LEAN, ENERGY & CLIMATE TOOLKIT

Achieving Process Excellence Through Energy Efficiency and Greenhouse Gas Reduction

www.epa.gov/lean

How to Use This Toolkit

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

Identifies an **important point** to remember

Defines an **important term** or concept

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

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

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Executive Summary

The U.S. Environmental Protection Agency (EPA) developed this *Lean, Energy & Climate Toolkit* to assist organizations in reducing greenhouse gas emissions and energy use while improving performance through Lean manufacturing activities. Drawing from the experiences and best practices of industry leaders, Lean and environmental service providers, and government partners, this toolkit provides practical strategies and techniques for improving energy and environmental performance while achieving Lean goals such as improved quality, reduced waste, and increased customer responsiveness.

There are many reasons to integrate Lean, energy efficiency and greenhouse gas reduction efforts including:

1. **Cost Savings:** Reducing energy costs has a significant impact on business performance, though costs may be hidden in overhead or facility accounts.
2. **Greenhouse Gas Management 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 go hand-in-hand with 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 other manufacturers, both large and small, have successfully used Lean methods to reduce energy use, risks, and costs (see Box 1).

Example Results From Lean and Energy Improvement Efforts (Box 1)

- ✓ A **Baxter International** facility saved $300,000 in energy costs in one year.
- ✓ **General Electric** reduced greenhouse gas emissions by 700,000 metric tons and saved $111 million in operating costs at facilities worldwide.
- ✓ **Toyota Motor Manufacturing North America** reduced facility energy use and greenhouse gas emissions by 19 percent per vehicle since 2000.
- ✓ **Cummins, Inc.** saved $1.2 million using visual cues to encourage employees to unplug during their holiday shutdowns.

Lean manufacturing and its relationship to greenhouse gas management is also addressed in this toolkit. Manufacturing companies who commit to reducing energy use are in turn committing to

reducing their greenhouse gas emissions, therefore reducing their impact on the environment and mitigating climate change. This toolkit describes a range of strategies for identifying Lean and energy improvement opportunities and reducing energy use with Lean methods. With the use of this toolkit, manufacturing companies can discover ways to lower their energy costs, improve their energy efficiency, and reduce their impact on the environment. 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.

Integrating Lean, Energy and Greenhouse Gas Management

To be most effective, Lean and energy efforts should be proactive, strategic, and systematic. Adopting an energy management system and building an energy program 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. Ideas discussed include:

- Energy In-Line Management
- Guidelines for Energy Management
- Lean Windows of Opportunity for Energy Savings

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.

Assessment Strategies

Lean, energy, and greenhouse gas assessment strategies involve observing shop-floor activities to identify signs of energy waste and greenhouse gas emissions, 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 multi-day plant-wide assessment of energy savings opportunities using a cross-functional team of employees.
- **Greenhouse Gas Inventories:** Create a greenhouse gas inventory to help your company understand your emissions reduction opportunities..
- **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 greenhouse gas emissions and energy wastes and variation.

Emissions Reduction Strategies

Many energy efficiency and greenhouse gas reduction 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 and greenhouse gases through Lean activities such as the following:

- **Energy Kaizen Events:** Identify and implement employee ideas for saving energy and reducing wastes through rapid process improvement events.
- **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:** Identify and 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, Employee Engagement 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.
- **Transportation Efficiencies:** Look at your company's transportation fleet and mobile equipment to see if there are opportunities to improve routes, reduce idling, minimize the number of trips, and improve overall efficiency of the fleet.

Going Further with Lean and Energy

Companies are increasingly taking additional steps to reduce and offset the environmental and climate impacts of their energy use. These activities look beyond standard operational practices. A few ideas for going further include:

- **Purchasing Green Power:** Many utilities offer customers the opportunity to purchase power that is generated from renewable sources or "green power."
- **Carbon Offsets:** Some organizations have committed to supplement their efforts to reduce energy consumption by offsetting the carbon emitted to the atmosphere by the energy that they do use.

Preface

Purpose of This Toolkit

*This **Lean, Energy & Climate Toolkit** offers Lean implementers practical strategies and techniques for enhancing Lean results—waste elimination, quality enhancement, and delivery of value to customers*—while improving energy efficiency and reducing energy use, greenhouse gas emissions, 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.

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).

This toolkit provides strategies and information that can be used throughout your Lean, Energy and Greenhouse Gas Management journey. Chapters 1-3 help you understand the relationship of Lean to energy use, the benefits of systematically reducing energy use through Lean and ways to integrate energy efficiency and greenhouse gas management efforts into your organization's business strategy and management practices. Chapters 4-6 describe how to identify and implement energy savings opportunities in the context of Lean. 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.

Key Questions Addressed by This Toolkit

Lean focuses on identifying and eliminating waste. Environmental improvement and energy reduction efforts that distract from classic Lean efforts 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 traditional Lean wastes and improvement opportunities. To accomplish this, the toolkit aims to answer the following questions:

What is the relationship between Lean and energy use and climate change?

Energy savings and greenhouse gas reductions are often obtained during traditional Lean events, but by explicitly focusing on energy use you can get substantially greater energy improvements. By eliminating manufacturing wastes, such as unnecessary processing and transportation, businesses reduce the energy needed to power equipment, lighting, heating, and cooling. Chapter 1 describes benefits of combining Lean, energy improvement, and greenhouse gas reduction efforts. Chapters 2

and 3 explore the relationship between Lean and energy use, and provide background information on energy use and costs.

How do you know how much energy is used in a facility and where it is being used?

A key step in effective Lean and energy efforts is learning where to target energy-reduction activities. Chapter 4 discusses techniques for assessing energy use and greenhouse gas emissions reductions, identifying opportunities to save energy in the context of Lean. Methods include energy treasure hunts, greenhouse gas inventories, value stream mapping, and Six Sigma.

How can you reduce energy use and greenhouse gas emissions with Lean methods?

Chapter 5 examines specific opportunities for using Lean to improve energy efficiency and reduce greenhouse gas emissions, including methods such as kaizen events, total productive maintenance, right-sized equipment, plant layout, standard work, transportation efficiency and visual controls.

CHAPTER 1
Introduction

Coordinating Lean, Energy and Greenhouse Gas Management is a powerful way to reduce costs. This chapter includes:

- Benefits of Coordinating Lean Energy and Greenhouse Gas Management
- Cost Savings
- Greenhouse Gas and Environmental Risk Management
- Competitive Advantage

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 "waste," Lean implementers can significantly reduce costs and enhance competitiveness, while also achieving environmental performance goals.

