Lean, Energy, and Savings: Energy Impacts of Lean Manufacturing

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ABSTRACT

Most utility programs focus on the “what,” that is, replacing one piece of equipment for another, more efficient piece of equipment. A key reason for this is to increase confidence in the amount of resulting energy savings. Utility programs that focus on “how,” that is, using a piece of equipment less or using it more optimally, often suffer from an inability to confidently quantify savings. At the same time, the last few decades have seen a proliferation of Lean Manufacturing practices across industry, where organizations focus on eliminating seven wastes: 1) excess product transport, 2) inventory, 3) excess movement, 4) waiting, 5) overproduction, 6) over processing, and 7) defects. Energy consumption is a component of each of these wastes. However, challenges in quantifying the energy savings resulting from waste elimination have slowed the integration of Lean with utility energy efficiency programs.

In 2011, the Northwest Energy Efficiency Alliance completed the Manufacturing Extension Partnership (MEP) Energy Project, an effort that applied energy efficiency concepts within the MEP organizations of the Northwest. A component of this project was to quantify the energy savings from a Lean implementation at a customer of one of the MEP organizations. The project team attempted to use a combination of top-down (facility-wide) and bottom-up (end-use) approaches to estimate the energy savings resulting from a reduction in system start-up time at a food processing facility. This paper provides details on the project approach, results of the project, and next steps to refine and improve the approach for the future.

Background

In 2010, the Northwest Energy Efficiency Alliance (NEEA) launched a project to apply energy knowledge and support for the region’s Manufacturing Extension Partnerships (MEPs). The MEPs work to make small- and mid-sized businesses more competitive via many improvement approaches, the most common being the application of Lean Manufacturing (Lean) principles.[1] As a part of that effort, NEEA’s project team, led by EnerNOC, determined the energy savings that resulted from implementation of process improvements identified using Lean principles. In fall 2011, EnerNOC worked with the Oregon MEP (OMEP) and a food-processing facility in Oregon to estimate energy savings from a reduction in start-up time for their manufacturing process (NEEA 2011). The success of this approach led to broader consideration of the application of Lean principles in the context of energy efficiency programs.

Lean Manufacturing and the Seven Deadly Wastes

Lean emphasizes maximizing customer value while minimizing waste. This philosophy is based in part on the practices of Henry Ford who, in his classic 1926 book *Today and Tomorrow*,

[1] The Lean Enterprise Institute – a non-profit education, publishing, research, and conference organization – describes Lean in more detail at http://www.lean.org/WhatsLean/.

said that if a processing step doesn't add value to the product, it's a waste. Simply put, if a particular action or activity does not add value to a product that the customer is willing to pay for, then that action or activity is wasteful and therefore should be eliminated.

The philosophies of Ford and American quality pioneer Dr. William Edwards Deming were taken to heart by the Japanese during the reconstruction of Japanese industry following World War II and became key concepts of *Kaizen*. *Kaizen* is a philosophy of improvement through waste elimination, productivity improvements, and sustained continuous improvement that is considered to be the "building block" of all Lean production methods (EPA 2011a).

Lean principles are different than mass production principles in that they focus on increased flexibility and quick response to changing customer demand. This, in turn, can lead to high quality at the lowest cost in the shortest amount of time. Toyota Motor Corporation management took Lean concepts and developed a management philosophy called Toyota Production System (TPS), from which the original seven "deadly" wastes were identified:

1. Transportation – Moving products unnecessarily
2. Inventory – All components and finished product not fulfilling current orders
3. Motion – Equipment, product, or people or moving more than required or necessary
4. Waiting – Product not in transport or processing, waiting for the next production step
5. Over-processing – More work done to a product than necessary
6. Overproduction – Production ahead of demand – considered the worst type of waste because it hides and/or causes the other wastes
7. Defects – Additional effort and cost are needed to fix defects

Recently, additional wastes have been suggested to reflect products rejected by the customer, waste of unused human talent, and other wastes. While these additions have been useful in practice, they have not been standardized as areas of focus.

