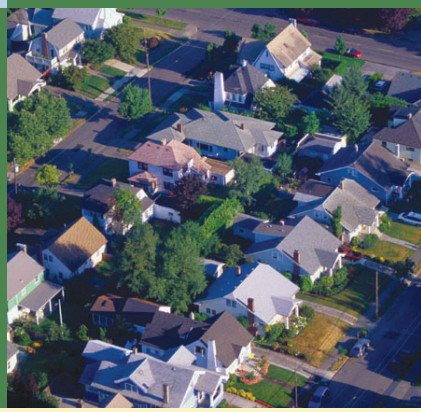

The Lean and Energy Toolkit

Achieving Process Excellence Using Less Energy

www.epa.gov/lean

Toolkit Format and Icons

The toolkit uses icons in the page margins to help you find and follow important information in each chapter.

Key Point Identifies an **important point** to remember

Key Term Defines an **important term** or concept

New Tool Presents a **technique or resource** that helps capture, communicate, or apply new knowledge

How-to Steps Describes **sequenced actions** to implement a tool

Chapters also include one or more **"To Consider"** text boxes that contain questions to help you explore how the information relates to your organization.

Acknowledgments

The U.S. Environmental Protection Agency (EPA) is grateful for the invaluable assistance of the organizations and individuals who helped develop this toolkit and shared experiences, tools, and techniques for integrating Lean manufacturing and energy management efforts.

EPA's Lean and energy partners include Baxter International, California Manufacturing Technology Consulting (CMTC), Eastman Kodak Corporation, Eaton Corporation, General Electric (GE), HNI Corporation, the National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership (MEP), and the U.S. Department of Energy. The EPA's National Center for Environmental Innovation and the Office of Pollution Prevention and Toxics participated in the development of this toolkit.

In addition to these organizational partners, this toolkit has benefited from the collective expertise and ideas of many individuals. In particular, EPA would like to thank the following individuals for their thoughtful contributions:

Susan Boone, Lean Six Sigma Trainer, GE Infrastructure

James Breeze, Energy Engineer/Project Leader, Worldwide Energy Office, Eastman Kodak Company

Jenni Cawein, Corporate Environmental Health and Safety (EHS) Engineering Manager, Baxter International

Gerald Church, Director of Energy Services, CMTC

Rob Currie, Director, Corporate EHS Engineering, Baxter International

Gretchen Hancock, Project Manager, GE Corporate Environmental Programs

Ernie Kulik, Corporate EHS, Eaton Corporation

Scott Lesnet, Member EHS Manager, HNI Corporation

Kirk Prather, Operations Manager Energy Services, CMTC

Douglas W. Prihar, Management Assistance Partnership Project Director, Nevada System of Higher Education

Randy Shultz, Facilities and EHS Manager, Eaton Truck, Shenandoah, Iowa

Scott Summers, Director and Vice President, EHS, Film Products Group, Eastman Kodak Company

Carroll Thomas, Partnership Catalyst, NIST MEP

Joe Wolfsberger, Vice President of Corporate EHS, Eaton Corporation

This toolkit was prepared for the U.S. Environmental Protection Agency by Ross & Associates Environmental Consulting, Ltd. (http://www.ross-assoc.com) in association with Industrial Economics, Inc. (EPA Contract # EP-W-04-023).

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Executive Summary

The U.S. Environmental Protection Agency (EPA) developed this *Lean and Energy Toolkit* to assist organizations in reducing energy use and improving performance through Lean manufacturing—the production system developed by Toyota. 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.

There are at least three reasons for integrating Lean and energy efficiency efforts:

1. **Cost Savings:** Reducing energy costs has a significant impact on business performance, though costs may be hidden in overhead or facility accounts.
2. **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.
3. **Competitive Advantage:** Lowering recurring operating costs, improving staff morale, and responding to customer expectations for environmental performance and energy efficiency increases your competitive advantage.

Linking Lean and Energy Use

Considerable energy savings typically ride the coattails of Lean activities because of Lean's focus on eliminating non-value added activities (waste). Without explicit consideration of energy wastes, however, Lean may overlook significant opportunities to improve performance and reduce costs. Companies such as Baxter International, Eastman Kodak, General Electric, Toyota, and 3M, as well as many smaller manufacturers, have successfully used Lean methods to reduce energy use, risks, and costs (see textbox).

Example Results From Lean and Energy Improvement Efforts

- ✓ A **Baxter International** facility saved $300,000 in energy costs in one year.
- ✓ **General Electric** has reduced greenhouse gas emissions by 250,000 metric tons and saved $70 million in energy costs since 2005 at facilities worldwide.
- ✓ **Toyota Motor Manufacturing North America** reduced facility energy use and greenhouse gas emissions by 30 percent per vehicle since 2000.

This toolkit describes a range of strategies for identifying Lean and energy improvement opportunities and reducing energy use with Lean methods. It is not necessary to implement all the techniques in the toolkit to succeed; instead, select and adapt the approaches that make the most sense for your organization.

Lean and Energy Assessment Strategies

Lean and energy assessment strategies involve observing shopfloor activities to identify signs of energy waste, measuring actual energy use and costs over time, and implementing energy savings opportunities through short, focused events. Strategies described in this toolkit include:

- **Energy Treasure Hunts:** Conduct a three-day plant-wide assessment of energy savings opportunities using a cross-functional team of employees.
- **Value and Energy Stream Mapping:** Integrate energy-use analysis into the Lean value stream mapping process to identify improvement opportunities within the context of the entire "value stream" of a product or service.
- **Six Sigma:** Use statistical process analysis and control tools to find and address root causes of energy wastes and variation.
- **Energy Kaizen Events:** Identify and implement employee ideas for saving energy and reducing wastes through rapid process improvement events.

Lean and Energy Reduction Strategies

Many energy efficiency best practices can be implemented without extensive analysis or planning. The Lean and energy reduction strategies in this toolkit describe ways to reduce energy use through Lean activities such as the following:

- **Total Productive Maintenance (TPM):** Incorporate energy reduction best practices into day-to-day autonomous maintenance activities to ensure that equipment and processes run smoothly and efficiently.
- **Right-Sized Equipment:** Replace oversized and inefficient equipment with smaller equipment tailored to the specific needs of manufacturing cells.
- **Plant Layout and Flow:** Design or rearrange plant layout to improve product flow while also reducing energy use and associated impacts.
- **Standard Work, Visual Controls, and Mistake-Proofing:** Sustain and support additional Lean and energy performance gains through standardized work procedures and visual signals that encourage energy conservation, and by making it easy or "mistake-proof" to be energy efficient.

Maximizing Lean and Energy Improvement Opportunities

In addition to explicitly using Lean methods to target energy wastes, facilities can take advantage of other windows of opportunity for energy savings that arise during Lean, including opportunities to install energy-efficient equipment, switch to less polluting fuel sources, and design products to use less energy. To be most effective, Lean and energy efforts should be proactive, strategic, and systematic. Adopting an energy management system that aligns with and supports your organization's Lean initiatives will enable your organization to achieve the greatest improvements in operational, energy, and environmental performance.

Preface

Purpose of This Toolkit

Key Point

*This **Lean and Energy Toolkit** offers Lean implementers practical strategies and techniques for improving Lean results—waste elimination, quality enhancement, and delivery of value to customers—while reducing energy use, costs, and risk.* The toolkit is also intended to introduce Lean practitioners to the extensive array of energy management resources available from EPA, the U.S. Department of Energy (DOE), and other organizations.

Key Term

The "Lean" methods discussed in this toolkit are organizational improvement methods pioneered in the Toyota Production System. *Lean production* and *Lean manufacturing* refer to a customer-focused business model and collection of methods that focus on the elimination of waste (non-value added activity) while delivering quality products on time and at a low cost. The toolkit assumes that you are familiar with Lean methods. For those who want to learn more about Lean, see EPA's Lean and Environment website (www.epa.gov/lean).

Key Questions Addressed by This Toolkit

Lean works well when it focuses on identifying and eliminating waste. Environmental improvement and energy reduction efforts that could distract Lean efforts from this prime focus may not get much traction. By contrast, this toolkit contains strategies and techniques that can enable Lean practitioners to easily identify energy wastes and improvement opportunities alongside the myriad other wastes and improvement opportunities uncovered by Lean. To accomplish this, the toolkit aims to answer the following questions:

What is the relationship between Lean and energy use?

Substantial energy savings typically ride the coattails of Lean. By eliminating manufacturing wastes, such as unnecessary processing and transportation, businesses also reduce the energy needed to power equipment, lighting, heating, and cooling. Chapter 1 describes benefits of combining Lean and energy improvement efforts. Chapter 2 explores the relationship between Lean and energy use, and provides background information on energy use and costs.

How does one know how much and where energy is used in a facility?

A key step in effective Lean and energy efforts is learning where to target energy-reduction activities. Chapter 3 discusses techniques for assessing energy use and identifying opportunities to save energy in the context of Lean. Methods include energy treasure hunts, value stream mapping, Six Sigma, and kaizen events.

How can one reduce energy use with Lean methods?

Chapter 4 examines specific opportunities for using Lean to reduce energy use, including Lean methods such as total productive maintenance, right-sized equipment, plant layout, standard work,

and visual controls. Chapter 5 discusses additional ideas for achieving process excellence with less energy use and environmental impacts.

CHAPTER 1
Introduction

Benefits of Coordinating Lean and Energy Management

Energy is a vital (and often costly) input to most production processes and value streams. By thinking explicitly about unnecessary energy use as another "deadly waste," Lean implementers can significantly reduce costs and enhance competitiveness, while also achieving environmental performance goals.