Benefits of Coordinating Lean, Energy & Greenhouse Gas Management
(Box 2)

- ✓ 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, since it is often viewed as a necessary cost of doing business and is accounted for as overhead. By linking energy management and greenhouse gas reduction efforts to Lean activities, these activities can be tied more directly to process improvement efforts that are regarded by senior managers as being vital to business success.

Cost Savings

Energy costs can have a significant impact on the financial performance of businesses. A 2009 survey of corporations conducted by Siemens found that energy cost savings are the top driver for corporate sustainability efforts and seventy-two percent of all respondents reported that lowered operating costs were the reason their firms participated in sustainability initiatives in general.[1]

Lean and Energy Use Reduction: Company Cost Savings Experience (Box 3)

- ✓ **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.

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. 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.

Greenhouse Gas and Environmental Risk Management

The environmental and climate impacts of energy use are 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). Emissions also occur when fuel is combusted during transportation of goods to and from facilities and within. Lean methodologies can help companies with an

[1] Siemens (2009). Greening of Corporate America: The Pathway to Sustainability from Strategy to Action. McGraw-Hill Construction.

effective way to identify opportunities to improve efficiency and reduce greenhouse gas emissions. This reduces business risks associated with greenhouse gas emissions and contributes to reduction targets.

Carbon dioxide is not the only by-product of energy use. 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.

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. When asked by the Economist how the recent economic downturn would affect companies' approaches to carbon reduction, 47 percent of respondents stated they planned to improve their focus as a cost saving measure.[2]

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 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'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.

[2] Economist Intelligence Unit (2009), Countdown to Copenhagen: Government, Business, and the Battle against Climate Change Survey published by The Economist Magazine.

Lean and Energy at Toyota (Box 4)

- ✓ Toyota, the model for "Lean" production systems at companies worldwide, is also a leader in energy and environmental performance.
- ✓ Since 2000, Toyota Motor Manufacturing North America reduced the average facility energy consumption per vehicle produced by 19 percent, and collectively reduced greenhouse gas emissions by almost 150,000 tons.
- ✓ Toyota's continuous improvement of energy performance earned the company the ENERGY STAR Sustained Excellence in 2010, its sixth consecutive ENERGY STAR award.
- ✓ Toyota used methods such as energy treasure hunts and kaizen events to achieve these results (Chapter 4 has more information on these methods).

Source: Toyota. 2010 North America Environmental Report. Accessed online at

http://www.toyota.com/about/environmentreport2010/

CHAPTER 2

Integrating Lean, Energy Efficiency and Greenhouse Gas Management

Lean, energy efficiency and greenhouse gas management efforts should all be part of the overall organizational strategy, with the ultimate goal being a culture that ensures efficiency. The sections in this chapter include:

- Energy In-Line Management
- Guidelines for Energy Management
- Lean Windows of Opportunity for Energy Savings

Understanding how your energy efficiency efforts and greenhouse gas reduction efforts relate to the rest of your company's operational strategies and goals is the first step in achieving your efficiency goals.

Energy In-Line Management

Reducing energy and saving money are hand-in-hand principles best understood from a bottom-up approach to energy management. Energy efficiency within a manufacturing company can be approached and addressed while still maintaining product quality and production line reliability. If energy efficiency is managed in a narrow "top-down" approach, energy efficiency projects are sometimes examined on a case-by-case basis without understanding its effects on total productivity and thus may not promote innovative "shopfloor" energy-saving ideas.

While corporate support for energy efficiency in lean manufacturing is critical to the success of the energy-saving techniques, building a strong organizational structure to promote employee accountability and systematizing the program is key. Establish clear goals for energy efficiency, effectively communicate those goals throughout the organizational structure, and track your progress within the company to achieve the best success.

It is the individual responsible for consumption or waste who will be the most innovative. For example, by having a line manager take the lead on the energy efficiency goals, responsibility for improvement is in the hands of the person who owns the consumption. The sustainability manager, who is typically responsible for these activities, cannot obtain significant energy improvements without the help of employees working on the shop floor who best know the equipment and operating procedures.

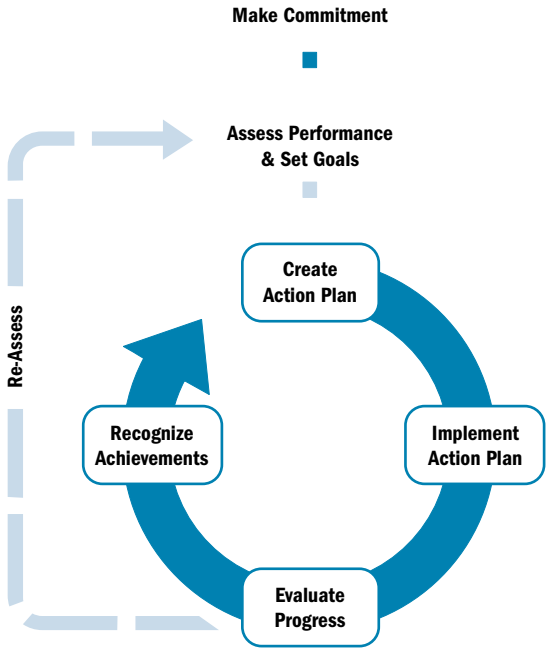
Guidelines for Energy Management

Pro-actively managing your organization's energy use is the first step toward efficiency improvements. *Energy management* is a systematic framework for understanding and identifying energy-related improvement opportunities similar in many ways to the Lean tools that you already use.

Strategically and systematically integrating energy and Lean improvement efforts will enhance their effectiveness and the value they bring to your company. Energy management systems can be tailored to suit your facility's needs, business opportunities, market risks, and specific goals and targets.

New Tool

Figure 1: ENERGY STAR Guidelines for Energy Management



EPA's ENERGY STAR program's *Guidelines for Energy Management* provide an organizational framework for establishing management structures, procedures, and processes that help establish an organizational culture that supports energy efficiency and Lean approaches. These guidelines have been implemented with great success by many U.S. Companies.[3]

The ENERGY STAR program has a variety of resources that can help establish an energy management program. For additional information please visit: http://www.energystar.gov.

These guidelines are just one way of managing your organization's energy use. There are numerous practical ways to consider energy waste and improvement opportunities during 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.