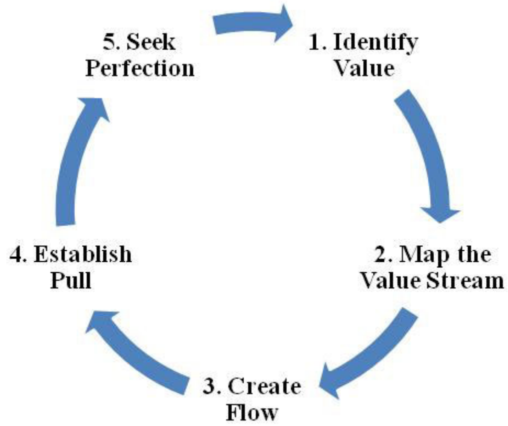
The steps to achieve Lean are summarized in Figure 1 on the next page, which illustrates the five-step thought process for Lean implementation (Lean Enterprise Institute 2013):

1. Specify value from the standpoint of the end customer by product family.
2. Identify all the steps in the value stream for each product family, and wherever possible eliminate those steps that do not create value.
3. Make the value-creating steps occur in tight sequence, so the product flows smoothly toward the customer.
4. Removing wasteful steps and establishing flow creates the ability to deliver only what the customer wants when they want it, which is referred to as "pull."
5. As value is specified, value streams identified, wasted steps removed, and flow and pull introduced, begin the process again and continue it until a state of perfection is reached in which perfect value is created with no waste.

Lean's Universal Application

According to the U.S. Environmental Protection Agency (EPA), most of the major U.S. companies that have been recognized by the EPA's ENERGY STAR program are also leaders in implementing Lean and Six Sigma. This shows that energy waste is already being acknowledged by leading Lean companies (EPA 2011b).

Figure 1. Five-Step Lean Process



Source: *Principles of Lean*. Lean Enterprise Institute, Inc. <http://www.lean.org/WhatsLean/Principles.cfm>.

To create momentum for energy performance improvements within individual manufacturing sectors and increase the number of companies benefitting from greater energy efficiency awareness, the EPA has produced a series of energy efficiency guides. These industry-specific guides are currently available for 14 manufacturing industries. However, implementation of Lean is not limited to manufacturing. Recently, companies in service industries such as banking and healthcare have been adopting Lean methods to reduce waste in service delivery and administrative processes and to more effectively meet customer needs (EPA 2003).

Energy Is Secondary In Lean

There are four basic goals of a lean enterprise (Manufacturing-Works 2013):

1. Improve quality
2. Eliminate waste
3. Reduce lead time
4. Reduce total costs

Reducing manufacturing process energy consumption is not an explicit goal of Lean. However, there are clear links between the energy use and wastes in the production process, such as the use of electricity to heat, cool, and light underutilized inventory spaces (Sciortino, Watson & Presnar 2009); energy can be thought of as a marker species for waste. As a result, significant opportunities to reduce energy costs may be overlooked. While this paper focuses on measureable energy savings, indirect or embedded energy savings can also be achieved through Lean principles and are worth further study.

Project Impetus

As this project began, we came to the conclusion that there was still a lot to learn about Lean and how it could impact energy consumption within a facility.

This project just scratches the surface with lean. The investigation into the energy impacts of Lean at this customer is just a tiny part of a larger on-going project at this facility. There are a lot of Lean projects out there yet to be done, meaning that there's still a lot more to investigate.

Almost no literature/research. While quite a lot has been written about Lean in general, not much has been written about the relationship between Lean and energy or how to quantify the energy impacts of lean manufacturing.

Interest in new programs. Utilities are always looking for new and innovative programs – whether it's new technologies or new approaches of encouraging efficiency. Encouraging lean manufacturing improvements for the sake of energy efficiency improvements certainly qualifies as one as an innovative program.

Non-energy benefits. As most traditional Lean improvements target other types of waste, within a utility program these can be seen as non-energy benefits (NEBs). Example NEBs include reduced man power, reduced insurance liability exposure, reduced staff hours, reduced scrap materials, and higher productivity.

