Strategic Energy Management Models: Is a Simple Model Enough?

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Abstract

Energy Trust of Oregon has provided strategic energy management (SEM) services to hundreds of industrial customers over the past ten years. The types of SEM services and participating facilities have evolved over this period. One thing that has remained constant is the requirement to develop and maintain energy models to monitor and track the facilities' energy consumption.

The resources that go into developing and maintaining the energy models, which often have customized specifications, baselines and savings measurement periods, can be significant. Energy Trust's industrial program has made a variety of changes that have focused on simplifying model development and streamlining data collection processes. Reducing costs associated with model development and maintenance has become more important as the program expands SEM services to small- and medium-sized industrial customers with smaller energy costs and savings potential.

To investigate ways to further standardize and automate the SEM model development process, we used a panel data model to estimate changes in electric consumption at SEM sites that had participated since 2012. The panel data model estimated SEM savings lower than the individual models in the first year after SEM participation. In subsequent years, the panel data model estimated energy reductions and savings that exceeded first-year SEM savings from the individual models.

Background and Introduction

Strategic energy management (SEM) focuses on achieving energy-efficiency improvements at industrial and commercial facilities through a variety of low-cost/no-cost actions in facility operations, maintenance, and behaviors (OM&B) and fostering a corporate environment that in the longer term will result in more energy efficient capital equipment upgrades. SEM actions can range from a simple process for regularly identifying and taking energy-saving actions, to establishing a formal, third-party recognized or certified SEM framework for continuous improvement of energy performance. SEM programs typically include high levels of corporate sponsorship and a set of energy reduction goals, principles, and practices emphasizing continuous improvements in energy performance or savings through energy management and an energy management system (EnMS). SEM programs are now well established across the United States and Canada. ISO 50001, which is highly complementary with SEM, is also expanding globally with over 22,000 facilities having adopted ISO 50001 by 2017 (83% in Europe and 15% in Asia).

Energy Trust of Oregon began offering SEM services to industrial customers in 2009 and to commercial customers in 2011. Since then, hundreds of facilities have participated in SEM, sometimes repeatedly. The types of SEM services and participating facilities have evolved over this period. One thing that has remained constant is the requirement to develop and maintain energy models to monitor and track the facilities' energy consumption.

The resources that go into developing and maintaining the energy models, which often have customized specifications, baselines and savings measurement periods, can be significant. Customers may have access to a variety of detailed data for a site at various levels of granularity (e.g., daily, hourly, weekly) that can be used to craft an energy model that can provide more accurate estimates of savings. It has been Energy Trust's experience that not all energy models are comparable – e.g., because the energy model for one customer may include several production variables, whereas the energy model for another customer may only include a single production variable, or because the energy model for one customer is a daily model, whereas the energy model for another customer is a weekly model – and that many of the detailed, site-specific data that are used to create an energy model during the first year of participation may not be consistently collected or available to a program after the SEM engagement period. Reducing costs associated with model development and maintenance has become more important as the program expands SEM services to small- and medium-sized industrial customers with smaller energy costs and savings potential. Earlier studies have identified potential areas for standardization and simplification (Stewart 2017, Degens 2017, SBW 2017) of energy models. Energy Trust's industrial program has made a variety of changes that have focused on simplifying model development and streamlining data collection processes.

This study attempts to assess the extent to which energy models can be simplified, while still achieving the program's overall task of tracking energy savings at a *portfolio* level. The term "portfolio" is emphasized to differentiate the need to estimate aggregate savings from the need to have an optimally specified model for participating customers' facilities. Specifying a model that does not depend on detailed proprietary customer data – e.g., production data – is one way to get around the issues of data availability and consistency.

Model Characteristics

Energy models that are estimated for each site are typically specified as:

$$energy = f(production, other)$$

where energy is primarily a function of production and a variety of other variables that are dependent on the specific site and production process(es). The models can follow a variety of formats and are concisely defined in Chapter 24 of the Unified Methods Project (UMP) (Stewart 2017).

