Industrial Energy Optimization: Managing Energy Consumption for Higher Profitability

The Rockwell Automation strategy aligns energy consumption with energy demand

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Executive Summary

There once was a time when large corporations viewed their brick-and-mortar offices and storefronts as the main strategic assets in their portfolios. Abiding by the real estate mantra of "location, location, location," it seemed preposterous that a web site could become a major source of competitive advantage. Nonetheless, those who proactively established and maintained an online presence leapt ahead of their competition; and the slowest to react to the new reality did not survive.

A similar seismic shift is occurring related to industrial energy consumption. Traditionally, energy has been viewed as a cost, a bill to be paid and an expense to be controlled. Those who are ready for the future, however, have matured into a new perspective toward energy and are shifting their operations, especially their manufacturing, to capitalize on the full value of energy as a "raw material," a resource that can be applied to grow and sustain their businesses into the future. Large and small companies alike will need to know exactly where that valuable energy is being used, to the point of tracking it as an ingredient in their recipes or a tangible component in the product assembly – and capturing it as a line item on the production Bill of Material (BOM), or other similar tracking methods, such as Giga Joules or BTUs per ton of product. Managing this information in real time gives them the means to manage it carefully in order to sustain a profitable business.

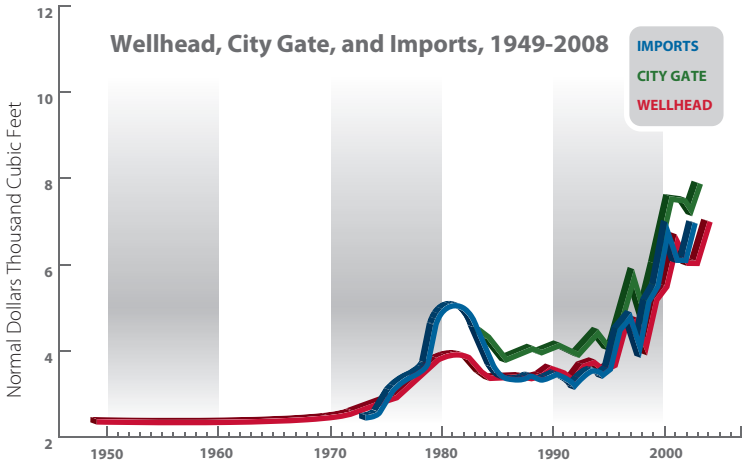
> *"Electricity is an input to production much like materials or labor. It is imperative that firms balance the needs of production and revenue generation with the costs associated with each input."*
>
> *– Aimee McKane, Senior Program Manager, Lawrence Berkeley National Laboratory*

While electricity is a common example discussed in this paper, there are many different types of energy consumption in manufacturing. For example, a recent food manufacturing industry report from the U.S. Environmental Protection Agency highlights petroleum, natural gas, coal and renewables as common sources for which consumption is on the rise. Regardless of the type of energy being consumed and the purpose, manufacturers have an opportunity to change their behavior with regard to how they view energy consumption in their facilities.

This paper describes the current economic and regulatory drivers compelling manufacturers to view their energy resources as a path to strategic competitive advantage, and for transforming their perspectives to an internal view on how they can manage energy resources from within the plant. It also details a methodology that can help manufacturers shift their points of view from treating energy as an undifferentiated overhead cost to managing it at a finite level as a cost of producing specific products.

The Complexity of Energy Management

Manufacturers around the world have put forth commendable efforts to reduce their energy consumption. Despite individual reduction efforts, the world's consumption of fossil fuels continues to grow, and a significant number of industrial energy users remain unaware of the energy efficiency opportunities available to them. According to the U.S. Energy Information Administration, world manufacturing energy consumption is projected to increase by 44 percent from 2006 to 2030. The sheer size of the unrealized opportunity is stunning. According to a recent report from McKinsey & Company, Unlocking Energy Efficiency in the U.S. Economy, "The industrial sector offers 3,650 trillion end-use BTUs of NPV-positive energy efficiency potential, equivalent to 18 percent of its forecast energy consumption in 2020." Economic uncertainty, increased scrutiny, regulatory incentives and concerns about global climate change are turning already attractive investments in efficiency programs into absolute necessities. Fortunately, for the first time in industrial history, the automation, control, optimization and information solutions necessary to conquer the energy challenge are in place or readily available and can be applied immediately to achieve measurable results.