Why Be Strategic About Energy Management? (Box 5)

- ✓ Find new opportunities to reduce wastes, energy use, 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

[3] GBN Global Business Network, Energy Strategy for the Road Ahead (2007)

Lean Windows of Opportunity for Energy Savings

Another reason to coordinate your organizational strategies is to ensure that you are looking for all the improvement opportunities. While significant energy efficiency gains go hand-in-hand with Lean implementation, some energy use and cost reduction opportunities may be left on the table.

This chapter focused primarily on energy efficiency, greenhouse gas management and ensuring that those activities are coordinated with your Lean efforts. 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 (retrofitting)**. 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.

These are just some of the more common opportunities that may be discovered during Lean, energy and greenhouse gas management events. We will discuss them in greater detail in later chapters.

To Consider

- ✓ How well coordinated are Lean activities with energy-efficiency and greenhouse gas management efforts in your organization?
- ✓ Who makes decisions involving energy use and power sources at your facility or company?
- ✓ How are energy costs allocated in 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 3
Overview of Energy Use and Lean

Before your company can begin to reduce its energy use and greenhouse gas emissions, you need to understand where your energy comes from. This chapter provides some basic background information on energy use including:

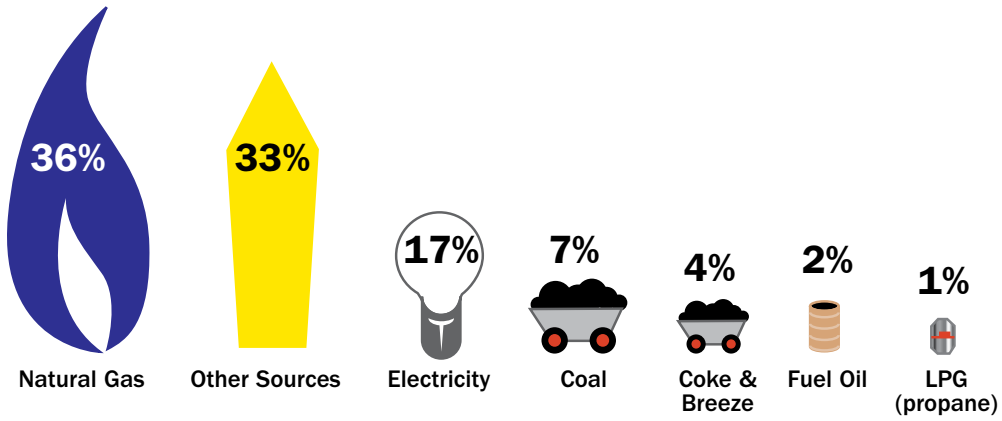
- Energy Sources and End Uses
- Understanding the Costs of Energy Use
- Energy Efficiency Benefits of Lean

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. It is also important to note that different fuel sources can have dramatically different greenhouse gas emissions. Figure 2 lists major energy sources used by the industry and manufacturing sectors in the U.S. economy.

Figure 2: Sources of Energy Used for U.S. Industry and Manufacturing, 2005 [4]



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*—how the energy is actually being used within the facility—reveals more useful information when identifying opportunities for improving efficiency and reducing costs. Box 6 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.

[4] U.S. Energy Information Administration, Annual Energy Review 2005, Washington, DC, July 2006. www.eia.doe.gov.

While identifying energy end uses is often straightforward, determining the amount of energy used by each process 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 4 discusses some strategies and techniques for better understanding energy uses and costs at your facility.

Energy End Uses: What Do We Use Energy To Do? (Box 6)

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

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 study by the National Association of Manufacturers[5]. *Consider targeting your facility's energy efficiency efforts on end uses that are likely to account for a significant portion of your facility's energy use*. Chapters 4- 5 describe specific strategies identifying and reducing the energy used by these and other types of processes.

Understand The Cost of Energy Use

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.

One of the primary 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

[5] National Association of Manufactures, Efficiency and Innovation in U.S. Manufacturing Energy Use, Washington DC. 2005.

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 MMBtu, or, thousands of cubic feet- Mcf) and a delivery charge for the transportation and delivery of the fuel. Fuel charges may vary seasonally and based on the amount consumed.

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 provided in Appendix C. ENERGY STAR also offers a free *Energy Tracking Tool* that helps organizations track all fuels, track progress towards reduction goals and generate reports.

Energy Efficiency Benefits of Lean Implementation

Significant energy savings are typically related to a manufacturing company's involvement in Lean activities—even without explicit consideration of energy use. The greatest benefits for lean implementation can be understood by thinking about energy in the context of Lean's "deadly wastes:"

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

Energy Use Reductions as an Indirect Result of Lean Activities

Environmental and energy wastes are not explicitly included in the seven deadly wastes of the Toyota Production System. This does not mean that these wastes are unrelated to Lean. 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 1 lists energy impacts associated with wastes targeted by Lean methods.

Table 1: 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 reprocessing, as well as heating, cooling, and lighting
Over 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

Despite these relationships between Lean 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 and fuel 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 4

Energy and Greenhouse Gas Assessment Strategies

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

1. Observe Energy Use on the Shop Floor
2. Energy Audits and Measuring Energy Use
3. Greenhouse Gas Inventories
4. Examine Energy Use with Value Stream Mapping
5. Use Six Sigma to Find and Eliminate Energy Waste and Variation

A. Observe Energy Use on the Shop Floor

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 7), to learn more about potential opportunities to reduce energy use. These are just some of the potential energy opportunities; see Appendix A for additional assessment tools and resources.

Questions for Understanding Energy Use (Box 7)

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?
- ✓ Is energy-efficient lighting 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 or closed to adjust heating and cooling?

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 8). 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 8)

With mentoring assistance from Toyota, General Electric (GE) launched an integrated Lean and energy initiative that has identified upwards of $110 million in energy savings through energy treasure hunts. GE's corporate commitment to energy use and greenhouse gas reductions has helped drive this effort. As of March 2009, GE:

- ✓ Conducted over 200 energy treasure hunts at GE facilities worldwide, and trained over 3,500 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
- ✓ Through those project have identified opportunities to eliminate 700,000 metric tons of greenhouse gas emissions and $111 million operational cost.

Source: Gretchen Hancock. (2009, May 13). How GE's 'Treasure Hunts' Discovered More Than $110M in Energy Savings. Retrieved from http://www.greenbiz.com/blog/2009/05/13/how-ges-treasure-hunts-discovered-more-110m-energy-savings .