Potential to expand pilots, step, and repeat. The approaches used in this analysis provide the potential for replication not only within the same facility, but within other facilities of a variety of different types. While Lean was initially aimed at manufacturing facilities, it has been adopted even by companies in service industries. Each iteration provides the opportunity to refine and expand the process, so that a consistent and open approach can be eventually developed.

Beginning of Project

Facility Management's Desire to Estimate Energy Savings from Changes in Operations

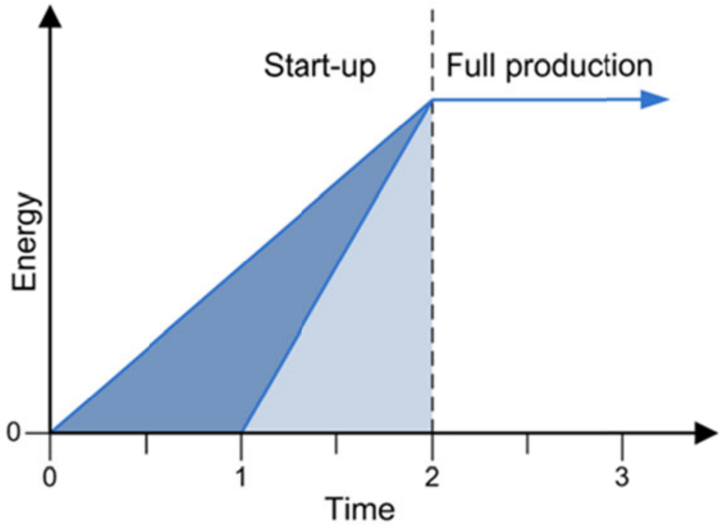
On behalf of the customer, a consulting engineer with OMEP engaged NEEA and EnerNOC to estimate energy savings that might result from the Lean process improvements implemented at the customer's facility. The customer's goal was a 10% reduction in overall energy consumption. Specifically, the customer's management was interested in estimating the energy savings that might be obtained by decreasing the daily start-up time from two hours to one hour.

Defining the Approaches to Estimating Energy Savings

Figure 2 illustrates the energy consumption that occurs as the facility starts up its production lines. The energy consumed by the production line during the standard two-hour start-up is represented by the line running diagonally from the origin of the chart (0, 0) to the point at which full production begins after two hours. The goal of reducing the start-up time to one-hour is represented by the second, steeper diagonal line that begins at the point in time "1" and reaches full production after one hour (where it meets the vertical dashed line). The two triangles formed by these two lines represent the energy consumed during the start-up process.

Geometrically, they are equal in area, which demonstrates the fact that cutting start-up in half also halves start-up energy consumption.[2]

Figure 2. Production Line Energy Use at Start-Up



Energy Savings Methodologies

In an attempt to estimate the potential energy savings resulting from the Lean Manufacturing improvements, EnerNOC created models by means of both top-down (facility-wide) and bottom-up (end-use) approaches.

Comparing the Methodologies

Top-down. Top-down models attempt to attribute aggregate energy consumption data to different processes, with the primary purpose of identifying long-term trends in energy consumption. Inputs commonly used by top-down energy models at the facility level include documented energy consumption, production, operating characteristics, and normalized for weather-dependent processes. Strengths of the top-down approach include the need for only aggregate data that is widely available, the ability to detect trends over time when historical data is used, and ability to compare across facilities. Top-down models do not include technological detail, overestimating adjustments to energy systems, and tend to ignore—or at least are unable to take into account—technological changes or unique attributes of business practice optimizations.