Energy has become one of the most elusive and hard-to-manage costs in manufacturing, with high levels of cost variability and supply volatility. Natural gas prices have fluctuated widely, as illustrated by the chart from the U.S. Department of Energy, which shows the wellhead, city gate and imports price per unit from 1949 to 2008.

Energy management principles apply to many forms of energy: Electricity, natural gas, oil, steam, compressed air, and even water.

Manufacturers face the very real possibility that water, gas, fuel oil, or electricity may simply not be available when they need them. For example, less than one percent of the world's water is available for human use; yet consumption is estimated to increase by 40 percent over the next 20 years. These risks and uncertainties can wreak havoc on a company's operations, ability to deliver, and ultimately their bottom line. By better understanding and managing energy consumption across the company, manufacturers can better defend themselves against these threats.

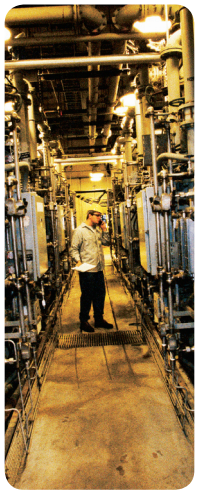
Companies also are confronted with the challenge of maintaining brand equity and corporate reputation in the face of increased scrutiny from consumers and major retailers who distribute their products. Large retailers such as Wal-Mart have begun to judge suppliers based on "scorecards" that track a product's environmental impact throughout the supply chain, illustrating to consumers a company's social responsibility. Consumers and stakeholders are using similar rating systems to pay closer attention to energy usage as they decide which products to buy. Furthermore, organizations are participating in voluntary programs for greenhouse gas reporting and other sustainability initiatives, such as the Carbon Disclosure Project, which create internal imperatives for continuous improvement in energy usage in order to improve reported metrics. As a result, manufacturers must better manage the energy used in their production processes and prepare for the possibility of carbon labeling and other finite measurements of energy usage at the unit level.

There are also regulatory concerns to manage. The U.S. Congress and the Executive Branch have proposed several initiatives that will compel manufacturers to do a better job of managing energy. Potential changes to the SmartGrid, including access to expanded supply and the possibility of real-time pricing, add to the complexity. And it's not just the U.S. At the end of 2006, the EU pledged to cut its annual consumption of primary energy by 20% by 2020. To help achieve this goal, it is working to mobilize decision-makers to set minimum energy efficiency standards and rules on labeling for products, services and infrastructure. These directives require multisite manufacturers to optimize not only within a single facility but also across a global network of manufacturers and suppliers. Emissions legislation such as cap-and-trade only adds to the multitude of reasons to focus extensively on energy management; attentive organizations are asking themselves how they can use these challenges not only to comply, but also to position themselves for success.

This is a time of unprecedented complexity for manufacturing: Managing production operations while balancing supply, pricing, retailer requirements, consumer demands, operational efficiencies, corporate image, compliance with regulations, and other demands is extremely challenging. By leveraging existing technologies in new and innovative ways, personnel throughout operations can meet these challenges and offer exceptional value to their organizations.

Energy in the Third Dimension: Managing Energy as an Input to Production

Some manufacturers have a one-dimensional view that industrial energy consumption is an unavoidable cost of doing business that can only be managed by using less. Progressive manufacturers are searching for answers to managing energy as part of a three-dimensional challenge: *Less, Cheaper, and Optimal.*



Some of the energy is used for facility operations, such as heating, cooling and lighting, and is not tied to a specific process or operation. Typically, however, the majority of the energy coming into the plant is used to power machinery, to convert raw materials into intermediate products, to generate steam, or to facilitate production. If it's used inefficiently, a plant manager can make behavioral and programming changes to use energy more productively. They can use less energy – for example, through scheduling production intelligently, taking advantage of more efficient equipment, or designing improvements, such as reuse of waste heat into their processes. They also can use cheaper energy – by managing where, how, and when energy is used in order to harness it when it is least expensive, such as during off-peak times.