B. Energy Audits and Measuring Energy Use

While a walk-through is an excellent way to identify and fix energy wastes that are clearly visible, you may still want to examine energy use more closely. Two strategies for learning more include:

1. Conducting an energy audit to understand how energy is used—and possibly wasted—across your facility.
2. Measuring the energy use of individual production and support processes.

1. Energy Audits

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 saving opportunities. Table 4 below provides examples of the top ten reduction recommendations based on data collected by the U.S. Department of Energy's Industrial Technologies Program.

Table 2: Top Ten Energy Reduction Recommendations [6]

#	Description	Times	Average Cost	Average Savings	Pay back	Implementation Rate
1	Utilize higher efficiency lamps and/or ballasts	10,532	$11,012	$5,592	2.9	56.71%
2	Eliminate leaks in inert gas and compressed air lines/valves	6,609	$1,317	$5,638	0.4	81.81%
3	Use most efficient type of electric motors	4,978	$10,733	$4,623	4.1	64.99%
4	Install compressor air intakes in coolest locations	4,625	$776	$1,755	0.9	48.56%
5	Utilize energy-efficient belts and other improved mechanisms	3,825	$2,339	$3,128	0.8	56.03%
6	Reduce the pressure of compressed air to the minimum required	3,448	$1,502	$3,550	3.6	49.36%
7	Insulate bare equipment	3,142	$3,610	$6,279	1.2	47.96
8	Install occupancy sensors	3,056	$2,082	$2,058	1.3	34.33%
9	Use more efficient light source	3,036	$8,807	$4,984	1.9	52.82%
10	Analyze flue gas for proper air/fuel ratio	2,160	$2,308	$8,011	0.6	68.70%

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

Energy Savings (Box 9)

- ✓ The E3 (Environment, Energy, and Economy) framework is a coordinated federal and local technical assistance initiative to help manufacturers adapt and thrive in a new business era focused on sustainability.
- ✓ An E3 pilot project in San Antonio, TX, resulted in a local detention equipment manufacturer realizing $85,000 in potential energy savings, reduced annual electric consumption of 159,000 kwh, reduced monthly electric demand of 48 kW, and reduced annual natural gas usage of 36,000 CCF.
- ✓ In Columbus, Ohio, six companies participated in an E3 pilot that identified energy savings of $1.7 million, environmental savings of $2.6 million, over 250,000 pounds of water pollutants avoided, and solid waste reductions of 24,000 pounds.
- ✓ See http://www.epa.gov/greensuppliers/e3.html for more information

[6] Table developed using U.S. Department of Energy's Industrial Technologies Program, ITP-IAC database. Accessed online Oct. 2010

2. Measuring Energy Use of Individual Processes

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)

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, install a flow meter to track natural gas inputs to ovens that provide process heat, or install electric meters in a particular process area to monitor electricity use. 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 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.

Common Energy Units (Box 10)

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

To Consider

- How much energy does your facility use?
- Which value streams and 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. Greenhouse Gas Inventories

In addition to energy use, your organization may also want to look at your overall impact on global climate change. Corporate greenhouse gas inventories help your company identify where emission reduction opportunities exist. A greenhouse gas inventory is simply an accounting of the amount of greenhouse gas emissions emitted to or removed from the atmosphere over a given period of time. Corporate greenhouse gas inventories focus specifically on the emissions of a company.

It is important to note that *depending on the quantity of your greenhouse gas emissions you may be required to report your emissions to EPA*. In October of 2009, EPA passed a rule requiring the mandatory reporting of greenhouse gases from large emissions sources in the United States.[7] In general, the reporting threshold is 25,000 metric tons or more of carbon dioxide equivalent per year. Most small business will fall below this threshold, and therefore not be required to report. For more information on this rule, and to better understand how your company may be affected please visit: http://www.epa.gov/climatechange/emissions/ghgrulemaking.html.

Greenhouse gases are released into the atmosphere and trap heat, slowly warming the earth. Carbon dioxide is the most talked about greenhouse gas, but it is not the only one. The principal greenhouse gases that enter the atmosphere because of human activities are:

- **Carbon Dioxide (CO_2):** Carbon dioxide enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (e.g., manufacture of cement). Carbon dioxide is also removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
- **Methane (CH_4):** Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.
- **Nitrous Oxide (N_2O):** Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
- **Fluorinated Gases:** Hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for ozone-depleting substances (i.e., CFCs, HCFCs, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases (High GWP gases).

[7] U.S. Environmental Protection Agency. Fact Sheet: Mandatory Reporting of Greenhouse Gases (40 CFR part 98). Washington, D.C., August 2010. Accessed online, July 5,2011.

New Tool

Corporate greenhouse gas inventories help your company calculate the emissions your organization is responsible for and provide you an idea of potential areas for improvement. For more information on greenhouse gases and how to develop a corporate greenhouse gas inventory please visit: http://www.epa.gov/climatechange/emissions/index.html.

Typically, when you reduce your energy use, you are also reducing your greenhouse gas emissions, but there are additional improvements that can be made to further reduce your company's global warming impact such as switching to fuel that emits fewer greenhouse gas emissions. Lean activities can be targeted at processes with high greenhouse gas emissions, or greenhouse gas emissions can simply be calculated in addition to energy efficiency reductions. This is just one more metric that could be calculated as part of a Lean and Energy event.

D. 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 previously for observing and measuring energy use to collect energy data for processes in the value stream, or consider 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 3: Example Value Stream Map shows a value stream map from a value and energy stream mapping project.

Example Results from Value and Energy Stream Mapping Projects
(Box 11)

