The Importance of Energy Efficiency in Lean Manufacturing: Declaring Energy the Ninth Waste

Michael Sciortino and Suzanne Watson, American Council for an Energy-Efficient Economy
Rosemary Presnar, Maine Manufacturing Extension Partnership

ABSTRACT

Collaboration among federal agencies to deliver services to the private sector constitutes a major challenge. The U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), the U.S. Department of Commerce (DOC) and other federal agencies deliver programs and resources to the private sector in order to overcome market barriers and achieve business operation transformation in the U.S. manufacturing and industrial sectors.

This paper focuses on a pilot program of the EPA and the DOC's Manufacturing Extension Partnership (MEP) program. The MEP runs programs throughout the country that assist private industrial manufacturing clients with services to improve the overall efficiency of production. One particular process delivered through the MEP program is Lean transformation: an established set of educational tools that helps eliminate wasteful practices. The EPA developed a relationship at the federal level with the MEP program to promote energy efficiency and environmentally sound behavior among U.S. manufacturers through a pilot program. In order to reflect the commitment of the numerous interested stakeholders, the MEP and EPA programs would leverage federal, state, and private sector dollars.

The pilot project described below is based out of the EPA's Region 1 territory and remains in its preliminary stages. Thus, this paper describes the potential for operating new energy-related programs through MEP Lean transformation programs in the context of falling industrial output and rising energy costs to aid American manufacturers in producing goods more efficiently and cost-effectively.

Introduction

The basic concept of Lean manufacturing, or Lean transformation as it is also known, is to do more with less. Companies conducting Lean programs in their facilities ultimately wish to process more transactions with fewer resources and less waste. Over the past decade, the concept of Lean manufacturing has gone through a dramatic evolution from an obscure and isolated practice to a mainstream methodology throughout the industrial manufacturing supply chain. Originally developed by Toyota to eliminate all non-value added activity, Lean methods help industrial manufacturers reduce waste involved with the "eight deadly wastes": overproduction, inventory, transportation, motion, defects, over-processing, under-utilized people, and waiting (EPA 2007b).

At its core, successful Lean programs create a cultural and people-oriented transformation by educating entire organizations on how to identify hidden wastes and empowering each employee to enhance the quality of production. In order to proceed with a Lean program, however, high-level management must be convinced that the cost savings are worth the investment of their time and resources. For thousands of companies, Lean programs proved to be a sound investment. By implementing educational and behavioral tools developed by public and private entities, Lean participants can achieve a fundamental shift in their human and corporate business culture.

The Manufacturing Extension Partnership (MEP) is the primary vehicle in which Lean programs are delivered. MEP leverages $100 million of federal funding through the National Institute of Standards and Technology into a nearly $300 million program by combining funds from industry and state and local governments. Operating 59 centers in 393 locations in every state, MEP provides its industrial customers with services to improve productivity and competitiveness, including programs in Lean manufacturing (MEP 2009). The Lean services provided by MEP centers are well-established, cost-saving programs that follow proven methods and guidelines.

Traditionally, the direct identification of energy efficiency opportunities has not been a part of the Lean process, but rather a peripheral capture gained in the effort to reduce other wastes like time and materials. The energy costs used in the manufacturing processes, however, have historically comprised such a small portion of the total cost that it has not factored in as a separate "waste" to be managed through the Lean process. Recent energy price spikes, price fluctuations, and the certainty of more to come have placed energy as a central resource when considering more cost-effective industrial production changes.

Energy costs have a significant impact on the financial performance of businesses. A January 2008 poll taken by Pricewaterhouse Coopers revealed that 60 percent of senior executives at large, multinational U.S. manufacturing companies believe that oil and energy prices are the leading barrier to company growth (Taub 2008). The U.S. manufacturing sector and the economy as a whole would benefit greatly from a reduction in energy consumption. Manufacturers directly use energy in all forms—electricity and natural gas to produce goods and maintain office operations, and vehicle fuel to receive raw materials and deliver finished goods. In total, the industrial and manufacturing sectors represent the largest share of energy consumed in the U.S. economy (see Table 1).