Benefits of Coordinating Lean & Energy Management (Box 1)

- ✓ Reduce operating and maintenance costs
- ✓ Reduce vulnerability to energy and fuel price increases
- ✓ Meet customer expectations
- ✓ Enhance productivity
- ✓ Improve safety
- ✓ Improve employee morale and commitment
- ✓ Improve environmental quality
- ✓ Reduce greenhouse gas emissions
- ✓ Remain below air permitting emission thresholds
- ✓ Increase overall profit

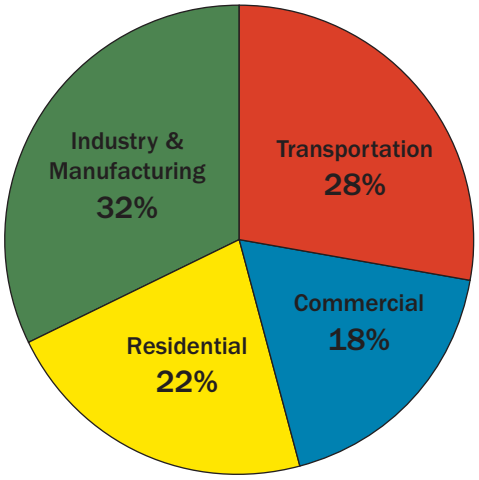
Many organizations can find it difficult to get senior managers to focus attention on energy use. Energy use is often viewed as a necessary support cost of doing business, and energy-efficiency efforts can sometimes have difficulty competing for organizational attention with other core operational needs. By linking energy management to Lean activities, energy-reduction efforts can be tied more directly to process improvement efforts that are regarded by senior managers as being vital to business success. In effect, energy improvements can ride the coattails of Lean activity while bringing significant benefits to the organization.

Cost Savings

Energy costs can have a significant impact on the financial performance of businesses. A September 2005 poll taken by the National Association of Manufacturers (NAM) revealed that 93 percent of directors from small and medium-sized manufacturing companies believe that higher energy prices are having a negative impact on their bottom line.[1]

Substantial opportunities exist to reduce energy waste in the industrial and manufacturing sectors. No segment of the U.S. economy has as much to gain from energy-use reduction as the manufacturing sector, as Figure 1 illustrates. Manufacturers are affected directly by the energy cost of making products (manufacturing), maintaining office operations (commercial), and receiving raw materials and delivering finished goods (transportation).

Share of Energy Consumed by Major Sectors of the U.S. Economy, 2005
(Figure 1)



Source: U.S. Energy Information Administration, Annual Energy Review 2005, Washington, DC, July 2006. www.eia.doe.gov.

Key Point

Energy use and cost information is, however, often decentralized and hidden from view in overhead or facilities accounts. Explicitly considering energy use in Lean implementation can reveal these hidden cost-reduction opportunities. And these opportunities have proven to be worth uncovering, as many companies have achieved significant cost savings as a result of energy reductions from Lean implementation. Reducing energy use and increasing energy efficiency is a proven strategy for cutting and controlling costs.

[1] National Association of Manufacturers (NAM), *Energy Efficiency, Water and Waste-Reduction Guidebook for Manufacturers: Proven Ways to Reduce Your Costs and Improve Operations.* www.nam.org/s_nam/bin.asp?CID=202138&DID=233434&DOC=FILE.PDF,(viewed September 2007), p. 5.

Lean and Energy Use Reduction:
Company Cost Savings Experience (Box 2)

- ✓ **Eastman Kodak Company** (New York) conducted energy kaizen events that significantly reduced energy use and resulted in overall savings of $15 million between 1999 and 2006.
- ✓ **General Electric** (Ohio) achieved cost savings of over $1 million at one facility due to fuel use reductions realized through Lean implementation.
- ✓ **Howard Plating** (Michigan) reduced energy use by 25 percent through a Lean implementation effort.
- ✓ **Lasco Bathware** (Washington) eliminated the need for a shrink-wrap oven when planning for a Lean event, reducing natural gas consumption by 12.6 million cubic feet and saving about $99,000.
- ✓ **Naugatuck Glass Company** (Connecticut) used Lean to cut product lead time and improve quality, while also reducing energy use by 19 percent.
- ✓ **Steelcase Inc.** (California) used Lean to improve operations, reducing fixed utility costs (including energy) by about 90 percent.

Climate Change and Environmental Risk Reduction

The environmental and climate impacts of energy use are rapidly becoming a major issue facing industry and society. Carbon dioxide (CO_2), a major greenhouse gas, is emitted to the atmosphere directly when fuels are combusted on-site and indirectly when electricity is consumed (particularly when fossil fuels are used to generate the electricity). Identifying and eliminating energy waste during Lean offers a smart, efficient way to reduce greenhouse gas emissions. As pressures increase for limits on greenhouse gases, documented early action by businesses can reduce business risk and contribute to reduction targets. In the meantime, publicly held businesses are finding that failure to proactively reduce climate risk can result in shareholder resolutions to force action.[2]

Energy use can have significant environmental impacts and risks in addition to climate change. On-site combustion of fuels in boilers, ovens, vehicles, and equipment can emit a variety of regulated pollutants, including carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxide (NO_x), particulate matter (PM), volatile organic compounds (VOCs), and a variety of air toxics. Combustion pollutant emissions can affect worker health, and trigger the need for costly permitting, monitoring, and emission controls. More broadly, reducing air emissions from combustion activities can help protect neighboring communities and public health. Storage and handling of fuels also pose a variety of worker health, safety, and environmental costs and risks, even in the absence of spills. Lean efforts can directly target and mitigate these impacts and risks.

[2] See the Investor Network on Climate Risk (www.incr.com) for current information on investor and shareholder initiatives related to climate change.

Competitive Advantage

Identifying and eliminating energy waste through Lean can improve a company's ability to compete in several ways. First, reducing the energy intensity of production activities and support processes directly lowers recurring operating costs with direct bottom line and competitiveness impacts. A recent study by the NAM and the Manufacturers Alliance (MAPI) found that U.S. companies have a 22 percent unit-cost disadvantage compared with overseas competitors in a number of process support cost areas, including energy.[3]

Second, eliminating energy waste and the associated environmental impacts through Lean can foster competitive advantage for some businesses. Customers and employees may view proactive environmental improvement efforts as an important attribute, affecting customer loyalty and the ability to attract and retain employees. Participation in climate partnership programs, such as EPA's Climate Leaders or local climate initiatives, can also provide businesses with public recognition for their energy use reduction achievements. For businesses that manufacture appliances, electronics, and other products that consume energy, Lean design methods can be used to lower the lifetime energy use of products.

It is not surprising that most of the major companies that have received awards from the EPA and Department of Energy's ENERGY STAR Program—companies such as 3M, Eastman Kodak, and Toyota—are also leaders in implementing Lean and Six Sigma. Energy waste is clearly on the radar of leading Lean companies. In addition, ENERGY STAR certification for energy-efficient products is an increasingly important factor in consumer-purchase decisions. For more information on ENERGY STAR, see www.energystar.gov.

Lean and Energy at Toyota (Box 3)

- ✓ Toyota, the model for "Lean" production systems at companies worldwide, is also a leader in energy and environmental performance.[4]
- ✓ Since 2000, Toyota Motor Manufacturing North America has reduced the average facility energy consumption per vehicle produced by 30 percent, resulting in a corresponding reduction in the CO_2 emissions of its facilities.
- ✓ In fiscal year 2006, Toyota's North American facilities reduced energy use per vehicle by 7 percent while increasing production by 4 percent.
- ✓ Toyota used methods such as energy treasure hunts and kaizen events to achieve these results (Chapter 3 has more information on these methods).

[3] National Association of Manufacturers (NAM), *Energy Efficiency, Water and Waste-Reduction Guidebook for Manufacturers: Proven Ways to Reduce Your Costs and Improve Operations.* www.nam.org/s_nam/bin.asp?CID=202138&DID=233434&DOC=FILE.PDF, (viewed September 2007), p. 5.

[4] Information in this box is from: Toyota North America, *2006 Environmental Report*, November 2006, p. 26, available at www.toyota.com/about/environment/news/enviroreport.html.

Lean and Energy: A Powerful Opportunity

This toolkit discusses how Lean can play a powerful role in reducing energy use and costs. In many cases, energy efficiency improvements ride the coattails of Lean. For example, right-sized equipment typically consumes less energy, and inventory reductions reduce demand for floor space that requires lighting, heating, ventilation, and air conditioning. By explicitly considering energy use in Lean efforts, organizations can often identify additional opportunities to save energy.

While the U.S. economy has made substantial improvements in energy efficiency in recent decades, there are significant opportunities for businesses to further improve energy efficiency. From 1975 to 2005, U.S. energy intensity (defined as the primary energy consumption per dollar of real gross domestic product, or GDP) dropped by 46 percent. Several recent studies, however, suggest that energy use could be reduced in the manufacturing and industrial sector by 75 percent at little cost using currently available technologies. Lean can help to identify and address these opportunities.

Strategic Lean and Energy Management

Creating a Roadmap for Lean and Energy Efforts

Key Term

For a variety of reasons, your facility may wish to pro-actively manage and reduce its energy use, while also achieving Lean goals such as improved quality, reduced waste, and increased customer responsiveness. *Energy management* is a systematic framework for understanding and identifying energy-related improvement opportunities. Energy management systems can be tailored to suit your facility's needs, business opportunities, market risks, and specific goals and targets. If you are interested in gaining outside assistance, the ENERGY STAR program is a resource for manufacturers interested in developing energy management programs.

An energy management framework can help you coordinate your company's energy reduction efforts with its Lean efforts. Strategically and systematically integrating energy and Lean improvement efforts will enhance their effectiveness and the value they bring to your company.

Why Be Strategic About Energy Management? (Box 4)

- ✓ Find new opportunities to reduce wastes, energy, and costs
- ✓ Reduce risks associated with an unreliable supply of energy, variable energy prices, and potential future climate change regulations
- ✓ Position your company to be a leader in energy and environmental performance
- ✓ Ensure that energy efficiency efforts support other organizational objectives and improvement processes, such as Lean and Six Sigma

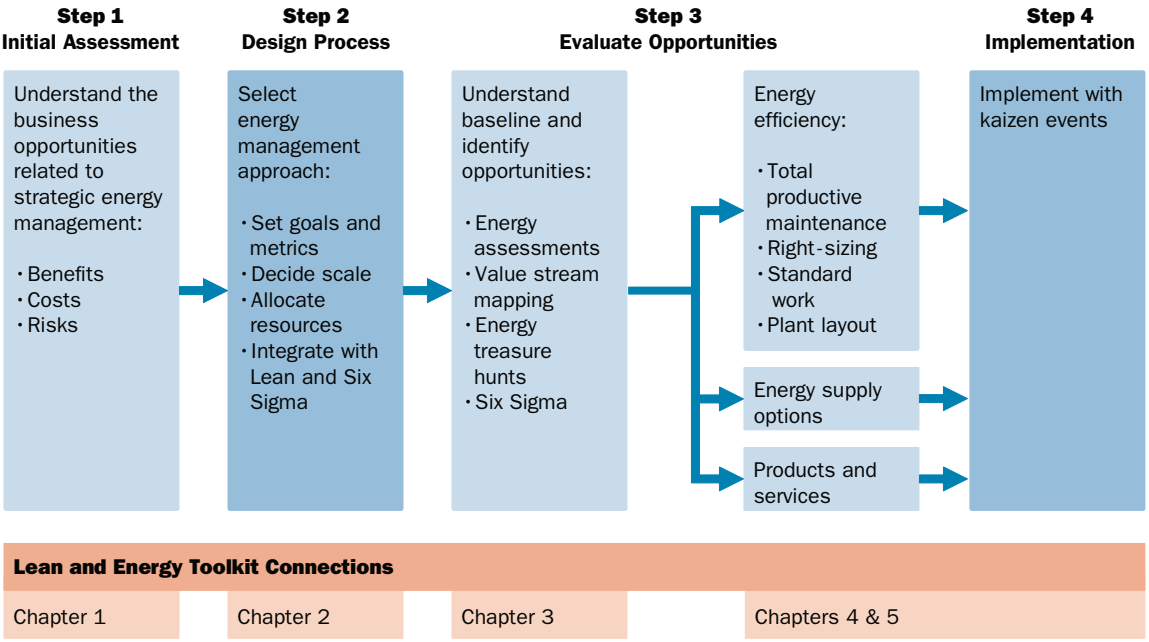
Even if your organization decides not to pursue a strategic approach to energy management, there are numerous practical ways to consider energy waste and improvement opportunities during Lean implementation. Chapters 3-5 of this toolkit contain many ideas for doing this.