Bottom-up. Bottom-up models are models that use input data that are more granular than the facility as a whole. The detailed data input of bottom-up modeling allows for the estimation of energy consumption of different end-uses and the effects of technology change and or specific behavior changes. However detailed data, especially broken down by energy end-use, are difficult and expensive to acquire on a large scale. Two classes of models can be identified

[2] This simplified diagram assumes that the ramp-up of energy consumption levels over the full period of the start-up are constant, whereas startup activities are probably more step-wise.

within bottom-up models: statistical and engineering. Statistical models are regression models that establish a relationship between facility energy consumption and various end-uses. Engineering models estimate the energy consumption of various end-uses by taking into account energy ratings and usage of equipment. They provide detailed profiles of individual facilities, but are data intensive. EnerNOC used an engineering approach to develop our bottom-up approach for this customer.

While it appears at first glance that the bottom-up approach might be more suitable for estimating the energy savings of a one-hour reduction in production start-up, both approaches are, in fact, necessary. As will be described in the following sections, there are inputs to the top-down model that are not included in the bottom-up approach and *vice versa*. Using these two approaches in a complementary manner will help avoid omitting potentially important inputs and factors in energy consumption at the facility.

Top-Down Models

To estimate the electric and natural gas energy consumption at the facility, EnerNOC developed two OLS (ordinary least squares) regression models. These models use as independent variables calendar month values—such as utility bills, weather, and production and product mix data—divided by the number of days in the month to determine average daily energy consumption. From the average daily energy consumption baselines one can then estimate monthly energy savings due to the implementation of lean practices or process optimization.

The independent variables were analyzed both individually and in combination to determine which were best able to model monthly energy consumption. When determining the best independent variables, one of the first tasks is to establish whether a statistical relationship exists between energy consumption and the independent variable. Using an exhaustive process, EnerNOC evaluated both linear and non-linear forms of each independent variable to determine which "significant, independent" variables would result in models consistent with criteria set forth in ASHRAE Guideline 14-2002 "Measurement of Energy and Demand Savings." EnerNOC used the following statistical indicators of model quality to determine the optimal combination of independent variables for each model:

- *t*-Statistic – The coefficient for every independent variable has a *t*-statistic greater than |2.0|, indicating that the coefficient is significantly different from zero.
- R^2 (Quality of Fit) – Model possesses an R^2 greater than 75%, which means the regression model captures at least 75% of the variation in monthly energy consumption.
- CV-RMSE – Must be less than 0.25; the Coefficient of Variation of the Root Mean Square Error (CV-RMSE) is used to describe how well a mathematical model represents the variability in the given data set. The lower the CV-RMSE, the better the model.

After the model is established, the baseline energy consumption is estimated using the coefficients from model along with post-implementation data for the factors they represent. The following equation is used to calculate electric energy savings:

$$kWh\_Savings = kWh\_Baseline - kWh\_Lean$$

Where:

kWh_Baseline	=	Monthly kWh from top-down model
kWh_Lean	=	Monthly actual kWh

Baseline consumption and savings are established in a similar way for natural gas.

Top-down electricity model. Independent variables analyzed for inclusion the electricity model included:

- Monthly weather (heating degree days [HDD] and cooling degree days [CDD]) measured at a local airport
- Monthly total production of all products (stated as daily averages)
- Monthly production for each of five individual products (stated as daily averages)

EnerNOC found weather data to be statistically insignificant for modeling electricity consumption, so it was not included in the final model. Production data for individual products were statistically insignificant for all but one product. That one product was most significant in non-linear (as both the square and cube of itself)[3] relationships with electricity. We also found that the product of the monthly production of three products was the most significant predictor of monthly electricity use.

Monthly electricity consumption at the facility was modeled using the equation below:

$$\text{Monthly kWh} = [\ \underset{(12.70)}{11{,}313.15} + \underset{(8.95)}{7.29 \times BGD} + \underset{(5.67)}{0.35 \times Alpha^2} - \underset{(-5.94)}{0.22 \times Alpha^3}\ ] * D$$

Where:

Monthly kWh	=	Monthly electricity consumption (kWh)
BGD	=	Product of average daily production of three products: Beta, Gamma, and Delta (Pounds/day)
$Alpha^2$	=	Square of average daily production of product Alpha (Pounds/day)
$Alpha^3$	=	Cube of average daily production of product Alpha (Pounds/day)
D	=	Number of days in month

The parenthetical values below each coefficient are the *t-statistics* for each independent variable. The absolute value of each is far greater than 2, indicating that each is significantly different from zero.