Table 1: Share of Energy Consumed by Major Sectors of the U.S. Economy

Sector	Percent Share
Residential	22%
Commercial	18%
Industry and Manufacturing	32%
Transportation	28%

Source: EIA (2005)

In a March 2007 report, the EPA outlined some broad energy trends in selected manufacturing sectors (EPA 2007a). Industrial energy use has been growing more slowly than energy use in the residential, commercial, and transportation sectors. This is because industry as a whole has become a smaller proportion of the economy, has shifted to less energy-intensive types of manufacturing, and has already implemented a number of energy-saving technologies. Nonetheless, rising energy costs, diminishing demand, and the pressures of global competition pose continuing challenges for industrial manufacturing sectors but also create an opportunity for energy efficiency to play an increasing role in helping businesses' competitive positions.

At the regional level, industrial uses account for 20% of New England's energy consumption (see Table 2). According to the DOE's Energy Information Administration, the manufacturing sector consumes 70% of the entire industrial share, which includes the agriculture, forestry, fishing, hunting, mining (including oil and gas extraction), and construction sectors (EIA 2005).

Table 2: Industrial Energy Usage in New England

State	Industrial % of Energy Consumed
Connecticut	16%
Massachusetts	17%
Maine	40%
New Hampshire	21%
Rhode Island	11%
Vermont	29%
New England	20%
United States	34%

Source: EIA (2005)

In most cases, the two major types of energy consumed in New England are petroleum and natural gas (see Table 3). In Maine, wood and waste comprises 52% of industrial energy usage. As a region, New England incurs significant loss of energy in the transmission and distribution of electricity, ranging from 11% in Maine to 40% in Rhode Island and Vermont. The New England average for this type of loss is 30% compared with the national average of 23%. The types of fuel used by industry have changed over time. During the last 50 years, industry has lessened its use of coal and shifted towards natural gas use. Recent increases in both the price and price volatility of natural gas may interrupt these trends, although over the short term, most sectors are not able to switch fuels easily. Industrial use of renewable fuels is growing, and is already higher than the use of renewable fuels in the residential, commercial, and transportation sectors (EPA 2007a).

Table 3: Industries Energy Usage as a Percent of Total Energy Usage in New England

State	Electricity	Petroleum	Natural Gas	Coal	Wood and Waste	Electrical System Energy Losses
Connecticut	14%	31%	20%	-	3%	32%
Massachusetts	12%	26%	31%	1%	3%	27%
Maine	5%	23%	7%	2%	52%	11%
New Hampshire	13%	36%	14%	0%	9%	28%
Rhode Island	17%	19%	24%	-	-	40%
Vermont	18%	24%	8%	-	10%	40%
New England	13%	27%	17%	1%	15%	30%
United States	10%	29%	26%	7%	-	23%

Source: EIA (2005)

Energy as the Ninth Waste

In October 2007, the EPA published its Lean and Energy Toolkit to assist companies with reducing energy usage and improving environmental performance through the Lean manufacturing process. Drawing from the experiences and best practices of multiple industry and government partners, this toolkit describes practical strategies and techniques to improve energy and environmental performance while achieving Lean goals such as improved quality, reduced waste, and increased customer responsiveness. According to the EPA, there are three reasons for integrating Lean and Energy efficiency efforts (EPA 2007b):

- **Cost Savings:** Reducing energy costs has a significant impact on business performance, though costs may be hidden in overhead or facility accounts.
- **Climate Change and Environmental Risk:** Proactively addressing the environmental and climate impacts of energy use is increasingly important to industry and society. Failure to do so is a potential business risk.
- **Competitive Advantage:** Lowering recurring operating costs, improving staff morale, and responding to customer expectations for environmental performance and energy efficiency increases your competitive advantage.

Environmental and energy wastes are not explicitly included in the common eight wastes addressed by Lean. This does not mean that the wastes are unrelated to the environment, however. Clear links exist between the use of energy and wastes in the production process, such as the use of electricity to heat, cool, and light underutilized inventory spaces. Environmental pollutants regulated under the Clean Air Act (i.e., sulfur dioxide and nitrogen oxides) are emitted due to industrial production. In general, the largest sources of energy-related emissions are external combustion boilers and manufacturing process equipment. In fact, companies may have already seen large energy use reductions from implementing Lean, because energy and environmental wastes are embedded in (or related to) the wastes, as shown in Table 4.