There are four general steps involved in developing an energy planning and management roadmap appropriate to your organization, as follows.[5]

1. **Initial Assessment:** Consider the opportunities, risks, and costs associated with strategic energy management.
2. **Design Process:** Understand your company's energy needs and how to approach energy management at your company.
3. **Evaluate Opportunities:** Identify and prioritize energy-related improvement opportunities, such as energy-efficiency actions, energy-supply options, and energy-related products and services.
4. **Implementation:** Use a management system such as the ENERGY STAR *Guidelines for Energy Management* to implement energy opportunities.[6]

Each of these steps is important for developing and implementing a strategy for Lean and energy improvements at your organization. Figure 2 presents a roadmap for energy planning and management that identifies potential connections to Lean methods and improvement techniques outlined in this toolkit.

Lean and Energy Management Roadmap (Figure 2)



Source: Adapted from Bennett, Charles J. and Whiting, Meredith Armstrong. *Business & Energy in the 21st Century*, *Navigating Energy Management: A Roadmap for Business*, The Conference Board Executive Action Series, No. 160.

[5] Bennett, Charles J. and Whiting, Meredith Armstrong. "Business & Energy in the 21st Century, Navigating Energy Management: A Roadmap for Business." The Conference Board Executive Action Series. No. 160. September 2005.

[6] The ENERGY STAR *Guidelines for Energy Management* are available at: www.energystar.gov/index.cfm?c=guidelines.guidelines_index.

Chapters 1 and 2 of this toolkit support steps 1 and 2 of the roadmap, in that they can help your organization understand the relationship of Lean to energy use and the benefits of systematically reducing energy use through Lean. Chapters 3–5 of the toolkit describe how to identify and implement energy savings opportunities in the context of Lean, supporting steps 3 and 4 of the roadmap. These strategies leverage Lean methods such as value stream mapping, kaizen events, total productive maintenance, and standard work to improve energy and operational performance, while also incorporating energy assessment and reduction tools that can enhance Lean implementation.

Lean and energy management can work together to increase profit, enhance productivity, and decrease energy consumption through sustained and continual improvements. This toolkit is designed to help your facility achieve these goals.

To Consider

- How well coordinated are Lean activities and energy-efficiency efforts at your organization?
- Who makes decisions involving energy use at your facility or company?
- How are energy costs allocated at your company? Are costs billed to overhead accounts or are they assigned to individual departments or value streams?
- How could your company benefit from improved Lean and energy management?

CHAPTER 2

Overview of Energy Use and Lean

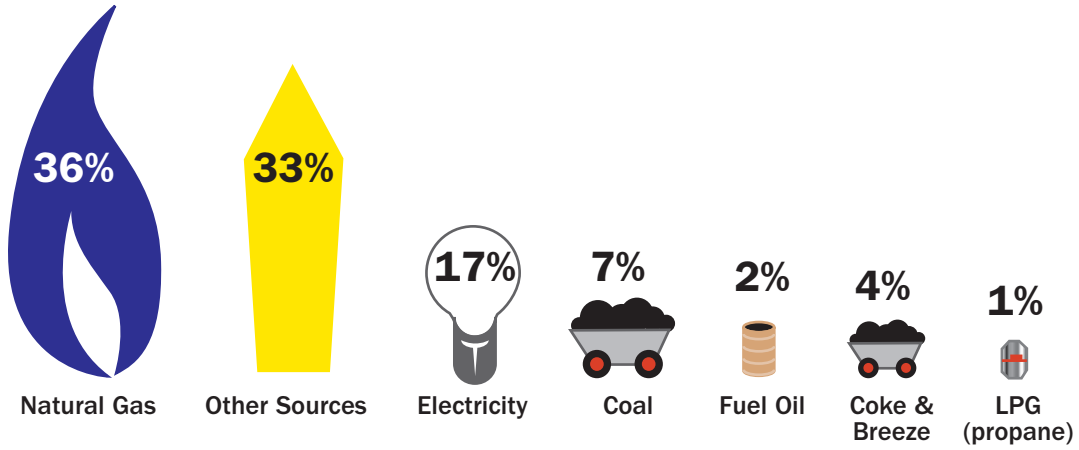
This chapter provides background information on energy use and describes how Lean implementation efforts can increase energy efficiency.

Energy Sources and End Uses

Key Term

In the manufacturing sector, the predominant *energy sources* are natural gas and electricity (a secondary source, typically generated off-site by a utility using one or more primary energy sources or fuels). Manufacturers also use other energy sources, such as fuel oil, for producing heat and power on-site. Some facilities have on-site co-generation, where they combust a fuel (e.g., natural gas or wood scraps) to produce heat and electricity. Figure 3 lists major energy sources used by the industry and manufacturing sectors in the U.S. economy

Sources of Energy Used for U.S. Industry and Manufacturing, 2005 (Figure 3)



Source: U.S. Energy Information Administration, *Annual Energy Review* 2005, Washington, DC, July 2006. www.eia.doe.gov.

Key Term

Aggregate, facility-level information on energy use (typically derived from monthly utility bills) only tells part of the story. Understanding the *energy end uses*—what work we use the energy to do—reveals more useful information to identify opportunities for improving efficiency and reducing costs. Box 5 lists several of the common end uses for energy in manufacturing. In an office setting, end-uses primarily include heating, ventilating, and air conditioning (HVAC), lighting, and operation of appliances and computers.

Energy End Uses: What Do We Use Energy to Do? (Box 5)

- ✓ Heating, ventilating, and air conditioning (HVAC)
- ✓ Lighting
- ✓ Process equipment operation
- ✓ Process heating and cooling
- ✓ Transportation

Key Point

While identifying energy end uses is often straightforward, determining the amount of energy used by each end use can be challenging—but *end use information is essential to targeting waste and improvement opportunities.* In the context of Lean, it may even be useful to understand energy end use information at the process and equipment levels. Chapter 3 discusses some strategies and techniques for better understanding energy uses and costs at your facility.

Looking at energy end uses across the manufacturing sector in the U.S. economy provides an indication of where efficiency improvement opportunities may exist. Tapping into sector-specific resources can help companies identify additional areas of efficiency opportunity within their sector (see Appendix B for information on sector-focused energy reduction resources).

Process heating accounts for 53 percent of direct energy end use at manufacturing facilities, while machine drives and motors account for another 22.1 percent, according to a recent study by NAM (see Table 1). Chapter 4 describes specific strategies for reducing the energy used by these and other types of processes.

Key Point

Consider targeting your facility's energy efficiency efforts on two key end uses that are likely to account for a significant portion of your facility's energy use. As shown in Table 1, the following end uses typically have energy savings opportunities:

1. *Process heat*
2. *Machine drives and motors*

For facilities without these types of energy end uses, HVAC systems and lighting may be good end uses to target.

Table 1: Manufacturing Sector Inputs for Heat, Power, and Electricity Generation by End Use		
Industrial Sector End Use Category	**Trillion British thermal unit (Btu)**	**Percentage of Total Direct End Use**
Indirect End Use (Boiler Fuel)	**3,635**	
Direct End Use	**7,655**	100%
All Process Uses	**6,323**	82.6%
Process Heating	4,055	53.0%
Machine Drive	1,691	22.1%
Electrochemical Process	298	3.9%
Process Cooling and Refrigeration	210	2.7%
Other Process Uses	69	0.9%
All Non-Process Uses	**1,314**	**17.2%**
Facility Heating, Ventilation and Air Conditioning	692	9.0%
Facility Lighting	211	2.8%
Conventional Electricity Generation	243	3.2%
Other Facility Support	96	1.3%
Onsite Transportation	69	0.9%
Other Non-Process Uses	3	0.0%
End Use Not Reported	**157**	
Total	**11,447**	

Source: Prepared by the Leonardo Academy from U.S. Department of Energy data, 1998 Data from *Annual Energy View 2003*, published September 2004.

Understand the Costs of Energy Use

Key Point

Understanding the costs of energy use can raise awareness of the potential value of identifying and eliminating energy waste during a Lean event. *The costs of energy use are not always "visible" to production managers because they are rolled up into facility overhead costs, rather than assigned to production areas.* Explicitly tracking costs associated with individual processes or equipment can encourage energy conservation. If, however, cost savings from energy efficiency improvements revert to overhead, or result in lower future budgets, production managers may not have an incentive to reduce energy use. It may therefore be necessary to create incentives for reducing energy use by sharing energy savings.

One of the primary data sources for energy cost data is your facility's utility bill. Utility bills often include the following types of data:

- **Consumption Charges:** Electricity is charged based, in part, on the amount of electricity used (in kilowatt-hours, kWh) in a billing period. The per kilowatt-hour rate for electricity may vary based on the time of year (e.g., winter or summer season) and/or the time of day (peak or off-peak hours).
- **Demand Charges:** For many electricity customers (all but small accounts), there will be a demand charge (per kilowatt) in the bill that is based on the peak electricity use each month averaged over a short time period (e.g., 15 minutes). Your facility may pay more for demand costs than consumption costs, although the two costs may be a single line item in the utility bill.
- **Fuel Costs:** For natural gas and other fuels, you may be charged for the amount of fuel you receive (for natural gas this is based on a per therm price) and a delivery charge for the transportation and delivery of the fuel. Fuel charges may vary seasonally and based on the amount consumed.