In this study we are trying to discern the program savings in aggregate, thus a panel model is specified that uses data consistently available to Energy Trust: monthly energy consumption, the dates of SEM engagement, and the estimated savings from capital projects completed at each site for which Energy Trust provided an incentive payment. The general form of the model will be:

$$energy_{it} = f(engagement_{it}, post\_year_{yit})$$

where:

$energy_{it}$	= energy consumption (electricity or natural gas) for site *i* in month *t*
$engagement_{it}$	= binary variable equal to 1 when site *i* is in their initial SEM engagement period in month *t*
$post\_year_{yit}$	= binary variable equal to 1 when site *i* is in post-SEM engagement year *y* in month *t*

This model is a reduced form compared to the panel model described in UMP. This model focuses on estimating the impact of the SEM and other program activity on energy consumption and does not include all the explanatory variables that determine energy consumption at a site. Non-SEM capital energy efficiency projects that occur independent of SEM will have their savings backed out of the regressions estimates after the regression model is estimate. The essential assumptions on which the model rests are that participation is not correlated with production and that there are no systematic year-to-year changes in production or the production process. These assumptions are also implicit in the site-specific energy models as large changes to production or production processes often lead to re-establishing the baseline period for a site.

SEM Participation and Analysis Data

Since 2009 there have been 309 industrial SEM engagements. These engagements have taken place at 197 industrial facilities. Some customers have completed multiple SEM engagements and some customers' companies have enrolled multiple facilities as part of a single engagement.

Energy Trust has provided a variety of SEM offerings over the last ten years:

- Year-long initial SEM engagements for cohorts of about ten customers
- Year-long initial SEM engagements for individual large customers with multiple sites
- Shorter (~six month) initial SEM engagements for smaller industrial customers
- Refrigeration Operator Certification (ROC) trainings aimed at sites with industrial refrigeration facilities
- "Kaizen Blitz" was offered early on and involved an intensive energy audit and energy efficiency recommendations coupled with access to engineering support services to help complete the energy efficiency recommendations
- Continuous SEM is available to customers as an annual offering after an initial SEM engagement to maintain and build on SEM activities

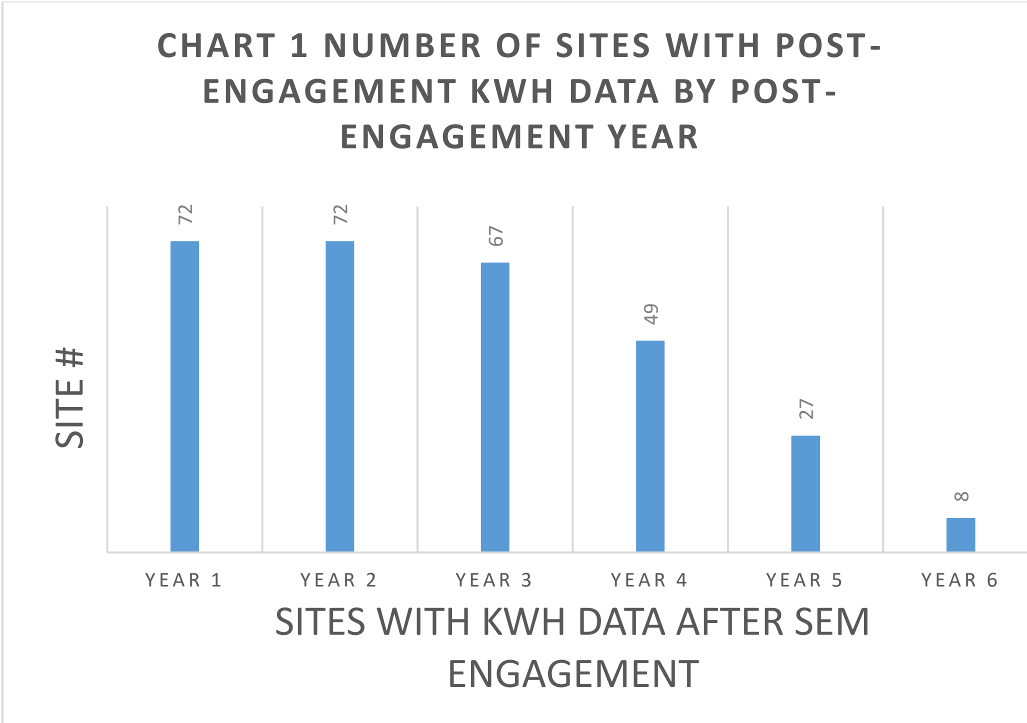
Over time, the offerings have been streamlined into offering a year-long initial engagement of industrial cohorts that are geographically close together. All participants are now encouraged to enroll in continuous SEM to receive ongoing support services.