Table 4: Energy Use Hidden in Lean Wastes

Type of Waste	Energy Use
Overproduction of Work In Process	More energy consumed in operating equipment to make unnecessary products
Inventory Excesses	More energy used to heat, cool, and light inventory storage and warehousing space
Transportation of Materials and Equipment	More energy used for transport
Motion	More energy used for transport
Defects	Energy consumed in making defective products More space required for work in process (WIP) movement, increasing lighting, heating, and cooling demand and energy consumption
Non-Value Added Processing	More energy consumed in operating equipment related to unnecessary processing Use of right-sized equipment often results in significant reductions in energy use per unit of production
Waiting	Wasted energy from heating, cooling, and lighting during production downtime

Source: EPA (2007b)

Given that energy is a vital and costly input to most production processes and value streams, unnecessary energy usage can be considered the ninth waste. By incorporating greater energy efficiency in the Lean process, Lean participants can significantly enhance competitiveness by lowering costs and reducing their vulnerability to energy price increases and fluctuations. Lean implementers can also achieve environmental goals by mitigating greenhouse gas and other air pollutant emissions, resulting in avoided environmental penalties and compliance costs. At the end of the MEP Lean and Energy pilot projects, it is expected that energy will be formally accepted as the ninth waste identified in the Lean transformation process.

Integrating Energy into the Lean Program

On January 31, 2008, representatives from the MEP programs in Maine, Massachusetts and New Hampshire met in Worcester, MA, with Suzanne Watson then with the Maine Department of Environmental Protection and Linda Darveau and John Moskal with EPA Region 1 (Boston) to discuss a pilot Lean and Energy project. The goal of the project was to integrate energy measures identified in the Lean and Energy Toolkit into the established Lean program, which commonly utilizes the Time Wise methodology to train manufacturers in Lean process improvement. The methodology was developed by Time Wise Management Systems (TWMS), doing business as Manufacturing Extension Partnership Management Services (MEP MSI).

The Time Wise methodology and associated products are the only comprehensive and complete Lean manufacturing services currently available. The hallmarks of the Lean product suite include comprehensive hands-on experiential training simulations, the most advanced aggregation of Value Stream Mapping techniques that form a Value Stream Management System, and Rapid Improvement (Kaizen) events that implement the supply chain changes identified in the mapping exercises. The Time Wise training model, which is modular in approach, uses internal facilitators to support self-managed implementation of Lean practices (TWS 2009). Every person assigned to this Lean program has been trained and certified in Time

Wise Management Systems' product line of Lean training and has implemented dozens to hundreds of Lean-related projects. During the EPA/MEP meeting, the Time Wise Lean Modules were reviewed and recommendations were outlined to provide guidance on how to modify the existing modules to include the energy measures identified in the Lean and Energy Toolkit.[1] While private, federal, and state funding used for the direct delivery of the pilot projects will not be used to change or modify TWMS training materials, the pilot outcomes will include a report suggesting changes to the materials as well as an overall report on specific results and EPA case studies.

Minimizing Risk, Assuring Value

Ultimately, it is expected that this New England-based pilot Lean and Energy project will be of value and use throughout the MEPs across the country. By incorporating energy into the recognized Time Wise methodology, the perception of risk is greatly minimized for clients. Lean programs running the Time Wise methodology have boasted real cost-saving experiences, which will help convince clients to participate in the newest energy and environmental feature. Furthermore, the tri-partite cost-sharing agreement involves institutional entities at the federal and state level, which guarantees the reliability of funds.

Essentially true to the model of the MEP program, the funding will be close to a three-way split between the states, the federal government, and the companies themselves. Funding was expected to include "skin in the game" up front from the six manufacturers identified to take part in the pilot project. EPA's Region 1 office offered up a portion as well. In the end, EPA funds are expected to constitute approximately one-third of the total funding involved in the final budget. MEP programs from the states of Massachusetts, New Hampshire, and Maine also plan to work with their respective state partners to come up with the remaining share in the form of staff time and resources. The financial arrangement is considerably favorable for manufacturers, who leverage potentially over two-thirds of the cost of the project with their investment. The value of this program for manufacturers will become evident as savings accrue due to more efficient production. As manufacturers begin to operate in a more stable economic environment, Lean and Energy programs, which require minimal up-front costs, will become a safe and palatable investment.

