance or greater. As expected, production has a strong and positive impact on electric usage and the amount of energy required per unit of production declines significantly when production is from facilities engaged in CEI. Energy usage is also significantly reduced with the investment in capital projects involving electric-saving measures. Finally, the simple trend variable shows a significant and rising use of electricity after accounting for the influence of production, CEI engagement and capital energy efficiency investments.

The ability to draw conclusions from the model is limited by the degree of correlation between the independent variables (multicollinearity). This is especially true with capital energy efficiency investments and the trend variable, both of which have relatively high variance inflation statistics, an indication of multicollinearity. With these limitations in mind, the following inferences are drawn from the model development process and the resulting model of aggregate electric usage:

- Based on a comparison of the estimated coefficients, CEI participation significantly reduces production related energy usage (17 percent lower).
- Capital energy efficiency projects appear to have a significant impact on reducing energy usage. However, quantifying the impact of capital projects using the regression equation is difficult because of interaction between the trend variable and capital projects.
- O&M projects do not significantly lower usage, possibly because they are already being captured in the CEI production variable.
- Attempts to model yearly representations of trends and impact variables were unsuccessful.
- There is evidence of a positive trend in non-production related electric usage (e.g. lighting, idle equipment) based on the simple trend variable.
- No influence of a trend was found on production related electric usage separate from the CEI related decrease.

Additional Findings and Observations

NEEA undertook the study of CEI data to assess whether analysis of a relatively long and consistent time series of energy usage and production of CEI facilities could be mined to learn more about the pattern of savings in these facilities. The econometric model demonstrated that both CEI participation and capital-measure-specific savings are, in fact, significant determinants of gross savings. However, the model on its own doesn't demonstrate how efficiencies would have changed over time or whether capital projects would have been undertaken without the CEI program. Moreover, the model does not discern patterns of increasing or decreasing savings or provide evidence to support or continue projecting savings.

In fact, capturing savings data, developing facility level savings models, populating the models and analyzing the data are time-consuming and expensive, and the results can be subject to changing assumptions, practices and methodologies. Despite these challenges, data are valuable in designing and revising CEI engagements to deliver specific outcomes and incorporate best practices, particularly when data are combined with implementer experience.

Twelve Key Interventions

Following is a list of 12 typical interventions over the life of a CEI engagement, with one indicating little impact on the overall engagement during the reporting period, and five indicating significant impact. The assessment of impact is subjective in nature but is based on a consideration of field assessment work and the top down analysis presented in this paper.

Table 3. Impact of 12 Facility level Interventions Over Time

	2005-2007	2008-2009	2010-2012 + 2013
Intervention			
1.Obtain executive commitment to implement SEM	5	2	NA
2. Baseline organizational SEM maturity and activity	5	NA	NA
3. Baseline energy project implementation activity	2	5	NA
4. Develop energy policy	1	5	NA
5. Create energy intensity reduction goal	1	5	5
6. Implement capital and O&M projects	1	5	5
7. Track progress to goal (revise goal as needed)	0	5	5
8 Regular reporting to executive level	0	5	5
9. Model development/regression analysis	0	3	4
10. Best practice sharing facility to facility within organization	0	0	4
11. Energy project opportunity list refresh (walk-throughs, audits)	0	0	4
12. Integrating CEI into related initiatives, such as Lean, Six Sigma, or sustainability	0	0	5

As previously indicated in Chart 3 above, savings increased by about four percentage points in years two and three, followed by a significant reduction in 2011 and 2012. The relatively small increase in savings over the final years of the engagement is consistent with a mature CEI effort. So-called "low-hanging fruit" was acquired in the earlier years, and latter-year savings are attributable primarily to behavior-based activities that inherently deliver smaller savings.

Best Practices for Long-Term SEM Engagements

NEEA's long-term CEI engagements have yielded not only savings for the facilities themselves, but to NEEA funders who are able to augment their savings acquisition efforts with savings from the CEI engagements. Moreover, findings from these long-term engagements are available to inform the multiple industrial and SEM program design efforts occurring in Idaho, Montana, Oregon, and Washington. NEEA has worked to identify key findings and recommendations for SEM design resulting from this experience and the analytical work reported in this paper. Notable among the lessons learned are resulting best practices that can significantly impact SEM program design. These best practices include:

1. Integrate SEM into existing facility infrastructure (whether it is Lean, sustainability, or an established management system such as ISO 9001 or 14001). Creating a new infrastructure strictly for energy makes SEM vulnerable to budget cuts and changing priorities.
2. Focus on the behaviors/purpose associated with the intervention, as opposed to the output. For example, an energy policy enables executives to demonstrate the company's commitment to energy reduction; it is the demonstration of the commitment that produces energy savings, not the energy policy itself.
3. Build in flexibility to energy team and meetings; they need not be standing monthly meetings comprising the same participants. Instead, they could be task-based and composed of the most appropriate participants to achieve the desired outcomes of the task.
4. Ensure documentation is easy to do and easy to use to ensure energy management survives personnel transitions.
5. Consider an energy intensity reduction goal rather than a simple energy reduction goal. Energy intensity more accurately reflects and supports the facility's business objectives.
6. Ensure the facility establishes key performance indicators (KPIs) and is able to track facility progress as early as possible in the engagement. Demonstrated progress motivates continued participation.
7. Integrate energy intensity reduction into the facility bonus structure so that energy rises to the same level as other business drivers.
8. Ensure those responsible for energy intensity reduction have not only the responsibility to reduce intensity, but have the authority to truly drive and sustain change.

References

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