Initially, participation in SEM precluded sites from receiving any of Energy Trust's industrial program incentives for capital measures. This was done so that SEM impacts could be cleanly isolated in energy models. As SEM also promotes capital projects, this program requirement was dropped. To estimate SEM savings, the program estimated the change in consumption for the facility from the baseline period and then subtracted out the estimated savings from any capital project(s) that have received incentives from the Energy Trust. This method is also described in UMP (Stewart 2017). One downside to this method is that any error in the estimated capital measure savings is attributed to SEM; however, it is often not possible to evaluate the savings from capital measures before SEM savings are estimated.

The analysis period for this study encompassed the 108 SEM participants from 2012 through 2017. SEM participants prior to 2012 could not be included because the monthly energy consumption data used for the study are in a different format prior to 2011. This study analyzes only electricity consumption as all participants had an electric energy model and took many SEM-related actions to reduce electricity consumption; gas models were much less common among SEM participants[1]. When analyzing the data, the kWh consumption is aggregated to the industrial site. A site can be made up of one or more buildings, have multiple electric accounts and meters, span multiple tax lots and even have portions of it operated by independent entities. However, most of its operations will be managed by a central entity that is the SEM participant. In addition, this study requires that each site have at least one year of energy consumption data prior to SEM participation, and two years of energy consumption data post-SEM participation, which meant some sites were screened out of the study. Additional sites were removed due to known changes such as the construction of new buildings, addition of renewable power generation, and/or plant closures. This left 72 sites. In aggregate, these sites had an estimated savings of 5.6% in the first year after their SEM engagement.

A panel data model was specified that allowed for an unbalanced dataset to be utilized in the analysis. Unbalanced data allowed for multiple years of post-engagement consumption to be included in the model. Chart 1 shows that all the sites have energy consumption for the first two years after receiving SEM services. The dataset becomes more unbalanced when additional post-engagement years are added to the analysis as fewer sites have had time to accrue this level of post engagement data.

[1] In Oregon many industrial customers are "transport" customers that purchase natural gas directly from third parties and not from the natural gas utility. Transport customers' natural gas purchases do not include a public benefits charge that supports Energy Trust and their gas usage is not a focus of any Energy Trust programs.



The model was specified as:

$$kWh\_per\_day_{it} = \alpha + \beta_e engagement_{it} + \sum_{y=1}^{6} \beta_y \, post\_year_{yit} + \varepsilon$$

Where:

$kWh\_per\_day_{it}$	=	average kWh per day for site *i* in month *t*
α	=	intercept
$engagement_{it}$	=	binary variable equal to 1 when site *i* in is the initial SEM engagement in month *t*
$post\_year_{yit}$	=	binary variable equal to 1 when site *i* is in post-SEM engagement year *y* in month *t*
ε	=	error term

Each of the coefficients have a simple interpretation. The intercept can be interpreted as the average daily kWh consumption for the average site in the year before participating in SEM, also known as the baseline period. The engagement period coefficient can be interpreted as the average daily change in consumption associated with the engagement period, relative to the baseline. The coefficients for each of the six post-year variables can be interpreted as the average change in consumption associated with each of the years after SEM participation relative to the baseline period.

The panel model was estimated using a generalized least squares specification with a heteroskedastic error pattern as consumption can vary quite widely between large industrial sites. Other regression estimation techniques were also employed generating similar results. The regression results are presented in Table 1.

Table 1. SEM Panel Data Generalized Least Squares Regression Results

(4,801 observations and 72 sites)

Variable	Coefficient	Std. Err.	z	P>z	95% Conf. Interval	
post_year1	-1,096.1	521.2	-2.1	0.0	-2,117.7	-74.6
post_year2	-2,840.2	526.0	-5.4	0.0	-3,871.2	-1,809.3
post_year3	-4,132.5	563.5	-7.3	0.0	-5,236.9	-3,028.2
post_year4	-6,943.3	605.3	-11.5	0.0	-8,129.7	-5,756.8
post_year5	-10,284.3	775.6	-13.3	0.0	-11,804.4	-8,764.1
post_year6	-12,973.3	1,474.9	-8.8	0.0	-15,864.0	-10,082.7
engagement	-551.6	507.1	-1.1	0.3	-1,545.5	442.3
intercept	23,785.4	368.5	64.5	0.0	23,063.1	24,507.7