However, the third, most sophisticated dimension – and the one that will ultimately have the most impact to financial performance – is in optimizing energy use so as to achieve production goals in the least expensive, most profitable way while balancing the many variables inherent to manufacturing. In other words, they can actively manage their energy as one of many inputs to the overall production equation. Such a sophisticated view is impossible if energy is viewed simply as plant overhead.

With cost pressures more stringent than ever, and the threat of insufficient resources already a reality for many companies, manufacturers should achieve higher profitability by managing their kilowatts and BTUs the same way they manage their capital: Reduce inefficiencies and waste while investing precious resources into the most profitable products and processes.

Today, many companies allocate energy costs evenly across a facility based solely on square footage, process unit or other similar measures. They accept high energy bills as unfortunate but necessary overhead and, in most cases, unknowingly spend more money on energy than necessary. The methodology outlined in this paper empowers manufacturers to strategically invest energy into their production processes to gain higher returns on their energy expenses by actively managing energy as an input to production.

"The cost of purchasing the energy needed for production by an industrial facility is viewed as managed input and typically receives significant attention, while the use of that energy once it is inside the factory is often viewed as simply the cost of doing business. While this is not true in all industrial facilities, experience has shown that unless the facility actively manages energy use and has a documented plan for doing so, these facilities are significantly less energy efficient than they could be. Without performance indicators that relate energy consumption to production output, it is difficult to measure or document improvements in energy intensity.

– Paul Scheihing, Technology Manager, Industrial Technologies Program, U.S. Department of Energy

A Paradigm for Inside-Out Energy Management

The following section describes a paradigm that manufacturers can use to make the transformation from passive energy users to strategic managers of their energy resources. This takes an "inside-out" approach and enables manufacturers to use their existing automation and power control investments to begin saving energy more effectively, and investing it more intelligently.

The methodology comprises seven pillars of capability. A manufacturer can begin to build its foundation with any of these pillars, either independently or simultaneously. As with any structure, it becomes increasingly stable with each additional pillar of support that is incorporated into the overall energy management program, but the pillars do not have to be addressed sequentially. A blueprint – or what we refer to as the "Greenprint" – for achieving energy optimization is outlined below.

- **Facility Monitoring** – Understand facility-level energy consumption to make better equipment runtime decisions
- **Production Monitoring** – Understand machine-level energy consumption of the plant floor in real time
- **Capturing Energy on the Production BOM** – View energy as a manageable input that can be documented on the production bill of materials
- **Modeling** – Use modeling and simulation solutions that factor in energy as a variable for optimizing profitability
- **Controlling** – Enable configurable automated optimization of production with energy as a variable
- **Responding** – Enable response to external market factors to optimize according to real-time supply
- **Scorecarding** – Extend the infrastructure to provide energy 'scorecards' and optimize the supply chain with energy as a consideration

Manufacturers using this architecture will gain better control over how they use energy, helping reduce the burden of energy costs on profitability and lessen the risks associated with external factors affecting energy price and supply. The following pages will describe each of these pillars in detail. First, it is important to note another ongoing activity – Assessment and Auditing – that manufacturers can introduce to their energy management programs to further support each of these pillars.

Foundation: Assessments and Auditing

Evaluate and target areas for improvement

An ongoing program of audits and assessments can be established and used to provide a strong foundation to each of the individual pillars. Energy assessments and audits can help companies identify a wide range of changes that they can make to help reduce their consumption. These can be simple, such as a walkthrough of a building or facility to identify quick-hit opportunities, or much more detailed efforts conducted in conjunction with the other pillars of this architecture. These are not one-time projects, but rather ongoing efforts to identify variables, such as how seasons might affect production variables and whether previously implemented improvements are continuing to perform as planned.

- **Where am I likely to find quick returns?**
- **What key metrics should I put in place?**
- **How can I encourage ongoing improvements?**

Such assessments can help to establish the scope of an energy savings effort, define key metrics, and put resources in place who can take a holistic view of energy for the organization. Recommendations may include low-investment modifications, such as shifting maintenance operations to non-peak times, or may be more involved, such as programming changes to equipment. Evaluation and prioritization of capital improvement opportunities can also be included in the analyses.