New Tool

Because of variation in energy use and costs, it can be helpful to use spreadsheets or other systems to monitor your facility's energy performance and costs over time. An example *Electrical Power Bill Analysis Worksheet* is below. Similar worksheets may be used to track monthly costs for natural gas and other fuels.

Table 2: Electrical Power Bill Analysis Worksheet					
Date	**Consumption**	**Consumption Cost**	**Peak Demand**	**Demand Cost**	**Total Cost**
(months)	**(kwh)**	**($)**	**(kW)**	**($)**	**($)**
Jan	198,800	$12,975	948	$8,759	21,734
Feb	331,200	$20,374	912	$8,427	28,801
Mar	245,000	$13,951	710	$6,560	20,511
Apr	305,600	$18,902	948	$8,759	27,661
May	368,000	$22,621	1,222	$11,290	33,911
Jun	318,400	$19,651	888	$8,205	27,856
Jul	289,200	$18,855	890	$8,223	27,078
Aug	335,600	$21,720	964	$8,907	30,627
Sep	367,600	$23,638	952	$8,796	32,434
Oct	387,200	$25,384	1,144	$10,570	35,954
Nov	350,000	$22,583	824	$7,613	30,196
Dec	374,400	$24,701	1,105	$10,210	34,911
Totals	**3,871,000**	**$245,355**	**11,507**	**$106,319**	**351,674**

Source: Muller, Michael R. Dr. *Self-Assessment Workbook for Small Manufacturers Version 2.0*, http://iac.rutgers.edu/database/technicaldocs/IAC_Manuals/selfassessment.pdf, October 2003.

Energy Efficiency Benefits of Lean Implementation

Key Point

Significant energy savings typically ride the coattails of Lean activities—even without explicit consideration of energy use. These coattails can be understood by thinking about energy in the context of Lean's deadly wastes.

Energy Use Reductions on the Coattails of Lean

The focus of Lean is on identifying and eliminating non-value added activity, or waste, from processes. Lean typically targets seven so-called "deadly wastes":

1. Overproduction
2. Inventory
3. Transportation
4. Motion
5. Defects
6. Over processing
7. Waiting

Key Point

Environmental and energy wastes are not explicitly included in the seven deadly wastes of the Toyota Production System. This does not mean that the wastes are unrelated to the environment, however. In fact, your company may have already seen large energy use reductions from implementing Lean, because energy and environmental wastes are embedded in, or related to, the seven deadly wastes. Table 3 lists energy impacts associated with wastes targeted by Lean methods.

Table 3: Energy Use Hidden in Lean Wastes

Waste Type	Energy Use
Overproduction	• More energy consumed in operating equipment to make unnecessary products
Inventory	• More energy used to heat, cool, and light inventory storage and warehousing space
Transportation and Motion	• More energy used for transport • More space required for work in process (WIP) movement, increasing lighting, heating, and cooling demand and energy consumption
Defects	• Energy consumed in making defective products • More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Overprocessing	• 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

Key Point

Despite these relationships between Lean deadly wastes and energy use, Lean efforts often overlook opportunities to save energy. *Your company can enhance its Lean performance by ensuring that energy-efficiency opportunities are explicitly identified during Lean activities.*

To Consider

- What energy sources does your facility use?
- What are the energy end uses at your facility?
- How much money does your facility spend on energy use each month?
- What energy improvements has your facility realized from Lean efforts?
- What areas of your facility might be good targets for future energy-efficiency improvement efforts?

CHAPTER 3

Energy Assessment Strategies

This chapter describes strategies and techniques for understanding how energy is used at your facility and identifying opportunities to reduce energy use and costs. This chapter discusses the following strategies:

A. Walk Through Processes to Observe Energy Use

B. Energy Audits and Measuring Energy Use

C. Examine Energy Use with Value Stream Mapping

D. Use Six Sigma to Find and Eliminate Energy Waste and Variation

E. Eliminate Energy Wastes in Kaizen Events

A. Walk Through Processes to Observe Energy Use

New Tool

Walking through and observing processes as they actually run at a facility can be a simple, but effective way to identify waste and find improvement opportunities. During the walk through, look for signs of unnecessary or inefficient energy use. Ask questions, such as the *Questions for Understanding Energy Use* below (Box 6), to learn more about potential opportunities to reduce energy use.

Questions for Understanding Energy Use (Box 6)

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?

Questions for Understanding Energy Use (Continued)

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?

New Tool

Walk throughs are a key step in value stream mapping and other Lean activities. Companies such as Toyota and GE frequently conduct "Energy Treasure Hunts" to find energy savings (see Box 7). An *Energy Treasure Hunt* is a three-day plant assessment event in which a cross-functional team of employees identifies opportunities to reduce unnecessary energy use. Project teams then implement the ideas that are likely to yield the greatest benefits through kaizen events.

Energy Treasure Hunts at General Electric (Box 7)

With mentoring assistance from Toyota, General Electric (GE) launched an integrated Lean and energy initiative that has identified upwards of $100 million in energy savings through energy treasure hunts. GE's corporate commitment to energy use and greenhouse gas reductions has helped drive this effort. From 2005 to 2007, GE:

✓ Conducted over 200 energy treasure hunts at GE facilities worldwide, and trained over 2,500 employees on how to conduct treasure hunts

✓ Used energy treasure hunts to identify 5,000 related kaizen projects, most of which are funded and in various stages of implementation

✓ Reduced greenhouse gas emissions by 250,000 metric tons and realized $70 million in energy cost savings from implemented projects

Source: General Electric, Ecomagination / Energy Treasure Hunt Team, 2007.

B. Energy Audits and Measuring Energy Use

While a walk through is an excellent way to identify and fix energy wastes that are readily apparent, you may be leaving energy savings on the table unless you examine energy use more closely. Two strategies for learning more include:

1. Conduct an energy audit to understand how energy is used—and possibly wasted—across your facility.

2. Measure the energy use of individual production and support processes.

1. Energy Audits

Key Term

An *energy audit*, sometimes referred to as an energy assessment, is a study of the energy end uses and performance of a facility. Energy audits can range in complexity and level of detail, from a simple audit involving a facility walk through and review of utility bills, to a comprehensive analysis of historical energy use and energy-efficiency investment options. Energy audits allow managers to compare a plant's energy use to industry benchmarks and identify specific energy savings opportunities.

In many locations, local utilities or non-profit manufacturing assistance organizations provide energy audit services for free or at reduced cost. There also are free tools available to help companies conduct energy audits. Appendix A describes service providers, resources, and tools for energy assessments.

Energy Savings From "Lean and Clean" Assessments (Box 8)

- ✓ The **Green Suppliers Network**, a partnership between EPA and the National Institute of Standards and Technology Manufacturing Extension Partnership, conducts "Lean and Clean" assessments for small and medium-sized companies.
- ✓ As of 2007, 49 assessments have identified energy savings of 247,165 million Btu and over 72 million kWh.
- ✓ These assessments also identified about $7.5 million per year in environmental savings and about $19.1 million per year in Lean savings.
- ✓ See www.greensuppliers.gov for more information.

2. Measuring Energy Use of Individual Processes

Key Point

You may not really know which process or process step uses the most energy—and therefore where the greatest energy savings might be—until you actually measure the energy use. During the analysis of the "current state" of a value stream or an individual process, collect data on how much energy each operation uses. Typical energy metrics include:

- Kilowatt-hours (for electricity)
- Therms (for natural gas)
- British thermal units (Btu)
- Energy intensity (energy use per production unit)
- Energy costs (dollar amount spent on energy)

Common Energy Units (Box 9)

Energy Units	Energy Equivalent
1 kilowatt-hour	3,412 Btu
1 Therm	100,000 Btu
1 cubic foot natural gas	1,000 Btu
1 horsepower	746 Watts

There are several techniques for measuring or estimating the energy used by production processes.

- **Metering:** One technique is to install meters to track the energy use of a process. For example, flow meters can be installed to track natural gas inputs to ovens used to provide process heat and electric meters can be used to monitor electricity use in a particular process area. Metering enables a facility to track energy use over short and longer time periods.
- **Estimating:** Another technique is to estimate energy use based on information provided by equipment manufacturers. Calculate energy use for specific equipment or process activities using equipment energy specifications (often obtained from equipment manuals or vendors) coupled with equipment operation data (e.g., number of hours the equipment is in different modes of operation). While such calculations are often not precise, they can indicate the order of magnitude of energy use.
- **Energy Studies:** Energy specialists can also help conduct detailed analyses of energy use and costs at both the facility level and the process level. This type of analysis can look not only at where and how much energy is used, but also opportunities to reduce energy costs through load shifting (shifting electricity use to off-peak times), changing the mix of energy sources, and other strategies.

To Consider

- How much energy does your facility use?
- Which value streams and production processes contribute the most to your facility's total energy use?
- What are the costs associated with this energy use?
- Where are the best places to look for energy savings?

C. Examine Energy Use with Value Stream Mapping

Key Term

One effective way to understand energy use at your facility is to integrate energy analysis into the Lean value stream mapping process. *Value stream mapping* is a method of creating a visual representation of the information and material flows involved in creating a product or delivering a service to a customer. Lean practitioners use value stream maps to understand where the largest sources of waste are in the value stream and to prioritize future process-improvement efforts.

Adding Energy Analysis to Value Stream Mapping

Your value stream mapping team can examine the energy use of processes in a value stream at the same time your team examines other data about the "current state," including Lean metrics such as cycle time (C/T), changeover time (C/O), and uptime. Use the techniques described above for observing and measuring energy use to collect energy data for processes in the value stream, or con-

sider asking internal or outside experts to assist with the energy analysis. This may involve collecting baseline data in advance of a value stream mapping event.

The key is to have both Lean and energy use data available when your value stream mapping team brainstorms and prioritizes improvement ideas for the "future state" of the value stream. This will leverage the whole systems thinking of Lean to maximize operational gains and energy savings. Figure 4 shows a value stream map from a value and energy stream mapping project.