The electricity model had an adjusted R^2 of 0.84, meaning that 84% of the variation in monthly electricity consumption is explained by the variation in the four independent variables.[4] The VC-RMSE of the electric model was 0.05.

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[3] Notwithstanding the squared and cubed production terms, no relation to or application of affinity laws is implied.

[4] The adjusted R^2 tempers the R^2 to account for the fact that increasing the number independent variables tends to inflate R^2.

Top-down natural gas model. For the natural gas model, EnerNOC analyzed the same set of independent variables as for the electric model.

For natural gas, EnerNOC found heating degree days (HDD) to be significant. Production data for individual products were also statistically significant. By regressing different combinations of products, three products were revealed as very strong predictors of natural gas consumption – one of which is the square root of monthly production.

Monthly natural gas consumption at the facility was modeled using the equation below:

$$Monthly\_NG = [\ \underset{(3.08)}{5.376 \times HDD} + \underset{(2.93)}{0.008 \times SqRt\_Alpha} + \underset{(6.49)}{0.072 \times Beta} - \underset{(-3.65)}{0.040 \times Delta}\ ] * D$$

Where:

Monthly_NG	=	Monthly natural gas consumption (Therms)
HDD	=	Average daily heating degree days for the month
SqRt_Alpha	=	Square root of average daily production of Alpha (Pounds/day)
Delta	=	Average daily production of Delta (Pounds/day)
Beta	=	Average daily production of Beta (Pounds/day)
D	=	Number of days in month

The natural gas model had an adjusted R^2 of 0.94 with a VC-RMSE of 0.06.

Bottom-Up Models

A "bottom-up" analysis entails identifying all energy using equipment, estimating or measuring the amount of energy each piece of equipment uses, and then using that information to determine energy use during a given period. This is a laborious task because identifying all energy-using equipment can be a challenge. Food processing facilities are complex and contain a large number of motor-driven systems, boilers, ovens, and other energy-consuming devices. In addition to identifying the equipment associated with specific processing lines, both the refrigeration and compressed air systems contributed to the facility's overall energy use and were, therefore, included in this assessment.

In brief, our approach consisted of developing a list of all energy-using equipment within the facility, deploying data loggers to collect information on equipment use patterns for some of the production equipment, and then estimating the input from various other major uses (e.g., lighting, compressed air, and energy associated with the refrigeration system) using additional sources. The efforts were linked to produce a single estimate of total energy consumed on a daily basis at the facility, and this estimate was compared to actual plant data to evaluate its accuracy.

Bottom-up electricity model. The electricity analysis started with identifying the electricity-consuming equipment on each production line. These were mostly motors used for mixing or conveying the food products. There were almost 60 pieces of electricity-consuming equipment involved with the production lines.

Using data on motor horsepower, voltage, amp draw, and utilization factor, EnerNOC estimated daily electricity consumption for a variety of end-uses using engineering methods (Table 1). Data from loggers were used when available to validate the engineering estimates of utilization factors used to estimate consumption.

Table 1. Summary of Daily Electricity Consumption

End-Use	Daily Consumption (kWh)
Production line motors	1,336
Compressor and condensers	9,506
Evaporator fans	4,541
Lighting	1,658
Office HVAC	2,912
Compressed air	1,592
Total Daily Plant Electricity Consumption	**21,545**

Bottom-up natural gas model. Natural gas consumption at the customer's facility was limited to two 200 horsepower high-pressure steam boilers. Each boiler was 85% efficient and able to provide 6,900 lbs of steam per hour. The steam was used in all the production lines as well as for producing hot water. Average hourly natural gas consumption during 2010 was 51.2 therms per hour. The daily natural gas consumption was estimated to be 1,229 therms per day and was calculated as follows:

$$\textit{Daily Natural Gas Consumption} = \textit{Therms/Hour} \times 24 \times \textit{UF} \times 0.7$$