Initial Meeting with Company Management

Six target companies were initially identified and early meetings were held in anticipation of the federal funding from EPA's Region 1 Office. The MEP Team met with the manufacturing company's management team to determine priorities, set achievable goals, and consider constraints. Letters of intent were signed and delivered from the companies as part of the submission of a proposed scope of work from Manufacturing Extension Partnership Management Services to the EPA. The participating manufacturers will include a subset of the original six companies who had agreed to participate prior to the economic downturn as well as newly recruited companies. The remaining portion of this paper is the proposed plan to proceed with once the economy allows new investments. The funding from EPA is now in place and the

[1] Recommendations were specific to the Time Wise® LE101 workshop: Principles of Lean Manufacturing, Time Wise® LE201: Value Stream Mapping Event, and Time Wise® LE202: Kaizen Rapid Improvement Event.

MEPs in New England are prepared to complete the project with the pre-selected manufacturers or those to be identified in the near future.

Once a project is ready to move forward, the MEP team consisting of representation from the three state MEPs (ME, NH, and MA) will conduct an assessment to determine the existence of an Energy Management System (EMS) at the pilot facility. If one is present, the MEP Team will further evaluate energy usage and costs, the responsible party for the EMS, and whether baseline energy measurements exist. The assessment will identify energy source uses and end-uses, monthly cost of energy use, peak shaving opportunities, which value streams and production processes contributed the most to the company's total energy use, and areas of the company's facility that can be targeted for energy efficiency improvement efforts. As part of this assessment, the MEP Team will rely on an external Certified Energy Auditor who will document any discrepancy findings and make recommendations.

During a follow-up meeting, the MEP Team and company management will identify a cross-functional team within the company that would be involved in Value Stream Mapping and Kaizen events. Company team members would represent both the company's corporate and production operations.

Lean Energy Awareness Plan

- **Preparation —** A Lean Energy Awareness eight-hour training session will be prepared for the participating companies. The preparation period will focus on incorporating energy terms and measures in the Time Wise LE101: Principles of Lean Manufacturing. Energy end use terms include but are not limited to heating, ventilating, air conditioning, compressed air, lighting, process equipment operations, process heating and cooling, and transportation. This is the portion of the project that is expected to prove that energy can become a full component to the MEP Lean process for manufacturers.

- **Awareness Training —** In this eight-hour accelerated learning workshop, the MEP Team plans to convey the benefits of using Lean Energy in a make-to-stock production environment to achieve breakthrough business performance. Awareness training will be open to all employees of the company. Key outcomes are expected to include:

    - Understanding the business case for an enterprise-wide Lean Energy Improvement as a way to profitably meet rising customer expectations in a globally competitive market
    - Understanding how Lean Energy Methods can simultaneously reduce total lead time, energy uses, and operational costs while improving service and quality

Value Stream Mapping Events

- **Preparation** — The MEP team will prepare for the Value Stream Mapping event by formulating an implementation plan based on the results of the assessment in the initial meeting with company management. Based on the process used, the MEP Team can incorporate some of the questions highlighted in the TLET in the Time

Wise LE201: Value Stream Mapping event to address energy usage. Depending on the usage, specific questions may include but not limited to:

Motors and Machines
- Are machines left running when not in operation? If so, why?
- Are energy-efficient motors, pumps, and equipment used?
- Are motors, pumps, and equipment sized according to their loads?
- Do motor systems use variable speed drive controls?

Compressed Air
- If compressed air is used, do you notice any leaks in the compressed air system?
- Do compressed air systems use the minimum pressure needed to operate equipment?

Lighting
- Is lighting focused where workers need it?
- Is lighting controlled by motion sensors in warehouses, storage areas, and other areas that are intermittently used?
- Are energy-efficient fluorescent light bulbs used?

Process Heating
- Are oven and process heating temperatures maintained at higher levels than necessary?

Facility Heating and Cooling
- Are work areas heated or cooled more than necessary?
- Do employees have control over heating and cooling in their work areas?
- Are exterior windows or doors opened to adjust heating and cooling?