Example Results From Value and Energy Stream Mapping Projects (Box 10)

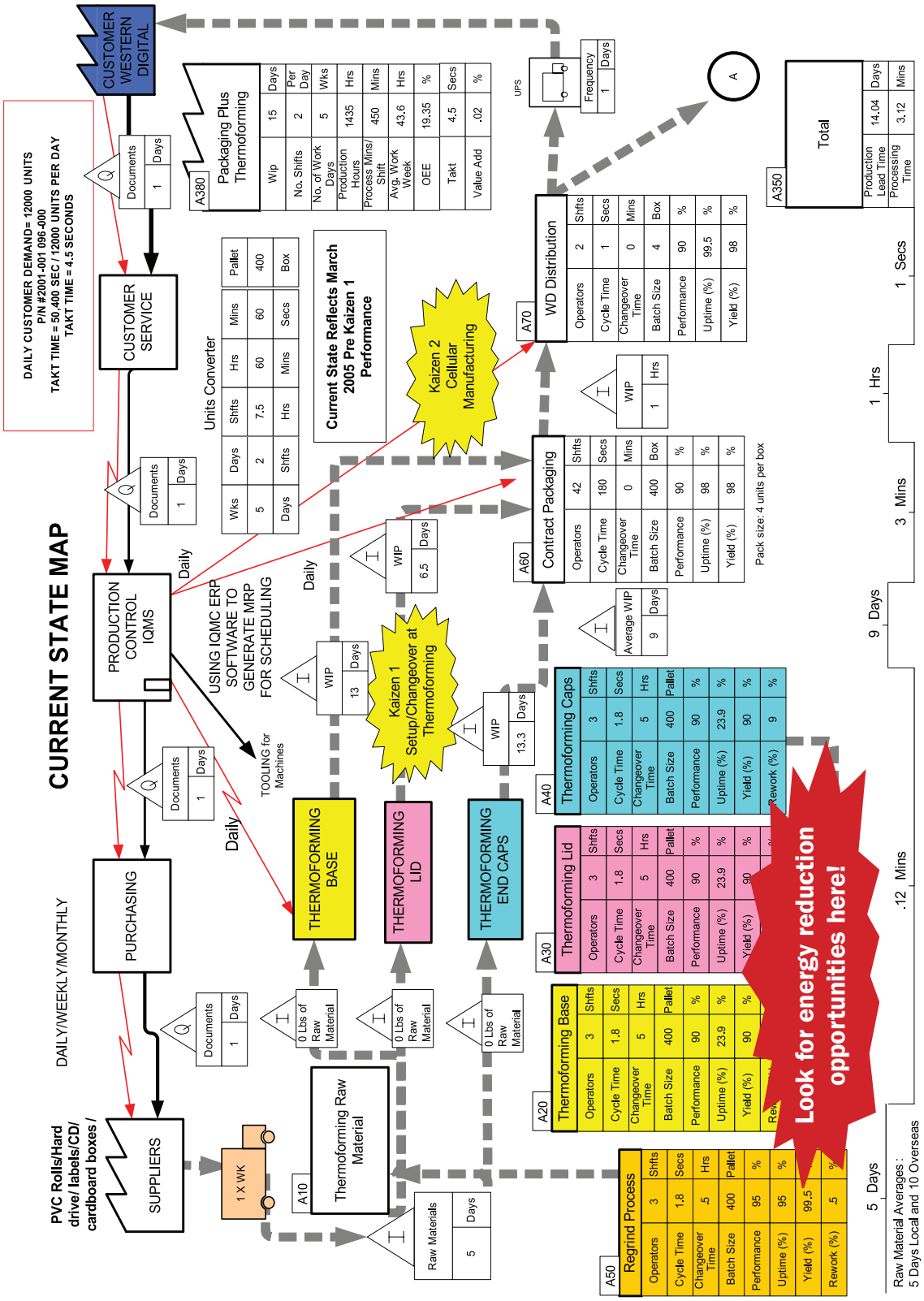
- ✓ **Mission Rubber,** a manufacturer of rubber couplings for the construction industry, conducted a five-day value stream mapping event and two kaizen events to shorten lead times and reduce energy use. The company saved an estimated 473,076 kWh and $40,000 in energy costs per year while increasing productivity and sales.[7]
- ✓ **Packaging Plus LLC,** a packaging provider located in La Mirada, California, saved $558,000 per year in labor, improved productivity 41 percent, and reduced annual energy use by 613,629 kWh, for a savings of $61,000 per year, by conducting a value and energy stream mapping workshop and two kaizen events.[8]
- ✓ **Trojan Battery Company,** a manufacturer of deep cycle batteries located in Santa Fe Spring, California, used value and energy stream mapping with kaizen events to decrease energy intensity by 33 percent in four months, saving 1,283,639 kWh and $100,000 per year in energy costs.[9]

[7] California Manufacturing Technology Consulting (CMTC). "Automotive Case Study: Mission Rubber." www.cmtc.com/success_stories/mission_rubber_Auto.html, accessed 23 Aug. 2007.

[8] CMTC. "Industrial Case Study: Packaging Plus LLC." www.cmtc.com/success_stories/ind_ppllc.html, accessed 13 Nov. 2006.

[9] CMTC. "Trojan Battery Company Case Study." Case Study No. 05-80760.

Example Value Stream Map (Figure 4)



Source: Packaging Plus LLC and California Manufacturing Technology Consulting

Another opportunity is to incorporate energy use data directly into current and future state value stream maps. Consider adding data on the average energy use or energy intensity of each process to the process data boxes in value stream maps, along with other regularly collected metrics. This will make it easier to spot key energy savings opportunities in the context of other improvement opportunities. Figure 5 shows an example *process data box with energy use data* (in kilowatt-hours per pound of output).

New Tool

Combining energy use analysis and value stream mapping is a proven technique for cutting energy costs and improving productivity. For example, the California Manufacturing Technology Consulting, a Manufacturing Extension Partnership center in California, has partnered with a local utility and an energy efficiency firm, Alternative Energy Systems Consulting, Inc., to conduct "Value and Energy Stream Mapping" projects with facilities (see Box 10 for examples).

Key Point

Example Process Data Box with Energy Use Data (Figure 5)

Milling
2 people
C/T = 2 min C/O = 2 hr Uptime = 74% **Energy/pound output = 1kWh**

Identifying Opportunities

Incorporating energy analysis into value stream mapping allows your team to consider energy reduction opportunities alongside other process improvement opportunities. You may find ways to reduce energy use that will also provide other production benefits, such as fewer defects from more reliable equipment. Here are a few things to consider:

- **Key Questions:** When you look at energy uses in the context of the entire value stream, ask two fundamental questions:
  - Is this energy end use needed?
  - Is there a way to deliver this end use more efficiently?
- **Eliminating Energy End Uses:** Eliminating entire energy end uses can result in substantial cost savings, improve production flow, and simplify processes. For example, when planning for a Lean and environment kaizen event, a Lasco Bathware manufacturing plant found it could eliminate a shrink-wrap heating oven. This resulted in an annual savings of $99,290 and 12.6 million cubic feet of natural gas.[10]
- **Support Processes:** Support processes may consume significant amounts of energy. *Even brief consideration of support processes in value stream mapping enables a Lean team to think more broadly when identifying wastes and improvement opportunities.*

Key Point

[10] Washington State Department of Ecology. "Lean & Environment Case Study: Lasco Bathware." Prepared by Pollution Prevention Resource Center and Ross & Associates Environmental Consulting, Ltd. Publication No. 07-04-009. April 2007. (www.ecy.wa.gov/pubs/0704009.pdf).

For example, particular processes may produce air emissions that go to a pollution control device (e.g., a natural gas-fired thermal oxidizer) or effluent that is sent to a wastewater treatment plant. Other support processes include lighting, heating, and cooling.

D. Use Six Sigma to Find and Eliminate Energy Waste and Variation

Key Term

Six Sigma refers to a collection of statistical analysis and process improvement tools designed to identify and eliminate variation (or defects) in a process. Although specific training is needed before using Six Sigma, many companies have added these methods to their continuous improvement toolbox, developing an improvement approach often known as Lean Six Sigma. Six Sigma analytical tools can be particularly useful for identifying energy waste in situations where there is a lot of energy use and when process-level data are available. Statistical analysis and process control methods can help isolate the root causes of energy use fluctuations and identify factors that result in energy waste.

Lean Six Sigma helped the 3M Company reduce energy use by 27 percent (when indexed to net sales) from 2000 to 2005. 3M has set a corporate goal for further energy use reductions of 20 percent for the period from 2005 to 2010, and the company views Lean Six Sigma as critical to realizing this performance goal.[11]

Six Sigma and Energy Savings at Baxter International (Box 11)

In a compelling example of Six Sigma and energy-efficiency integration, a Baxter International facility in Spain saved €220,000 (approximately $300,000) in one year by installing energy meters, tracking daily energy use, and using kaizen events to reduce energy use. The facility recorded daily energy use for one year and used statistical process control (SPC) analyses to set a standard range of deviation. Each time energy use exceeded average use by 15 percent, the facility held a kaizen event to address the root causes of the peak. In addition to cutting energy costs, this initiative lessened the facility's overall energy use and variability.

Source: Interview with Jenni Cawein, Manager, Corporate Environment, Health, and Safety Engineering, Baxter International, 30 May 2007.

E. Conduct Energy Kaizen Events

Key Term

After identifying the production areas that consume large amounts of energy, your facility can further analyze and eliminate wasteful energy practices through *kaizen events*, or rapid process improvement events. In kaizen events, which typically last 3-5 days, a cross-functional team of employees identifies and implements process changes to reduce wastes such as idle time, inventory, and defects. Kaizen events create important windows of opportunity to consider ways to eliminate

[11] See U.S. EPA, "3M: Lean Six Sigma and Sustainability" case study, www.epa.gov/lean/studies/3m.htm.

energy waste. Revisit the results of energy audits or assessments to familiarize your Lean team with information that can be used to identify energy wastes during a kaizen event. Asking key questions during a kaizen event, such as those in Box 6, can also help to ensure that energy-reduction opportunities are identified as part of Lean implementation.