Facility Monitoring

Understand facility-level energy consumption and demand management to make better equipment runtime decisions

- **What amount of energy am I consuming?**
- **When will I hit a peak and how might that increase my costs?**
- **What is the quality of the energy and how might that affect my production?**

Before a manufacturer can begin to manage its energy consumption, it first has to gain visibility into facility energy usage and quality patterns. You can't manage what you can't see. At the facility level, building management personnel monitor the facility's metering infrastructure to collect data about all the energy resources – water, air, gas, electricity and steam– in relation to equipment usage and environmental conditions. This data is logged and time-stamped in an energy historian software program in order to establish trends or discrepancies in energy quality and consumption, and to establish benchmarks for future improvement.

With this big picture view of a facility's overall energy use, building management personnel can identify and make operational changes to help reduce energy consumption and costs, such as shedding loads or lowering power levels for a few minutes when the facility is approaching peak use. The information gathered at the facility monitoring level also helps manufacturers understand and manage power quality. With a log of historical data, building management personnel can identify power quality issues, such as voltage sags or harmonics that can cause damage to equipment inside the plant and cause power factor problems on the energy grid. Knowing these risks, manufacturers can better protect their equipment and also avoid incurring penalty fees from the utility companies who will charge manufacturers for their efforts to correct power factor issues on the grid.

Many manufacturers have also implemented programs to use this data to correlate energy use to production and estimate the amount of energy used for various products or batches. Though the resolution of the data at this level is limited, this can be a good baseline that can be driven to further, more useful levels of granularity within other pillars of the energy management foundation.

The Power of Knowledge

A manufacturer operating a liquid-blending application uses a series of pumps that run continuously at 7 to 8 megawatts (MW). On a particularly slow day, plant personnel decided to perform a routine maintenance task that required them to switch over to a back up set of pumps. Before shutting down the first set of pumps, they started up the back up set and, for approximately 45 minutes, both sets of pumps were running during the changeover process. This brought the facility's energy consumption from 8 MW to 13 MW. Unfortunately, this task occurred during the facility's peak demand window of 10 a.m. to 10 p.m. and the facility received a peak penalty charge from their energy company that totaled $95,000 for the year, costing an entire month's profit.

Production Monitoring

Understand energy consumption of equipment on the plant floor

- **How much of my company's energy use is actually occurring on the plant floor or production unit level versus the facility 'envelope'?**
- **Which pieces of equipment or production assets use the most energy, and when?**

Within the pillar of production monitoring, manufacturers extend data collection and analysis practices down to the plant floor, where plant managers can collect information about energy consumption as it relates to the machines, lines and production units involved in the manufacturing process. As a first step, an automation solutions provider consults with the manufacturer to identify useful data collection points across machines and lines, and assists with programming the information system to store and analyze that data. This effort also can involve machine OEMs, as they have unique insights into how their machines perform at other facilities. Many manufacturers already are collecting data that is useful for energy management in their control and information systems. For example, food manufacturers or life sciences companies may be collecting this information for regulatory reasons. However, most do not leverage this data for energy management purposes, and actually allow this crucial information to be continually overwritten in the controller.

Once a system is in place that extracts energy information from the plant floor, manufacturers gain the capability to separate plant floor consumption data from facility consumption data. In other words, both corporate management personnel and plant management gain a clearer view of exactly how much of the company's overall energy use is consumed by the manufacturing process versus how much is consumed by operational functions such as data centers. Whereas businesses traditionally have allocated energy costs evenly across a facility regardless of actual consumption variances, micro-monitoring allows them to track and project energy expenditures according to actual use throughout the facility.

More importantly, manufacturers can view this information in a reporting dashboard where a plant manager can pinpoint variable energy costs on the plant floor, and begin to consider ways to improve profitability. Manufacturers also can influence machine design practices to improve energy management such as specifying motors in different power ranges or attaching monitoring devices to assist with data collection. There are other considerations as well. For example, it is common today for MES systems to preclude operators from turning on equipment that they are not qualified to use. With visibility into peak demand systems, a manager can similarly preclude an operator from turning on an energy intensive machine when the facility is close to reaching peak demand.