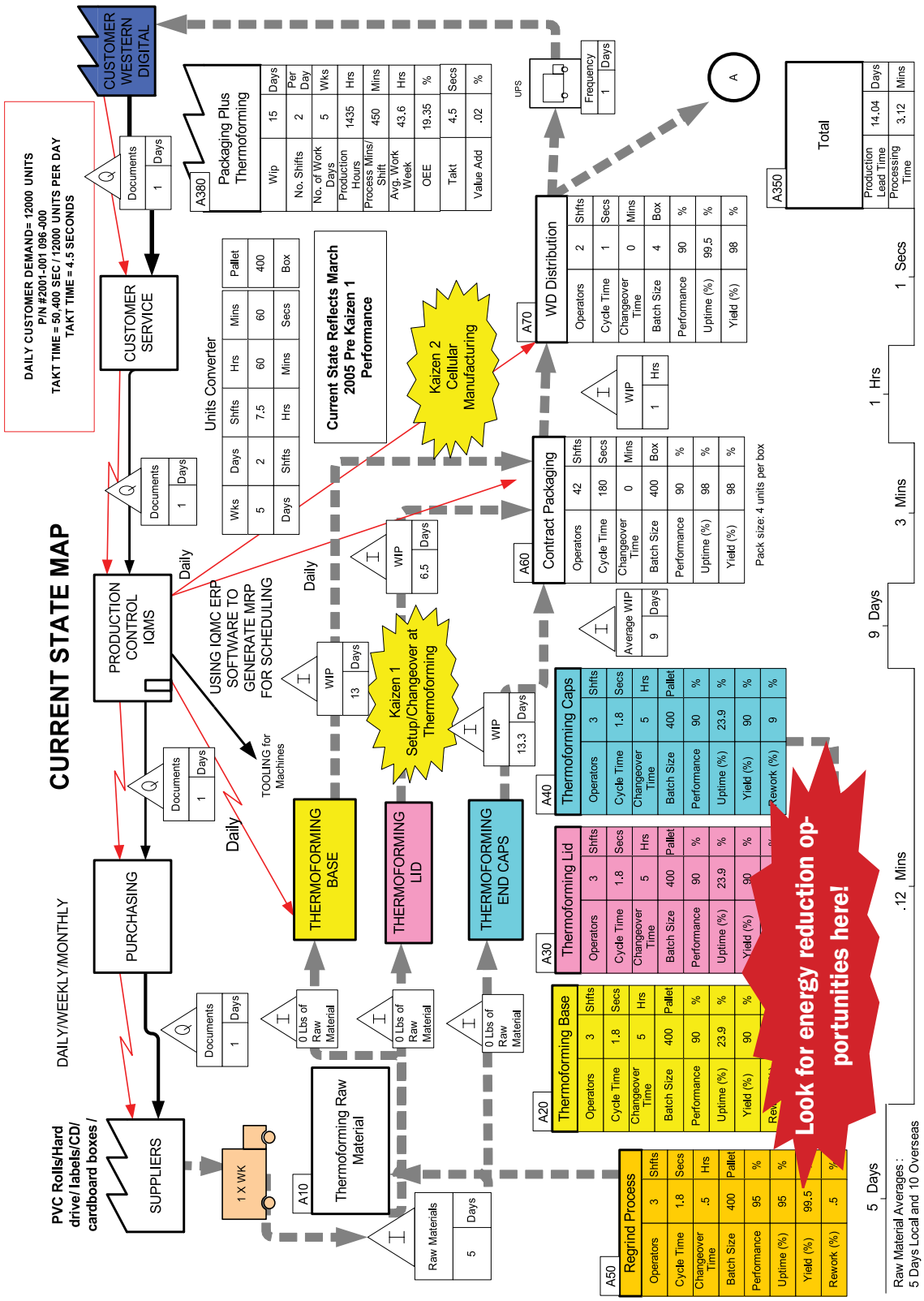
- ✓ **Mission Rubber**, a manufacturer of rubber couplings for the construction industry, conducted a five-day value stream mapping event and two kaizen events to shorten lead times and reduce energy use. The company saved an estimated 473,076 kWh and $40,000 in energy costs per year while increasing productivity and sales[8].
- ✓ **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[9].
- ✓ **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[10].

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

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

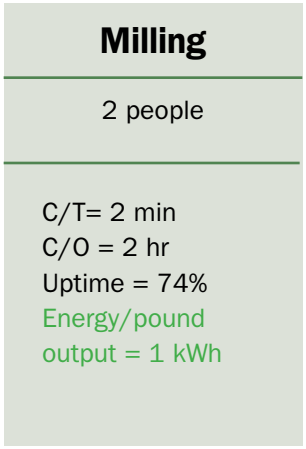
[10] CMTC. "Trojan Battery Company Case Study." Case Study No. 05-80760.

Example Value Stream Map (Figure 3)



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 4 shows an *example process data box with energy use data* (in kilowatt-hours per pound of output).

Figure 4: Example Process Data Box with Energy Use Data



Combining energy use analysis and value stream mapping is a proven technique for cutting energy costs and improving productivity. For example, California Manufacturing Technology Consulting, a Manufacturing Extension Partnership center in California, 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 11 for examples).

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. When you look at energy use in the context of the entire value stream, ask two fundamental questions:

- **Is this energy end use needed?** 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.[11]

- **Is there a way to deliver this end use more efficiently in 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*. 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.

[11] 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)

E. 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 substantial 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 reduced worldwide energy use by 46 percent (when indexed to net sales) from 2000 to 2010. 3M set a corporate goal for further energy use reductions of 25 percent for the period from 2005 to 2015, and the company views Lean Six Sigma as critical to realizing this performance goal.[12]

Six Sigma and Energy Savings at Baxter International (Box 12)

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.

[12] 3M Corporation. Sustainability at 3M. Accessed at http://solutions.3m.com/wps/portal/3M/en_US/3M-Sustainability/Global/

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?
- Do you know what processes and areas of your facilities have the most greenhouse gas emissions? What ideas do you have for reducing those emissions?
- 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?

CHAPTER 5

Energy and Greenhouse Gas Emission 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. Conduct Energy Kaizen Events
B. Use Total Productive Maintenance to Reduce Equipment Energy Waste
C. Replace Over-Sized and Inefficient Equipment with Right-Sized Equipment
D. Design Plant Layout to Improve Flow and Reduce Energy Use
E. Encourage Energy Efficiency with Standard Work, Visual Controls, and Mistake-Proofing
F. Reduce Greenhouse Gas Emissions through Transportation Efficiencies

A. Conduct Energy Kaizen Events

After identifying the production areas that consume large amounts of energy or account for a large portion of your greenhouse gas emissions, your facility can further analyze and eliminate wasteful 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 energy waste. Revisit the results of energy audits, assessments or your greenhouse gas inventory 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 7, can also help to ensure that energy and greenhouse gas 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 13)

- ✓ 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

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.[13] Table 3 shows examples of energy savings opportunities identified during a kaizen event.

Table 3: Example Actions Identified at a Kaizen Event [14]

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**

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

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

B. 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 14)

- ✓ 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 Losses That Lower Equipment Efficiency

Key Poi

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 in energy costs.