The estimated coefficients all have a negative sign, indicating that on average, the sites experienced a reduction in consumption after participating in SEM. Sites even experienced, on average, a small reduction in electric use during the SEM engagement period, though the estimate is not statistically significant and not claimed by the program. The reductions in consumption increase from year to year after engagement, going from an average reduction of 1,000 kWh per day in the first year to an average reduction of nearly 13,000 kWh per day in year six. All the post-year coefficients are significantly different from zero at the 95% confidence level.

Many of these sites also completed capital projects that resulted in energy savings during the analysis period. Therefore, the estimated reductions cannot be solely attributed to the SEM program. To address this, the cumulative energy savings associated with capital projects at each site is calculated and averaged out for each specific post-SEM engagement year. The average daily savings for all sites was calculated and then subtracted from the initial coefficient to obtain an estimate of SEM savings after taking into account other measures. The results are presented on Table 2.

The regression results, after backing out energy savings from capital projects, indicate that estimated SEM savings range from 3.6% in year one to nearly 48.6% in year six. The number of sites that are represented in years five and six is much smaller than those that were used to estimate the first four post-SEM engagement coefficients and may not be representative of the population. Another factor is that much of the analysis rests on the assumption that few, if any, systematic production changes occurred at these sites. One of the things we have learned in our SEM evaluations is that many production facilities do experience significant changes over time (Huckett 2019). Some of these changes will be production volumes while others will experience changes in the actual production process, changes to the physical site, and in some cases even what product is being produced.

The individual SEM models developed by the program implementors estimated savings of 6.8% of consumption in the first year. This is more than the 3.6% estimated by the panel data model, however within the error bands. One of the benefits of the panel data model is that energy reductions from subsequent years are estimated. The panel data model estimates indicate that the savings rate increased over the subsequent years and by the second year did exceed the first-year SEM savings estimates from the individual models.

Table 2. Annual KWH Reduction Adjustments and Attribution

Variable	Estimated Average Daily kWh Reduction	Cumulative Average kWh Savings Per Day from Capital Projects	SEM Average kWh Daily Reduction	Percent Reduction Relative to Baseline	Number of Sites Represented
post_year1	-1,096.1	239.2	-857.0	-3.6%	72
post_year2	-2,840.2	649.1	-2,191.1	-9.2%	72
post_year3	-4,132.5	894.2	-3,238.3	-13.6%	67
post_year4	-6,943.3	984.8	-5,958.5	-25.1%	49
post_year5	-10,284.3	1,114.1	-9,170.2	-38.6%	27
post_year6	-12,973.3	1,407.1	-11,566.2	-48.6%	8

One of the takeaways from this analysis is that sites that participated in SEM consistently reduced their electricity consumption over a period of years after participating in SEM. In addition, the savings increased over time, which lends support to the theory that sites will internalize energy efficiency actions in their standard operating procedures and that savings will increase as further opportunities arise and are addressed. One sign of this happening is that these sites increasingly made further capital energy efficiency investments over that same time period, as seen in the "Cumulative Average Savings Per Day from Capital Projects" column in Table 2. A recent study [Erika 2019] showed conclusively that SEM participants participated in capital programs at higher rates and made larger investments compared to industrial customers who did not participate in SEM. The results also lend support to the program assumption that that SEM savings persist over time and that current measure lifetime used by Energy Trust may be too conservative.

Currently, we do not argue for using the results of this simplified model to track energy savings at a portfolio level. The issues of systematic changes to production volumes, production process, to the sites, as well as the product(s) manufactured at the site itself loom larger, especially in the later years. The fact that data from fewer sites are used to estimate the later year coefficients causes the representativeness of those results to be questioned. What we do propose is to investigate how these estimates change when production data are incorporated into the simple model. This can be done with a nested subsample of sites that have complete sets of production data available. Gathering these data is not an insignificant task, but if the resulting analysis indicates that a reduced form savings model can provide a simplified method for estimating program level savings, this investment would be well worth it.

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