This knowledge could also add a new dimension to commonly-used OEE (operational equipment effectiveness) equations which currently only take into account product quality, equipment uptime, and production output rates. By gaining a clearer understanding of energy consumption at the plant-floor level, manufacturers could modify the OEE calculations to include energy efficiency.

Energy in Action

A North American packaging company used plant floor energy consumption data to determine that a piece of equipment was using an excessive amount of energy during first shift. The company rescheduled production on that piece of equipment to the second shift and saved $66,000 in one year due to reductions in peak demand charges.

Capturing Energy on the Production BOM

View energy as a manageable input that can be documented on the production bill of materials

- **How do I plan my energy costs in advance?**
- **How much energy does each production load require?**
- **How can I capture energy usage at the unit level?**

Once manufacturing energy consumption data is stored and analyzed in the information system, plant managers can begin to see clear trends in how energy has been used among various historical events such as a specific product cycle or batch. Armed with this information, manufacturers can be confident in their measurement and documentation of energy usage at the unit level. Capturing that knowledge provides immediate benefit and also enables future improvement: Manufacturers no longer have to guess what energy consumption will be for similar production runs in the future. They actually can begin to project in advance how much energy will be required for similar loads or batches. In doing so, they move to a new pillar of the energy management architecture in which energy requirements are included in resource planning and scheduling decisions in the same way that the availability of raw materials or other inputs are considered an element on the bill of materials.

Empirically tying energy consumption requirements to the bill of materials enables a plant manager or production scheduling manager to make proactive production decisions and better manage energy investments in a way that will generate a greater return. For example, by knowing that certain batches require more energy, managers can move those batches outside peak windows. In addition, the unit-level energy consumption information becomes valuable input to sustainability scorecards and other reporting mechanisms.

This knowledge enables better overall business decisions as well. Knowing how much energy (and therefore additional cost) is required to manufacture a specific product, a product marketing professional may realize that specific product is not priced appropriately to generate a strong margin and can make adjustments accordingly.

At this stage, energy no longer is regarded as a set allocation that is simply part of unavoidable overhead. Manufacturers who add energy to the bill of materials can actively manage it as an input to achieve higher profitability.

Modeling

Consider energy as a process variable to optimize production and schedules

- **How will certain production changes affect energy consumption on a specific production cycle?**
- **How will those changes in energy consumption affect my profitability and other metrics?**

Once manufacturers have insight into how much energy is required to run a specific production cycle, they can pair that information with other production variables to gain a clearer view of the total cost to manufacture that product. Specifically, production scheduling managers can leverage production simulation software tools to input variables, such as peak and off-peak energy costs, raw material costs, labor and projected emissions, and pre-test "what-if" scenarios to see how production outputs and costs will change as a result of modifications.

Within this pillar, manufacturers can optimize all production assets and forecast the most economical way to manufacture their products, using energy as one of the variables. Looking beyond individual production cycles, they also can forecast the full sequence of production scheduling to optimize overall production.

The value of simulating production schedules is particularly apparent to manufacturers who run many one-off production cycles, such as what is commonly done by manufacturers with frequent product changeovers. They are able to maximize the value of a variety of variables including energy, labor, equipment and raw materials – making the best possible use of all production inputs without running a test cycle that would likely result in production scrap or misgauged resource needs and costs.

Controlling

Enable configurable automated optimization of production with energy as a variable

With all the manufacturing applications and automation solutions on the plant floor generating data, the next pillar in the energy management architecture is to drive all data sets into a single automated solution that can identify, model, visualize and present control options, or automatically control, production changes. Within this pillar, the modeling capability would automatically implement decisions without unnecessary management intervention. Furthermore, these decisions can extend past simple plant floor production variables to include additional variables that are not being directly measured by plant personnel.