Success Measures

Each company will have a series of predefined goals developed at the outset from the assessment process. These goals will be aligned with other facilities that are suppliers or customers to an individual site. These goals will be the measures of success and can be measured in classic Lean Energy terms, e.g., reduced cycle time, percentage reduction in inventories, and improved throughput pull cycles as well as consensus-defined financial goals that can be measured in terms of dollars and person-hours. The awareness plan and value stream mapping will identify areas for improvement and lead to Kaizen events, which involve a few energetic days of activity in which the changes are implemented. By adhering to the "Plan/Do/Check/Act" Kaizen methodology, each process improvement step will be monitored to ensure that the cost-savings and cost-readiness goals are on target in terms of schedule and savings over the long term.

Other measurement resources to be considered by clients include the ENERGY STAR Institutional Program's Portfolio Manager, which provides some comparison data for small and medium-sized manufacturers but could be used as a tracking tool. Also, energy service companies (ESCos) are available as consultants to work with companies on various levels and possibly share costs to implement energy efficiency upgrades.

Conclusion

Although the Lean and Energy pilot projects have yet to save energy or costs for American manufacturers, the program is positioned to become an immediately impactful industrial energy-efficiency program as the economy recovers. The efforts of the EPA and MEP to integrate energy into a mainstream production efficiency program will help industrial clients save money and reduce the emission of harmful pollutants. The project also makes progress towards inter-agency partnerships that promote energy-efficiency programs. Energy efficiency gains can be achieved over multiple years and in various aspects of the manufacturing process, so federal agencies such as the DOE and EPA should continue to learn from the MEP partnership and apply the experience to future collaborations with the common goal of improving energy efficiency.

Impending cap and trade legislation, skilled workforce needs, and increasing energy costs will certainly catalyze federal investments in energy efficiency. The Lean and Energy pilot program demonstrates not only how to leverage public and private funds, but also how to leverage established cost-saving programs to effectively incorporate energy efficiency. The Lean and Energy approach is an elegant pairing that promises transformation of operations rather than a piecemeal approach. American manufacturing must adapt to new realities and recognize new opportunities provided by coordinated federal resources for energy efficiency improvements.

References

[EIA] Energy Information Administration. 2005. *Annual Review 2005*. Washington D.C.: U.S. Department of Energy, Energy Information Administration.

[EPA] Environmental Protection Agency. 2007a. *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*. Prepared by ICF International. Washington D.C.: U.S. Environmental Protection Agency.

———. 2007b. *The Lean and Energy Toolkit.* Prepared by Ross & Associates Environmental Consulting, Ltd. in association with Industrial Economics, Inc. Washington D.C.: U.S. Environmental Protection Agency.

Elliott, R.N. and B. Hedman. 2001. *The Role of CHP in Addressing Texas's Need for Pollution Reduction and Growth in Energy Demand*. ACEEE Report IE011. Washington, D.C.: American Council for an Energy-Efficient Economy.

Elliott, R.N. and M. Spurr. 1999. *Combined Heat and Power: Capturing Waste Heat.* ACEEE Report IE983. Washington, D.C.: American Council for an Energy-Efficient Economy.

Hayes, R.H. and G.P. Pisano. 1994. "The New Manufacturing Strategy." *Harvard Business Journal,* January-February: 77-86.

Markey, E.J. 2009. "Save American Energy Act." Bill H.R. 889. Washington, D.C.: U.S. House of Representatives.

[MEP] Hollings Manufacturing Extension Partnership, National Institute of Standards. 2009. *About MEP*. http://www.mep.nist.gov/about-mep/index.htm. Washington, D.C.: U.S. Department of Commerce.

Nadel, S. 2006. *Energy Efficiency Resource Standards: Experience and Recommendations*. ACEEE Report E063. Washington, D.C.: American Council for an Energy-Efficient Economy.

Shipley, A.M., N. Greene, K. McCormack, J. Li, and R.N. Elliott. 2001. *Certification of Combined Heat and Power Systems: Establishing Emissions Standards.* ACEEE Report IE014. Washington, D.C.: American Council for an Energy-Efficient Economy.

Taub, Stephen. 2008. "Energy Costs Top Manufacturer's Concerns." *CFO.com.* http://www.cfo.com/article.cfm/10601468/c_2984411. January 30.

[TWS] Time Wise Solutions, LLC. 2009. *Time Wise Solutions Homepage*. http://www.timewisesolutions.com. Time Wise Solutions, LLC.