Consider using one or more of the strategies for integrating energy-reduction efforts into TPM (Box 15) to improve energy and equipment efficiency at your facility. This chapter focuses on describing energy savings opportunities associated with autonomous maintenance (strategy #1); previous

chapters of this toolkit provided guidance on identifying energy wastes, conducting energy kaizen events, and developing energy management systems (strategies #2-4).

Strategies for Integrating Energy Reduction Efforts Into TPM (Box 15)

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

Autonomous Maintenance Improves Energy Efficiency

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.

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.

Use checklists such as the *Energy Reduction Checklists for Combustion, Steam Generation, and Process Heating Systems* (Box 16) 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. DOE has a variety of software tools, fact sheets, and other publications that can be helpful in optimizing the efficiency of your equipment.

Energy Reduction Checklist for Combustion, Steam Generation and Process Heating Systems (Box 16)

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

For more information and best practices for improving the efficiency of the systems above visit DOE's website:

http://www1.eere.energy.gov/industry/industries_technologies/

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.

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

Key Point

Over-Sized Equipment (Box 17)

✓ Over-sizing building fan systems, on average, occurs by 60 percent.

✓ Most chillers are oversized by 50–200 percent.

✓ Potential energy savings from right-sizing, 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 05 July 2011.

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. Another option is to use this opportunity to look for equipment that uses a cleaner burning fuel source. This could help reduce your greenhouse gas emissions.

Three Ways to Right-Size Your Fan System (Box 18)

- ✓ **Use smaller, energy-efficient motors**. Right-sizing 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, 2008 Edition. http://www.energystar.gov/ia/business/EPA_BUM_Full.pdf, accessed 05 July 2011.

D. 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 19 provides an example of the significance of plant layout and flow in reducing energy use.

Flow and Energy Use (Box 19)

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.")

E. Encourage Energy Efficiency with Standard Work, Visual Controls, Employee Engagement 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 7 and 16 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]

[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.

The Pacific Northwest Pollution Prevention Resource Center (PPRC) prepared a *Facility Checklist for Identifying Environmental Issues During Lean*.[16] This checklist is intended for use on the manufacturing floor to help companies identify additional environmental opportunities, including, but not limited to, energy efficiency and greenhouse gas emission reduction opportunities. Table 4, below, is an adaptation of the Energy Use portion of the checklist highlighting the things to look for and some of the questions you should ask when assessing your facility. The full checklist can be found at http://www.pprc.org/solutions/Lean_Green_facility_checklist_4_10.pdf.

Table 4: Example Energy Use Checklist

Energy Use Checklist

Things to Look For:

- Old lighting systems (T-12, yellow/blue/greenish hue lighting, incandescents)
- Unnecessary lights/heat on, possible over-lit areas, or less lighting possible with better placement?
- Standard efficiency pumps, motors, fans, belts
- Motors, fans, pumps running idle when not needed
- Throttled pumps and fans to control flow rate
- Older refrigeration/heating systems, space heating
- Older kilns/ovens (including baffles, fans, etc.)
- Listen/feel for air leaks, especially at connections
- Read readily visible air capacity and pressure gauges for high pressure drops through lines and equipment)
- Aged compressed air and supplied air systems, or throttle controls, poppet valves
- Using compressed air to dry parts, other poor choices
- Air compressor running when not needed
- No evidence of heat recovery from coolant waters, ovens, other low grade or higher-grade heat
- Onsite wastewater treatment (possible to reduce generation of wastewater, and thus, energy to treat)
- Uninsulated ovens, kilns, heater bands on extrusion, etc.

[16] Pacific Northwest Pollution Prevention Resource Center. Facility Checklist for Identifying Environmental Issues during Lean. March 2009. http://www.pprc.org/solutions/Lean_Green_facility_checklist_4_10.pdf. Accessed 06 July 2011.

Energy Use Checklist

Questions to Ask:

- Do you have energy management system in place?
- Employee suggestion system for energy improvement?
- What is payback criteria for energy projects?
- When did you last conduct an energy audit?
- Recent upgrades of motors, lighting, belts, drives, pumps for energy efficiency?
- Do you know efficiency ratings of any of above that have not been upgraded?
- Are any motors over-sized for their purpose? Operating at partial load?
- Air: centrifugal screw compressors that operate at more than full load capacity for >70% of the time? Are throttle controls, or poppet valves used? (*May be improvement opportunity for variable speed drive, load/unload instead of throttle, on/off controls or low/unload instead of poppet*).
- Is compressor cooling water discharged to sewer? Air discharged to atmosphere? (Opportunity for heat recovery?).
- Do you use most-efficient nozzles for air applications?
- Do you have regular maintenance schedule for above equipment?
- Have refrigeration system(s) been optimized?

Key Term

Visual Controls

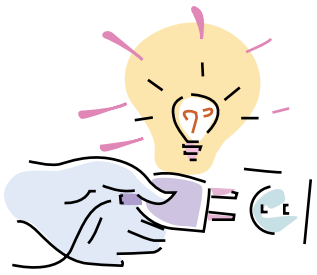
Visual controls are used to reinforce standardized procedures and to display the status of an activity so every employee can see it and take appropriate action. Visual controls standardize best practices for energy and equipment use, and can be adopted facility-wide.

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 5)
- Identify the annual energy cost, energy use, and/or carbon emissions of equipment if it is left on continuously and display it on the equipment to raise awareness and encourage conversation.

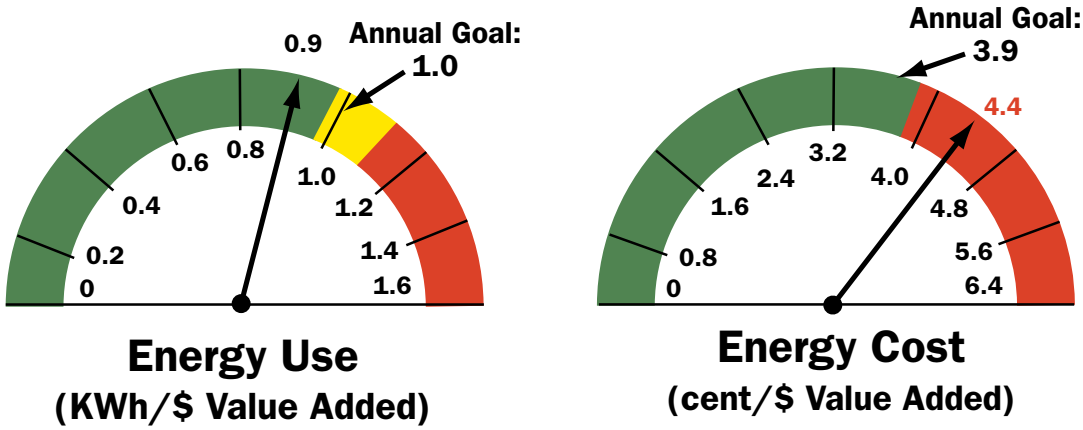
Example Visual Control
(Figure 5)

Unplug When Not in Use



Visual controls also provide a powerful way to track actual results against targets and goals, and encourage additional improvement. Figure 6 shows a dashboard representation of how energy use and cost at a facility compares to annual goals.