- **How will daily temperature, humidity, or other environmental changes affect energy consumption in the facility?**
- **How can I make and implement effective decisions in a timely manner, given the multiple competing challenges I'm faced with every day?**

The secondary challenge solved at this phase is that manufacturers also gain a better understanding of how the source of energy can affect production. With this advanced control and optimization capabilities, manufacturers can tie information about the cost of energy resources and the quantity needed for production, and make better decisions about which resources to consume. For example, if the cost of natural gas increases, the control system might indicate to a manufacturer that they will save money by generating their own energy until the price comes down. Or it might determine that a different ratio of energy resources will be beneficial to cost, but damaging to emissions rates. All these considerations can be modeled and optimized automatically within this framework, using the control system already in place.

A plant manager for a chemical manufacturer comes in to work to discover that two of his staff are out sick. One of his machines is due for maintenance, and his production is nearing the limit of his emissions credits. The order he had planned to produce today has been changed due to an urgent request from a key customer for a product that is particularly energy intensive. He's concerned about exceeding his demand window for energy and about meeting the shipment deadline for the order. How can he balance these complex priorities?

Responding

Enable response to external market factors to optimize according to real-time supply

- **How should I augment my energy consumption visibility and control in preparation for and response to the current economic and regulatory climate?**
- **Might there be options to use SmartGrid innovations to improve my profitability?**

Within the "Responding" pillar of the architecture, manufacturers are able to make external market and regulatory influences part of their overarching energy management strategy. With a strong, centered understanding of the energy consumption within their own plants, manufacturers can establish effective programs to achieve plant-wide energy optimization. At this point, firmly confident in the management activities within the plant, it is possible to shift the perspective back to the outside of the facility and begin to focus on how to make intelligent economic decisions based on altering energy consumption in response to market fluctuation and regulatory demands. For example, the open market for electricity on the grid may require manufacturers to commit to 5-, 10-, or 15-minute blocks of energy use. By modeling production and correlating it to energy consumption needs, manufacturers can predict whether or not they will reach production targets using less energy than the permit allows. If so, the company procurement function can contact other plants on the industrial complex and sell remaining time blocks or kilowatt hours. Similarly, models can determine the most profitable production scenario given the real time market value of emissions or efficiency credits.

Scorecarding

Extend the infrastructure to provide energy 'scorecards' and optimize your supply chain with energy as a consideration

- **Can I maintain my brand position in light of scorecarding initiatives from governments and power retailers such as Wal-Mart?**
- **As energy price and supply continue to fluctuate, can I enable flexibility in my supply chain to minimize energy usage?**

Many manufacturers envision an imminent future where governments, power retailers, and even consumers may demand "sustainability scorecards" on products, such as carbon or energy labels. They are concerned about their readiness to comply and how they might optimize their scores, not only to support their brand reputation and sales, but also to support their own corporate responsibility initiatives.

Furthermore, they recognize that with the ongoing convergence of information from multiple sources, it may be possible to better optimize their full supply chain to enhance their sustainability and energy programs. For example, in the factory of the future, a manufacturer might wish to enhance their operations to select raw materials or shipping choices that will support an ideal "sustainability score." An ice cream manufacturer, for example, might choose a dairy based not only on the price of the milk, but also on the potential carbon or energy footprint of shipping the milk to the facility. Additionally, the transportation routes for the outbound product can be optimized to account for weather factors that might impact the energy needed to chill and store the product.

"Wal-Mart's 'supply chain of the future' initiative, for example, is targeting 20 percent energy savings in its supplier base by 2012."

McKinsey Report, p. 103

Such possibilities may seem distant to many. Fortunately, manufacturers can rest easy, confident that the pillars of energy management that they place over time will establish a firm foundation for meeting such challenges.

As energy costs and supplies continue to fluctuate and manufacturing consumption of energy resources comes under more scrutiny from consumers, businesses and governments, manufacturers will find that it is not only responsible, but also essential to their businesses to address energy management practices. Fortunately, the necessary combination of automation and information provides solutions that are available today to help manufacturers monitor, measure, model and control energy for optimal profits. Manufacturers who adopt the Rockwell Automation approach to energy management are able to leverage their existing automation and power system investments to make more of energy resources which helps lower production costs, optimize profits, and address economic and regulatory drivers.

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