Consider conducting energy-focused kaizen events at your facility to:

- Understand how energy is used in a particular process
- Brainstorm opportunities to reduce energy use in that process
- Implement those ideas in a short time frame

What is an Energy Kaizen Event? (Box 12)

✓ Relies on a short burst of intense activity (3-5 days)
✓ Focuses on eliminating energy waste
✓ Involves multi-functional teams (e.g., utilities specialists, process specialists, product specialists, quality facilitator, and/or others)
✓ Makes changes during the event
✓ Stresses non-capital improvements

Key Point

Energy kaizen events combine a detailed energy-use assessment with immediate implementation of energy-reduction opportunities. From 1999 to 2005, Eastman Kodak used energy kaizen events to generate a total of $14 million in annual energy savings. Since then, energy kaizen events, along with other improvement efforts, have enabled Eastman Kodak to shut down one of the company's two powerhouses in Rochester, New York. This resulted in over $20 million in additional annual savings.[12] Table 4 shows examples of energy savings opportunities identified during a kaizen event.

[12] Discussion with James Breeze, Energy Engineer/Project Leader, Worldwide Energy Office, Eastman Kodak Company, September 2007.

Table 4: Example Actions Identified at a Kaizen Event[13]

Energy Waste Identified	Counter Measure	Savings Opportunity
Main supply fans (air conditioners) run 24 hours/day	Change non-critical systems run time schedule	$47,000
Fan motors are over-sized	Lower horsepower on motors	$27,000
Some exhaust fans run 24 hours/day	Change exhaust fans to 2 speed and run at slow speed during off hours	$18,000
Heat recovery unit from exhaust fans run faster than needed	Bypass tilt coils and slow down fans	$24,000
Room lights are always on and emit more light than needed	Install motion sensors to control lights and reduce number of lamps	$25,000
Water recirculation pumps are running but are not required	Shut down and remove	$20,000
Total Opportunity		**$161,000**

The next chapter outlines practical strategies for reducing energy use through Lean events as well as day-to-day maintenance and operations activities.

To Consider

- Has your facility conducted an energy assessment (such as an energy treasure hunt, a facility walk through to identify energy wastes, or a formal energy audit and utility bill analysis) recently?
- Has your facility used value stream mapping, kaizen events, and/or Six Sigma to identify energy wastes and reduce energy use?
- Are there any energy-intensive processes that could be targeted in your organization using Lean Six Sigma methods?
- What practical steps will you take to identify and address energy waste during upcoming Lean events at your facility?

[13] Adapted from a presentation by Eastman Kodak Company to the Business Roundtable Climate Resolve Teleconference, April 2004.

CHAPTER 4
Energy Reduction Tools and Strategies

This chapter describes best practices for reducing energy use with Lean methods, focusing on process-level opportunities. It includes the following strategies:

A. Use Total Productive Maintenance to Reduce Equipment Energy Waste

B. Replace Over-Sized and Inefficient Equipment with Right-Sized Equipment

C. Design Plant Layout to Improve Flow and Reduce Energy Use

D. Encourage Energy Efficiency with Standard Work, Visual Controls, and Mistake-Proofing

A. Use Total Productive Maintenance to Reduce Equipment Energy Waste

Key Term

Total productive maintenance (TPM) is a Lean method that focuses on optimizing the effectiveness of manufacturing equipment. TPM builds upon established equipment-management approaches and focuses on team-based maintenance that involves employees at every level and function.

What is TPM? (Box 13)

- ✓ The goal of TPM is to build a robust enterprise by maximizing production system efficiency (overall effectiveness).
- ✓ TPM addresses the entire production system lifecycle and builds a concrete, shopfloor-based system to prevent all losses. It aims to eliminate all accidents, defects, and breakdowns.
- ✓ TPM involves all departments, from production to development, sales, and administration.
- ✓ Everyone participates in TPM, from the top executive to shopfloor employees.
- ✓ TPM achieves zero losses through overlapping team activities.

Source: The Japan Institute of Plant Maintenance, eds., *TPM For Every Operator*, (Portland, OR: Productivity Press, 1996), p 11.

Six Big Losses That Lower Equipment Efficiency

Key Point

Increased equipment operating efficiency reduces energy waste. When machines are optimally tuned to accomplish the desired work, energy inputs are most efficient. TPM's emphasis on equipment efficiency can lead to reduced costs, increased productivity, and fewer defects. TPM focuses on

the six big losses that lead to equipment inefficiency:

1. Breakdowns
2. Setup and adjustment loss
3. Idling and minor stoppages
4. Reduced speed
5. Defects and rework
6. Start and yield loss

Eradicating the six big losses maximizes the productivity of equipment throughout its lifetime. With proper equipment and systems maintenance, facilities can reduce manufacturing process defects and save an estimated 25 percent in energy costs.[14]

Consider using one or more of the *Four Strategies for Integrating Energy-Reduction Efforts into TPM* (Box 14) to improve energy and equipment efficiency at your facility. This chapter focuses on describing energy savings opportunities associated with autonomous maintenance (strategy #1); other parts of this toolkit provide guidance on identifying energy wastes, conducting energy kaizen events, and developing energy management systems (strategies #2-4).

Four Strategies for Integrating Energy-Reduction Efforts Into TPM
(Box 14)

- ✓ Integrate energy-reduction opportunities into autonomous maintenance activities
- ✓ Train employees on how to identify energy wastes and how to increase equipment efficiency through maintenance and operations
- ✓ Conduct energy kaizen events to make equipment more efficient
- ✓ Build energy-efficiency best practices into systems for management of safety, health, and environmental issues

Autonomous Maintenance Improves Energy Efficiency

Key Term

One distinctive aspect of TPM is autonomous maintenance. *Autonomous maintenance* refers to ongoing maintenance activities operators undertake on their own equipment. Typical activities include: (1) daily inspections, (2) lubrication, (3) parts replacement, (4) simple repairs, (5) abnormality detection, and (6) precision checks. Autonomous maintenance provides an opportunity to integrate process-level energy-reduction strategies into ongoing equipment maintenance.

Key Point

Many simple energy efficiency best practices can be implemented without extensive analysis or effort. Autonomous maintenance already captures a number of best practices, such as cleaning, proper lubrication, and standardized maintenance practices. Your facility can enhance TPM effectiveness by integrating energy-reduction best practices for specific types of processes into ongoing autonomous maintenance activities.

[14] Manufacturing Extension Partnership of Louisiana, "Energy Management." mepol.org/site.php?pageID=180, accessed 13 June 2007.

New Tool

Use checklists such as the *Energy-Reduction Checklists for Combustion, Steam Generation, and Process Heating Systems* (Box 15) to identify opportunities to decrease energy consumption while also increasing equipment efficiency. These checklists are based on best practices compiled by the U.S. DOE's Energy Efficiency and Renewable Energy Department.

Energy-Reduction Checklists for Combustion, Steam Generation, and Process Heating Systems (Box 15)

Combustion Systems

- ✓ Operate furnaces and boilers at or close to design capacity
- ✓ Reduce excess air used for combustion
- ✓ Clean heat transfer surfaces
- ✓ Reduce radiation losses from openings
- ✓ Use proper furnace or boiler insulation to reduce wall heat losses
- ✓ Adequately insulate air or water-cooled surfaces exposed to the furnace environment and steam lines leaving the boiler
- ✓ Install air preheat or other heat recovery equipment

Steam Generation Systems

- ✓ Improve water treatment to minimize boiler blowdown
- ✓ Optimize deaerator vent rate
- ✓ Repair steam leaks
- ✓ Minimize vented steam
- ✓ Implement effective steam trap maintenance program

Process Heating Systems

- ✓ Minimize air leakage into the furnace by sealing openings
- ✓ Maintain proper, slightly positive furnace pressure
- ✓ Reduce weight of or eliminate material handling fixtures
- ✓ Modify the furnace system or use a separate heating system to recover furnace exhaust gas heat
- ✓ Recover part of the furnace exhaust heat for use in lower-temperature processes

Source: U.S. DOE, Energy Efficiency and Renewable Energy Website, "20 Ways to Save Energy Now." www.eere.energy.gov/consumer/industry/20ways.html, accessed 13 June 2007.

By training operators on energy-reduction best practices and checklists applicable to manufacturing processes and equipment at your facility, operators will be better able to save energy in their day-to-day operations and maintenance activities.

B. Replace Over-Sized and Inefficient Equipment with Right-Sized Equipment

Key Term

Lean thinking often results in the use of right-sized equipment to meet production needs. *Right-sized equipment* is designed to meet the specific needs of a manufacturing cell or an individual process step, rather than the processing needs for an entire facility. For example, rather than relying on one large paint booth or parts cleaning tank station to service all painting and degreasing needs for a facility, Lean principles typically lead organizations to shift to right-sized paint and degreasing stations that are embedded in manufacturing cells.

In conventional manufacturing, equipment often is over-sized to accommodate the maximum anticipated demand. Since purchasing a new large piece of equipment is often costly and time-consuming, engineers often design in additional "buffer capacity" to be sure that the equipment does not bottleneck production. Box 16 shows results from recent studies documenting equipment over-sizing.

Over-Sized Equipment (Box 16)

- ✓ Over-sizing building fan systems, on average, occurs by 60 percent
- ✓ Most chillers are oversized by 50–200 percent
- ✓ Potential energy savings from rightsizing, energy-efficient motors, and variable speed drives is 50–85 percent

Source: U.S. EPA and DOE, ENERGY STAR Program, "Partner Resources for HVAC contractors." www.energystar.gov/index.cfm?c=contractors.cont_prod_installcheck, accessed 13 June 2007.

Key Point

Since right-sized equipment is geared toward a specific end use and production capacity, it often is much more energy efficient than conventional, large equipment. Large, "monument" equipment often runs well below capacity, significantly reducing energy efficiency per unit of production. For example, the natural gas or electricity needed to fire a large dryer oven is typically the same whether the line is being run at capacity or if only a few parts are being processed.

Three Ways to Right Size Your Fan System (Box 17)

- ✓ **Use smaller, energy-efficient motors.** Rightsizing a 75-horsepower (hp) standard efficiency motor to a 50-hp energy-efficient motor will reduce your motor energy consumption by about 33 percent
- ✓ **Use larger pulleys.** Replacing an existing belt-driven pulley with a larger one will reduce its speed, saving energy costs. Reducing a fan's speed by 20 percent reduces its energy consumption by 50 percent
- ✓ **Use static pressure adjustment variable air volume (VAV) systems only.** Reducing static pressure in your VAV system reduces the fan horsepower consumption. By gradually reducing the static pressure setpoint to a level low enough to keep occupants comfortable, you will reduce energy consumption

Source: U.S. EPA and U.S. DOE ENERGY STAR Program, Building Upgrade Manual, December 14, 2004. www.energystar.gov/ia/business/BUM.pdf, accessed 13 June 2007.