Dashboard Visual Controls (Figure 6)



Engaging Employees in Energy & Greenhouse Gas Management Efforts

Key Pol

Employees are one of your strongest assets when implementing your energy and greenhouse gas management programs. Getting them involved through competition, awards, and recognition is a great way to help employees feel like part of these efforts, and if they own the improvements it will be much easier to sustain any changes. There are several ways companies have engaged employees including:

1. Competition and Pledges
2. Recognition and Rewards

Figure 7: Materials Used by Cummins in Employee Engagement Energy-Reduction Efforts

Competition and Pledges

By fostering interest in energy reduction and encouraging employees to take the initiative to reduce their energy consumption, a company can save thousands of dollars each year. Cummins, Inc., an engine manufacturing company in Columbus, Indiana, created a program to encourage employees to keep energy use to a minimum over holiday shutdowns. The 2008 and 2009 "Unplugged Challenge" campaigns saved a combined 1,900 tons of greenhouse gas emissions and $1.2 million .[17]

[17] Cummins, Inc. Sustainability Report 2009-2010. Accessed on-line http://cmipef.cummins.com/CMIPEFMIG/CumminsNA/SiteContent/en/BinaryAsset/Attachments/Cummins/Cummins_2010_SustainabilityReport_FULL.pdf

Cummins has also piloted an "Energy Champion" program, an intensive week-long program to empower employees and equip them with the knowledge to implement energy saving practices both at work and at home. Figure 7 shows examples of the materials Cummins developed for this campaign.

Recognition & Rewards

Key Term

Another way to engage employees is to create recognition programs or other incentives for improving energy use within the company. This is an area where you can get creative. Look at creating a program that recognizes the team or organizational unit who has reduced their energy use the most, or who has had the most inventive solution to an energy or greenhouse gas issue. Post this information in a break room or other prominent common space.

You may also want to consider a monetary award or paid time off to the employee who comes up with a great cost saving idea. Sharing the benefit of these improvements with the employees only makes them want to work harder to identify additional areas where energy and cost savings can be found.

Mistake-Proofing

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.

F. Reduce Greenhouse Gas Emissions Through Transportation Efficiencies

Transportation in the form of personnel travel, product shipment, and product movement between facilities is often a large contributor to a company's greenhouse gas emissions. Companies can significantly reduce their greenhouse gas emissions using a variety of tools including employee commuting programs, looking into alternative fuels, and well-planned just-in-time deliveries.

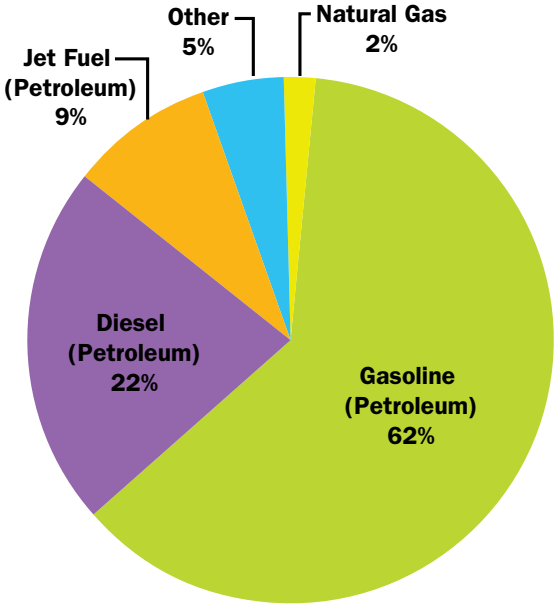
Finding Efficiencies in Vehicle Fleet and Mobile Equipment

In America today, about 28% of the energy we use goes to transporting people and goods from one place to another.[18] The majority of companies use vehicles and other mobile equipment as an integral part of their daily operations—from maintenance trucks used for parks and recreation to indoor and outdoor forklifts and other gas-powered equipment. These vehicles and equipment burn gasoline, diesel, and other fuels, which results in greenhouse gas emissions. In addition, vehicles with air conditioning or refrigeration equipment use refrigerants that can leak.

Emissions from vehicles and mobile equipment are a great place to look for savings. Several strategies for reducing emissions and maximizing efficiency include:

- Use alternative fuels (including corn or cellulosic ethanol, bio-diesel, natural gas and even diesel, and possibly in the future, hydrogen fuel cells)
- Use hybrid electric vehicles
- Reduce total vehicle miles traveled
- Reduce overall idling time for all vehicles

Figure 8: Fuel Used for Transportation, 2007



New Tool

The U.S. Department of Energy has developed a *tool to help determine where the most significant energy savings are in your vehicle fleet*. Please visit their Energy Efficiency & Renewable Energy Alternative Fuels website at https://www.afdc.energy.gov/afdc/prep/index.php for more information.

EPA also has a program that can help you reduce emissions from your vehicle fleet. SmartWay is an innovative brand that represents environmentally cleaner, more fuel-efficient transportation options. The SmartWay brand identifies a variety of different products and services related to transportation. Vehicles, fuel options, partnerships, and financing information are available on the website: http://www.epa.gov/smartway .

These strategies do not just apply to transportation outside of you facility. Consider what changes can be made to the way you transport your materials around your facility. Forklifts can be a major emission source. Using Lean techniques you may be able to optimize the plant layout in such a way that you no longer need forklifts (see section D above). If, however, you just cannot get away from using forklifts, consider purchasing electric models.