Where:

Daily Natural Gas Consumption	=	Daily natural gas consumption in therms
Therms/Hour	=	Hourly natural gas consumption at full-load
UF	=	Utilization factor
0.7	=	Boiler combustion efficiency

Energy Savings Due To an Hour Reduction in Production Time

Ultimately, the final electricity and natural gas savings estimates were based solely on the bottom-up models. The top-down models as specified were of little use in estimating the savings resulting from a time-dependent process change. The two models developed for this analysis were primarily dependent upon production, which would not have been impacted by the change in start-up duration.

Base on the bottom-up model, the estimated total daily energy savings due to the one-hour reduction in daily start-up time was 5.1 MMBtu, or approximately 2.6%, which was about one-quarter of the customer's goal of 10%. The annual value of these savings was about $31,000.

Electricity

Once the daily plant electric energy was categorized, estimates of the impacts from shutting down a production line earlier were made. This required some engineering judgment due to the lack of certainty in some impacts, such as the savings due to reduced refrigeration load on the blast freezers.

The electricity savings estimate is based on the assumption that the amount of heat removed by the refrigeration system did not change (since no product was yet being cooled). In addition, the production lines ran one hour less on high load (i.e., one hour more on low load), and the evaporator fans in the blast freezer ran for 15 hours per day rather than 16.[5] (The evaporator fans in the other freezer and cooler did not run any more or less frequently because there was no change to this process). Further, there was some heat rejection from the blast freezers to the ambient, so the compressors and condensers did not have to work as hard to remove that heat. Energy savings from reduced blast freezer use were assumed to be about 5% of overall compressor and condenser daily electricity use. It was necessary to calculate these savings using engineering estimates due to a scarcity of logged data.

In order to compute electricity savings, the analysis summarized in Table 1 was repeated assuming 15 hours of production time. Lighting, office HVAC, and compressed air energy use were excluded as it was assumed that those end-uses too would remain unchanged. Table 2 shows that total estimated electricity savings were approximately 758 kWh (2.6 MMBtu) per day or 3.5% of daily plant use. Annually, electricity savings would be approximately 277,000 kWh with a value of about $22,000.

Table 2. Daily Electricity Savings Potential Estimate

	Production Period Consumption (kWh/day)	
End-Use	**15-Hour Duration**	**16-Hour Duration**
Production Line Motors	1,263	1,336
Evaporator Fan Energy	3,141	3,351
Compressors & Condensers	9,031	9,506
Total Consumption	**13,436**	**14,194**
Electricity Savings	***758***	–

Natural Gas

Estimating the natural gas savings was more straightforward than for electricity. Since there was only one end-use, it was possible to determine the hourly consumption from the daily consumption. It was only left to determine the gas consumption rate during startup.

A significant volume of hot water was used to clean the facility each day. This water was heated using steam from the two boilers. However, decreasing the length of the startup was not likely to have a significant impact on cleaning water use.

Steam was used for cooking only during production hours. While the boilers were ready to provide steam during non-production hours, no cooking steam was consumed during startup, since no product was ready to be cooked.

One hour's worth of the daily natural gas consumption of 1,229 therms is 51.2 therms and provided a starting point for determining the natural gas savings. Since little steam would be used during startup, the amount of gas saved was less than 51.2 therms. EnerNOC estimated that one-half of the hourly consumption, or 25.6 therms (2.56 MMBtu), would be a reasonable savings figure.[6] This is about 2% of daily natural gas consumption or annual savings of approximately 9,340 therms with a value of about $9,000.

[5] The blast freezers typically ran only during the 16 daily production hours and two of those 16 hours were during the start-up period.

[6] It was necessary to estimate natural gas savings, since it was not possible to measure steam use for cooking at the facility.

Conclusions

The top-down models were not capable of estimating the savings resulting from a time-dependent process change. One alternative approach, which was not feasible at the time, would have been to develop a daily consumption model that included operating hours. This would have better provided the ability to estimate the impacts of the reduced start-up time.