C. Design Plant Layout to Improve Flow and Reduce Energy Use

Lean thinking focuses on improving the flow of product through the production process. Facilities arrange equipment and workstations in a sequence that supports a smooth flow of materials and components through the process, with minimal transport or delay. The desired outcome is to have the product move through production in the smallest, quickest possible increment (one piece). *Improving the flow of product and process inputs can significantly reduce the amount of energy required to support a production process.* Box 18 provides an example of the significance of plant layout and flow in reducing energy use.

Key Point

Flow and Energy Use (Box 18)

- ✓ Dutch engineer Jan Schilham (Interface Nederland) redesigned a heat transfer pumping loop originally designed to use 70.8 kW of pumping power to use 5.3 kW—92 percent less—with lower capital cost and better performance. The new design cut the measured pumping power 12 times and only took a change in design mentality. Lessons learned include:
- ✓ **Use big pipes and small pumps rather than small pipes and big pumps.** Optimizing the whole system together will yield fat pipes and tiny pumps, leading to dramatically decreased operating costs.
- ✓ **Lay out the pipes first, then the equipment.** Installing the pipes before the equipment will decrease pipe friction and allow equipment to be optimally located to improve overall production flow.

Source: Amory Lovins. Energy End Use Efficiency, September 2005, pp. 16-17. (Commissioned by InterAcademy Council, Amsterdam, www.interacademycouncil.net, as part of its 2005–06 study, "Transitions to Sustainable Energy Systems.")

D. Encourage Energy Efficiency with Standard Work, Visual Controls, and Mistake-Proofing

Standard Work and Energy Use

Key Term

Standard work is an agreed-upon set of work procedures that establish the best and most reliable method of performing a task or operation. The overall goals of standard work are to maximize performance while minimizing waste in each operation and workload. Standard work is the final stage of Lean implementation in that it helps sustain previous Lean improvements and serves as the foundation for future continuous improvement (kaizen) efforts.

Your facility can maximize Lean and energy gains by incorporating energy reduction best practices into standard work (e.g., consider drawing from the *Questions for Understanding Energy Use* and the *Energy-Reduction Checklists* in Boxes 6 and 13 of this toolkit). Example uses of standard work include:

- Build energy reduction best practices into training materials, in-house regulations, and standard work for equipment operation and maintenance
- Include energy reduction tips in weekly team meetings and monthly facility newsletters
- Add energy reduction best practices into "shine" checklists used when implementing 5S (or 5S+Safety)[15]

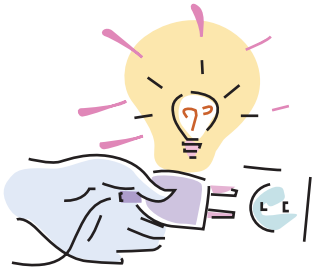
Visual Controls

Key Term

Visual controls are used to reinforce standardized procedures and to display the status of an activity so every employee can see it and take appropriate action. Visual controls also standardize energy and equipment use best practices and can be adopted facility-wide along with other in-house standards.

Example Visual Control
(Figure 6)

Unplug When Not in Use



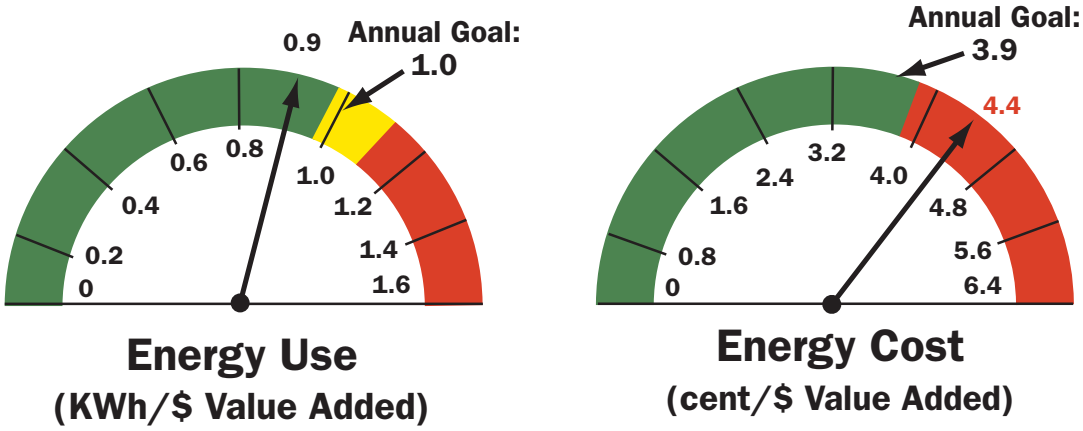
These easy-to-use cues can be as simple as the following techniques:

- Color-code pipes and other facility conveyances to help operators quickly identify and report key information (e.g., leaks)
- Install a sign over on/off switches or power outlets to remind operators to turn off or unplug equipment that is not in use (for example, see figure 6)

[15] 5S is a Lean method involving five steps (Sort, Set in order, Shine, Standardize, and Sustain) to establish a clean, neat, and orderly workplace. Many companies add a sixth "S" for Safety.

Visual controls also provide a powerful way to track actual results against targets and goals, and encourage additional improvement. Figure 7 shows a dashboard representation of how energy use and cost at a facility compares to annual goals.

Dashboard Visual Controls (Figure 7)



Mistake-Proofing

Key Term

Mistake-proofing (also known by the Japanese term *poka-yoke*) refers to technology and procedures designed to prevent defects and equipment malfunction during manufacturing processes. Mistake-proofing is used by manufacturers to prevent and easily identify operational errors; it offers an unobtrusive approach to standardizing equipment use.

One simple energy-efficient action is to automatically power down energy-consuming equipment when not in use. Process equipment and lighting do not always need to be on or energized. Mistake-proofing devices such as occupancy sensors and lock-out/tag-out de-energizing steps are a simple, low-cost means to power down equipment that is not in use. By mistake-proofing equipment, a facility can waste less energy, time, and resources, as well as prevent rework.

To Consider

- Which of the Lean techniques mentioned in this chapter—TPM, flow, right-sized equipment, standard work, visual controls, and/or mistake-proofing—does your organization use?
- What ideas do you have for using Lean techniques to integrate smart energy habits into your organization's work?

CHAPTER 5
Conclusion

Lean Windows of Opportunity for Energy Savings

While significant energy efficiency gains often ride the coattails of Lean implementation, some energy use and cost reduction opportunities may be left on the table. This toolkit provides numerous ideas for leveraging Lean events and methods to explicitly identify and eliminate even more energy waste. As discussed in Chapter 4, Lean methods can also be used to ensure that energy-saving practices become fully integrated into an organization's culture and the way it does its work. The net result is right-sized energy use that minimizes costs and environmental impacts.

Key Point

It is important to remember that when implementing Lean, there are critical windows of opportunity for reducing energy use. *When a process is being reconfigured as part of a Lean event, a window of opportunity arises for making additional process changes to improve energy efficiency at a lower marginal cost.*

Failure to explicitly consider energy use during Lean events may miss several key types of opportunities. These opportunity areas include:

- **Upgrade the energy efficiency of equipment.** Efficiency upgrades for motors and drives for equipment, air compressors, lighting, and other energy consuming equipment often have rapid payback periods.
- **Switch to a less-polluting fuel source.** In some cases, there may be an opportunity to consider switching fuel sources used in a process. For example, it may be more efficient to switch from burning wood scrap to natural gas for generating process heat.
- **Design new buildings to be smart energy users.** Life-cycle energy costs for new and renovated buildings can be significantly reduced when energy conservation is incorporated into decisions at the design phase. See EPA's Green Building website (www.epa.gov/greenbuilding) for more information.
- **Increase the fuel efficiency of your fleet.** For some businesses, vehicle fuel costs are a major portion of operating expenses. Consider vehicle fuel efficiency when making fleet purchase and lease decisions. See EPA's SmartWay Transport Partnership website (www.epa.gov/otaq/smartway) to learn how to make your fleet more efficient.
- **Design products to use less energy.** If a Lean effort touches on product or service design, consider how the product or service affects customers' energy use. This can open new opportunities for adding value.

Going Even Further with Clean Energy

Addressing the environmental impacts of energy use does not need to stop with Lean. Companies are increasingly taking additional steps to reduce and offset the environmental and climate impacts of their energy use. These steps can enhance employee and customer perceptions of a company's environmental commitments and help reduce an organization's greenhouse gas footprint. Here are a few ideas:

- **Green Power.** Many energy utilities provide the opportunity for customers to purchase a percentage of their electricity as "green power." Utilities invest the proceeds from green power charges in the development of new renewable energy sources. See EPA's Green Power Partnership website (www.epa.gov/greenpower) for more information on purchasing electricity from renewable energy sources.

- **Carbon Offsets.** Some organizations have committed to supplement their efforts to reduce energy consumptions by offsetting the carbon emitted to the atmosphere by the energy that they do use. While the development of markets for selling and verifying carbon offsets is in the early stages, a number of organizations have emerged to broker sales of carbon-offset sales. Funds generated from the purchase of carbon offsets are invested in energy-efficiency projects, renewable-energy projects, or other efforts designed to reduce greenhouse gas emissions.

To Consider

- Can you think of creative ways that your organization can reduce energy use and greenhouse gas emissions?
- Do you have any major renovations, construction projects, or purchase decisions coming up in which energy savings opportunities could be considered?
- Are there things you could do to help your customers and/or suppliers reduce their energy use and greenhouse gas emissions?

The Lean and Energy Journey

This toolkit represents the beginning of an exciting journey. As customer and societal expectations around energy efficiency, environmental performance, climate protection, and sustainability continue to increase, Lean initiatives offer compelling opportunities to improve both economic performance and energy efficiency. We hope that this toolkit spurs creative thinking and innovation within your organization and encourages you to explore these opportunities.

We also hope to learn from your Lean and energy experiences and to refine the techniques presented here in future versions of this toolkit. We wish you success on your Lean and energy efficiency journey.

Your Thoughts on the Lean and Energy Toolkit

Now that you have finished this toolkit, reflect on what you read by answering these questions:

- What strategies and tools in the toolkit seemed particularly interesting and useful?
- What steps will you take next to improve Lean and energy management integration at your organization?
- What Lean or other process improvement methods do you think might have good opportunities for improved Lean and energy performance?
- What other information and tools would assist your organization to improve its Lean and energy efficiency efforts?