[18] Source: U.S. Energy Information Administration, Annual Energy Review 2009. http://www.eia.gov/energyexplained/index.cfm?page=us_energy_use, accessed 07 Jan. 2011

UPS: Fuel Efficiency Through Fleet Optimization (Box 20)

- ✓ UPS has one of the largest and most extensive ground delivery networks in the world and in 2009, improved the fuel efficiency of that network by 4.7%.
- ✓ The company focuses heavily on improving the efficiency of their network using both improved routing technology and alternative fuel/technology vehicles.
- ✓ Fleet optimization strategies include:
  - Allocating pick-ups and deliveries to the most efficient number of vehicles
  - Loading vehicles most efficiently for the order of delivery, so that routes and miles driven can be kept to a minimum.
  - Routing vehicles so that they reach required destinations in the least amount of time and miles driven.
  - Selecting route options that minimize idling time spent waiting for lights and turns.
  - Identifying stopping locations that enable multiple deliveries.
  - Keeping drivers on route and on schedule via a handheld compute
- ✓ In 2009, these strategies allowed UPS to avoid driving 20.4 million miles and 20,000 metric tons in emissions.
- ✓ In 2009, UPS also reached a total of 1,883 alternative fuel/technology vehicles in their fleet.

Source: UPS. Delivering the World, Sustainability at UPS 2009. Accessed on-line at http://www.responsibility.ups.com/Sustainability, 6, July 2011.

Key Term

Just-in-time delivery is another Lean principle which means you are only receiving supplies as they are needed. This methodology can also be applied to delivery schedules, maximizing delivery volume, while minimizing distance traveled with each drop. By optimizing your delivery schedule so that trucks are being loaded and deployed efficiently you should be able to limit the number of trips taken and therefore reduce your emissions. Box 20, shows how UPS optimized its fleet to reduce vehicle miles traveled and optimize delivery efficiencies.

Ways to Reduce Your Employees' Commutes (Box 21)

Fuel combustion from employees commuting to work is another important emissions source to consider. Similar to a vehicle fleet, personal employee vehicles use gasoline and other fuels which, when burned, generate greenhouse gas emissions. Encouraging carpooling and other commute-reduction strategies can reduce your overall emissions. It is also a great way to encourage employee participation and empower them to make a difference.

Some additional ideas to help reduce greenhouse gas emissions from employee commutes include providing:

1. Financial incentives for commuters (mass transit allowances)
2. Preferred parking for hybrid vehicles
3. Vans for carpooling
4. Financial incentives to help with purchase of fuel-efficient vehicles
5. Alternative scheduling (flexible work schedules and compressed work weeks)
6. Encouragement to walk and cycle to work
7. Shower facilities, bike locks, and parking for bicycles

While the employee commute does not have as direct a link to your lean manufacturing activities, it is a direct way to involve your employees and often will improve morale, creating a culture that is more open to innovation.

To Consider

- Which of the Lean techniques mentioned in this chapter—TPM, 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? Into your workforce?
- In what ways could your company improve shipping practices or fleet management to reduce greenhouse gas emissions?

CHAPTER 6
Conclusion

Going 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 supplement their efforts to reduce energy use by offsetting some of their carbon emissions with the purchase of carbon offsets. While the development of markets for selling and verifying carbon offsets is in the early stages, a number of organizations have emerged to broker 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. Visit http://www.carbonfund.org/ to calculate your carbon footprint and purchase an offset to reduce your footprint.

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 efforts you could undertake 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. EPA hopes that this toolkit spurs creative thinking and innovation within your organization and encourages you to explore these opportunities.

EPA hopes to learn from your Lean and energy experiences and to refine the techniques presented here in future versions of this toolkit. EPA wishes you success on your Lean and energy efficiency journey.

Your Thoughts on the Lean, Energy & Climate 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, energy, and greenhouse gas management integration in 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, energy efficiency, and greenhouse gas management efforts?

Please contact EPA to share your experiences with Lean and energy improvements and/or to discuss partnership opportunities by emailing lean@epa.gov

Appendices

Appendix A

Energy and Greenhouse Gas Management 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 Resources and Tools

E3 & Green Suppliers Network

www.e3.gov

E3 – Economy, Energy, and Environment – is a coordinated federal and local technical assistance initiative that is helping manufacturers across the nation adapt and thrive in a new business era focused on sustainability. In the process, E3 is boosting local economies and benefiting the communities with creation of "green jobs" and reduced environmental impacts.

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.

Energy Efficiency Opportunity Calculator for Small and Medium Sized Manufacturers

http://texasiof.ces.utexas.edu/tools.htm

Texas Industries of the Future has developed a tool to provide managers or engineers at small- or medium-sized manufacturing plants with a list of questions and a calculator so that they can quickly assess whether they have opportunities for energy and cost savings at their facility.

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/technicaldocs/
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.

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
http://www.energy.wsu.edu/PublicationsandTools.aspx
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.

U.S. DOE Save Energy Now Energy Program
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 Assessment Service Providers

ENERGY STAR Directory of Energy Service and Product Providers
http://www.energystar.gov/index.cfm?c=expert_help.find_exp_help
U.S. EPA's 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.

U.S. DOE Best Practices Plant-Wide Energy Assessments
http://www1.eere.energy.gov/industry/saveenergynow/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.

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.

Greenhouse Gas Management Tools and Resources

EPA Resources for Greenhouse Gas Emissions
http://www.epa.gov/climatechange/emissions/index.html#ggo
This website provides a variety of resources and information related to greenhouse gas emissions and greenhouse gas inventories.

EPA's Greenhouse Gas Equivalencies Calculator
http://www.epa.gov/cleanenergy/energy-resources/calculator.html
This calculator may be useful in helping you communicate the results or targets of your greenhouse gas management strategy. It converts your emissions into carbon equivalents and then equates that to common terms (e.g. your emissions are equivalent to the electricity use of 3000 homes for one year).

PPRC 's Climate Change Solutions
http://pprc.org/hubs/index.cfm?page=subsection&hub_id=1012&subsec_id=101
This website is part of the Pacific Northwest Pollution Prevention Resource Center's topic hub for climate change. It provides access to a variety of tools, calculators, strategies and technologies that can help reduce your greenhouse gas emissions.

For additional resources please visit our website, www.epa.gov/lean

Appendix B

Sector-Focused Energy Reduction and Greenhouse Gas Management 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

EPA's High Global Warming Potential (GWP) Programs
http://www.epa.gov/highgwp/voluntary.html
High GWP gases are part of a family of non-CO2 gases that contribute to global climate change. EPA is currently working with several industries to make substantial progress in reducing emissions by developing and implementing cost-effective improvements to industrial processes. Industries involved include:

- Electric Power
- Aluminum (VAIP)
- Magnesium
- Semiconductor

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[19]

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

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

[19] 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.

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	$0.54

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-August 2011
EPA-100-K-07-003