The bottom-up analyses could have been fine-tuned to provide estimates close to the hourly consumption figures from the billing data. However, the same issue arises as with the top-down analyses in that one cannot easily differentiate between production and non-production hours. As a result, it was very difficult to accurately estimate the energy savings from a one-hour reduction in start-up by simply estimating the average energy use over a one-hour period of the day.

Next Steps

The most immediate next step is to identify more pilot projects upon which the energy savings estimation methodology could be further investigated and developed. The most important aspect of which would be to develop top-down modeling methodology that includes an expression of operating or process duration.

Additional Pilots

Having adequate opportunities to investigate and develop methodologies is critical to the potential future success of this approach. Two potential paths to additional pilot projects are the consultative and cohort techniques.

One-on-one consultative lean (Consultative Lean). The consultative approach provides the customer with access to a technical service provider (TSP) that provides specific consultative advice to help the customer set-up a Lean program. The Consultative Lean approach is straightforward: the participating customer receives frequent and personalized attention throughout the implementation period.

Cohort lean (Lean Cohort). The cohort approach places customers into groups that work alongside each other, supported by a TSP, for one year or longer, coming together in quarterly workshops, participating in monthly webinars, and working on their own in-between these sessions. Structured groups are composed of approximately 5 to 12 program participants sharing best practices and learning together in a group setting. The cohort is typically filled with non-competitive participants. However, by mutual agreement, competitors may participate in the same cohort. Cohorts are typically established for a geographic area, as the cohort participants usually convene for quarterly workshop events.

In general, larger customers are a good fit for Consultative Lean while relatively smaller customers are often better suited for the Lean Cohort track. However, this is not a firm rule.

Additional Steps

Once the energy savings estimation methodology has been vetted through additional pilots, there are several other next steps, many of which have already been implemented in similar projects.

Model improvement. The total value of the electricity and natural gas savings were estimated to be approximately $31,000. This estimate is based on available data and we feel that it could have been improved significantly were more granular data available to improve the quality of the models and results. Improved granularity could be accomplished by:

- Having access to more data loggers installed on major processes and equipment to provide more points of measurement (e.g., individual motors and other points of energy consumption).
- Obtaining more frequent (e.g., hourly) observations for all points of measurement (energy consumption as well as production).

Energy savings from other types of waste. The approach taken in this assessment to determine the potential energy savings from a one-hour reduction in start-up time could also be adapted to estimating the energy-saving impacts of reducing or eliminating other types of waste. Looking back at the seven "deadly" wastes identified by Toyota Motor Corporation, there are three wastes where there is the potential to identify and realize energy savings:

- Transportation – The customer currently has refrigerated space in several off-site facilities. Will moving those spaces to sites closer to their facility reduce fuel and labor costs to move the products? And will the shorter distance reduce the amount of energy required to cool the products?
- Inventory – Are products being made at a rate less than the capacity of the line? Is there a pinch point in the line that constrains the entire line's capacity? Both of these problems could be resulting in wasted energy consumption.
- Motion – Like many food processing facilities, the energy inputs to the processes may not be located in the most efficient location. Could the boilers be distributed to locations closer to the points where steam and hot water are needed? The ability to distribute energy inputs could lead to lower losses.

Energy mapping. A detailed energy mapping combined with a thorough evaluation of each of the Lean manufacturing improvements made at the facility could reveal a significant number of points where energy savings are occurring.

How energy is used in each of the seven deadly wastes. Future research could quantify how energy is used (and wasted) in each of the seven deadly wastes. Not all manufacturing facilities experience all seven types of waste. However, the ability to identify which wastes are more likely to occur by industry type could prove extremely valuable.

Which waste should be targeted? Quantifying energy consumption and waste by type of waste and industry would then allow business owners and operators the ability to target specific wastes for correction. The ability to target wastes further provides the ability to prioritize and budget for necessary investigations and improvements.

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