Please contact EPA to share your experiences with Lean and energy improvements and/or to discuss partnership opportunities by using the form found at: www.epa.gov/lean/auxfiles/contact.htm

Appendices

Appendix A

Energy Assessment Service Providers, Resources, and Tools

This appendix describes resources for identifying public and private energy assessment service providers and provides information on several resources and tools for identifying energy savings opportunities at manufacturing facilities.

Energy Assessment Service Providers

U.S. DOE Industrial Assessment Centers (IACs)

www1.eere.energy.gov/industry/bestpractices/iacs.html

IACs, which are located at 26 universities across the United States, provide no-cost energy and waste assessments to eligible small and medium-sized manufacturers. Teams of engineering faculty and students from IACs conduct energy audits or industrial assessments of manufacturing facilities and recommend actions to improve productivity, reduce waste, and save energy.

U.S. DOE Best Practices Plant-Wide Energy Assessments

www1.eere.energy.gov/industry/bestpractices/plant_wide_assessments.html

Mid-size and large manufacturers can apply for a cost-shared Plant-Wide Energy Assessment offered by U.S. DOE. The assessments are comprehensive and systematic examinations of energy use reduction opportunities at industrial facilities. All major aspects of energy consumption are addressed, including process operations and plant utility systems. Plants are selected through an annual competitive solicitation process, with a maximum award of $100,000.

U.S. DOE Save Energy Now Energy Savings Assessments

www1.eere.energy.gov/industry/saveenergynow/

Through the Save Energy Now program, the U.S. DOE offers Energy Savings Assessments to the nation's most energy-intensive manufacturing facilities. The focus of these assessments is on immediate opportunities to save energy and money, primarily by focusing on energy-intensive systems such as process heating, steam, pumps, fans, and compressed air.

ENERGY STAR Directory of Energy Service and Product Providers

www.energystar.gov/index.cfm?fuseaction=SPP_DIRECTORY.

The U.S. EPA and U.S. DOE ENERGY STAR Program offers a searchable on-line directory of private energy service and product providers. The directory includes energy management service companies, energy improvement contractors, and energy service companies, as well as other types of service providers and equipment manufacturers.

Energy Assessment Resources and Tools

Energy Efficiency Toolkit for Manufacturers: Eight Proven Ways to Reduce Your Costs

www.fypower.org/pdf/manufacturer_toolkit.pdf

The National Association of Manufacturers has developed this toolkit outlining energy conservation strategies, case studies, and resources for manufacturers seeking to reduce energy use and costs. The toolkit is based on the results of an energy-efficiency survey of over 400 manufacturing companies.

ENERGY STAR Guidelines for Energy Management

www.energystar.gov/index.cfm?c=guidelines.guidelines_index

The ENERGY STAR website describes a seven-step process for effective energy management. The guidelines are based on the successful practices of ENERGY STAR partners for improving the energy, financial, and environmental performance of businesses. In addition to practical guidelines, the ENERGY STAR website offers several energy assessment tools and resources.

IAC Self-Assessment Workbook for Small Manufacturers

http://iac.rutgers.edu/database/technicaldocs/IAC_Manuals/selfassessment.pdf

This workbook presents a step-by-step methodology for small manufacturers to identify opportunities to reduce energy use, improve operations, and reduce costs at their facilities. The workbook includes practical tips, checklists, and examples of common energy cost savings opportunities.

Industrial Audit Guidebook Developed by the Bonneville Power Administration

www.bpa.gov/Energy/N/projects/industrial/audit/index.cfm

The Bonneville Power Administration's Industrial Audit Guidebook provides practical instructions, tips, and guidance for performing walk-through energy audits of industrial facilities to identify opportunities to reduce electrical energy consumption. Organized as a checklist of questions, the guidebook is intended for technical and non-technical audiences to assist with the first step in an energy audit: touring a facility and quickly identifying energy savings opportunities.

Green Suppliers Network Lean and Clean Assessments

www.greensuppliers.gov

The Green Suppliers Network (GSN) is a collaborative partnership between EPA and the National Institute of Standards and Technology Manufacturing Extension Partnership (NIST MEP) that works with large companies to provide low-cost "Lean and Clean" facility assessments to small and medium-sized businesses in several sectors. These assessments include detailed consideration of energy reduction opportunities.

Quick Plant Energy Profiler and Other U.S. DOE Software Tools

www1.eere.energy.gov/industry/bestpractices/software.html

Available from the U.S. DOE, the Quick Plant Energy Profiler (Quick PEP) is an online software tool designed to help personnel at industrial plants understand how energy is being used at their plants and how to reduce energy use and costs. Other U.S. DOE software tools allow industrial plant personnel to identify and analyze energy efficiency opportunities associated with compressed air systems, building and process heating systems, and motors, as well as other applications.

Resource Efficiency Management Resources from Washington State University

www.energy.wsu.edu/pubs/default.cfm

Washington State University's Resource Efficiency Management Program has developed several workbooks, checklists, and other guidance for conducting energy audits. Other resources available on the website include fact sheets describing energy-efficiency opportunities for commercial and industrial users.

Appendix B

Sector-Focused Energy Reduction Resources

This appendix describes energy conservation and efficiency resources that are tailored to particular industrial sectors.

ENERGY STAR Industries in Focus

www.energystar.gov/index.cfm?c=in_focus.bus_industries_focus

ENERGY STAR's Industries in Focus creates a momentum for energy performance improvements within individual manufacturing sectors. Focuses provide industry-specific energy management tools and resources, develop the corporate structure and systems to better manage energy, and reduce energy use within an industry. Participation is voluntary; however, most companies welcome the opportunity to network with peers. Generally, focuses enjoy the participation of most of the major companies within an industry. Participating sectors include:

- Cement manufacturing
- Corn refining
- Food processing
- Glass manufacturing
- Motor vehicle manufacturing
- Petrochemical processing
- Petroleum refining
- Pharmaceutical manufacturing
- Pulp and paper

Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes

www.epa.gov/sectors/energy/index.html

This EPA publication outlines energy trends, energy-efficiency opportunities, and energy challenges across selected manufacturing sectors. This report is an analytical document and does not convey any Agency decisions. The report's findings and policy options are based on the available data used in this analysis. Sectors profiled in this report include:

- Aluminum
- Cement
- Chemical
- Food
- Forest products
- Iron & steel
- Metal casting
- Metal finishing
- Motor vehicles
- Motor vehicle parts
- Petroleum refining
- Shipbuilding

U.S. Department of Energy, Industrial Technologies Program (ITP)

www1.eere.energy.gov/industry/about/index.html

ITP leads national efforts to improve industrial energy efficiency and environmental performance. ITP's mission is to improve the energy intensity of the U.S. industrial sector through a coordinated program of research and development, validation, and dissemination of energy efficiency technologies and operating practices. ITP partners with industry and its many stakeholders to reduce our nation's reliance on foreign energy sources, reduce environmental impacts, increase the use of renewable energy sources, improve competitiveness, and improve the quality of life for American workers, families, and communities. Sectors in the ITP program include:

- Aluminum
- Chemicals
- Forest products
- Glass
- Metal casting
- Mining
- Petroleum refining
- Steel

Appendix C

Energy Conversion Resources and Rules of Thumb for Estimating Energy Cost Savings

Energy Metrics Conversion Table

Energy Unit	Energy Equivalent
1 kilowatt-hour (kWh)	3,412 British Thermal Unit (Btu)
1 Therm	100,000 Btu
1 cubic foot of Natural Gas	1,000 Btu*
1 gallon #2 Oil	140,000 Btu*
1 gallon #4 Oil	144,000 Btu*
1 gallon #6 Oil	152,000 Btu*
1 gallon propane	91,600 Btu*
1 ton coal	28,000,000 Btu*
1 boiler horsepower (hp)	9.81 kW
1 horsepower	746 W
1 ton refrigeration	12,000 Btu/hr

*Varies slightly with supplier

Rules Of Thumb for Estimating Energy Cost Savings[16]

The following rules of thumb are a useful resource for understanding the potential cost savings of energy conservation and waste minimization efforts.

Cost Savings are Based on the Following Assumptions:

- Electricity: $0.05 per kWh
- Natural Gas: $0.350 per one hundred cubic feet (ccf)
- Man Hours: 2,000 hours per year per shift

[16] Adapted from: Office of Industrial Productivity & Energy Assessment. *Useful Rules of Thumb for Energy Conservation and Waste Minimization.* Rutgers, the State University of New Jersey. July 9, 1996.

1. High pressure steam leaks (125 pounds per square inch gauge [psig]) = $150 to $500 per leak per shift per year.

2. Low pressure steam leaks (15 psig) = $30 to $110 per leak per shift per year.

3. Compressed air leaks (100 psig) = $30 to $90 per leak per shift per year.

4. Submetering an evaporative cooling tower can result in sewage treatment savings (assume 1 percent water loss to evaporation), including:

   - $9 per ton per shift per year based on size of tower in tons.
   - $3 per gallons per minute (gpm) per shift per year based on gpm of water through tower.

5. Typical motor operating cost = $62 per horsepower (hp) per shift per year.

6. High pressure compressed air system reduction (assume 100 psig system):

   - 10 pounds per square inch (psi) compressor discharge reduction = 5 percent reduction in energy consumption.

7. Cost of heat lost through hot, uninsulated pipes:

   - 25 psig steam: $375 per 100 feet per shift per year.
   - 50 psig steam: $430 per 100 feet per shift per year.
   - 75 psig steam: $480 per 100 feet per shift per year.
   - 100 psig steam: $515 per 100 feet per shift per year.

8. Installing insulation can reduce 90 percent heat loss on a hot, uninsulated surface.

9. Average heating and cooling costs:

	Comfort Cooling Costs (per ft^2/year)	Comfort Heating Costs (per ft^2/year)
Michigan	$0.12	$0.26
Tennessee	$0.30	$0.35
Texas	$0.52	$0.24

10. Combustion efficiency of a typical boiler or furnace is 80 percent.

11. Upgrading to an energy-efficient motor can result in savings of about 5 percent over the operating costs of a standard motor. A typical standard motor has an efficiency of 90 percent.

12. Benefit of fuel switching:

    - Switching from electric heat to natural gas or #2 fuel oil can reduce heating costs by 78 percent.

13. Cost savings for demand reduction (or load shifting):

    - Move operating shift to off-peak times: $75 per hp per year.
    - Move "other electric equipment" to off-peak: $120 per kW per year.

United States Environmental Protection Agency
www.epa.gov/lean
Revised-October 2007
EPA-100-K-07-003