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Lean for green manufacturing

Manufacturers have many reasons to reduce their environmental impact, yet many are missing substantial opportunities to become greener without having to make significant investments. By adapting the lean approach to include energy efficiency, a new green production system can be designed, helping firms to reduce their CO_2 emissions by 10 to 15 percent.

By Andrew Gonce and Ken Somers

There is an increasing consensus that some human activities have harmful side-effects that impact the environment. Manufacturing activities are a particularly significant source of environmental impact because many processes are particularly energy intensive. Industrial activities drive approximately 27 percent of the global CO_2 emissions directly, with power generation comprising another 37 percent.[1] This type of impact implies that the manufacturing sector has a significant ability to influence global emissions.

So far, many corporate attempts made to reduce environmental impact have focused on indirect activities. Printing fewer pages or switching to low energy lighting are admirable steps, but as long as manufacturing companies fail to target their core operations they can only hope to achieve small improvements. Energy consumed directly during manufacture accounts for nearly 90 percent of the CO_2 emissions inherent in the production of a mobile telephone. For relatively simple products, such as a case of beer brewed for local consumption, energy use in production can be an even more important contributor to overall environmental impact, accounting for more than 90 percent of overall CO_2 generation.

Why then, have manufacturers been reluctant to tackle the major sources of energy consumption and environmental impact in their operations? Many companies are concerned that significant changes to production techniques will be needed in order to affect overall emissions. These changes, they worry, will be extremely expensive to implement, or will have unacceptable impact on quality, flexibility or productivity.

These manufacturers should reconsider. Our experience suggests that a significant fraction of the energy consumption in many manufacturing operations comes not from what is being done (the process), but in the way it is being done (the management). Simple operational changes designed to maximize energy efficiency can cut overall consumption by as much as 15 percent, with little or no capital investment.

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[1] 2007 International Energy Agency (IEA) *World Energy Outlook*

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Reducing the carbon footprint of manufacturing operations

Manufacturers have four dimensions with which to tackle CO_2 emissions from their processes.

- First, they can reduce emissions at source by switching to non-fossil fuel energy sources such as hydroelectric or nuclear power.
- Second, they can take steps to improve the energy efficiency of their existing processes.
- Third, they can select technologies, processes and materials that produce less CO_2.
- Fourth and finally, they can take steps to mitigate existing emissions: by investing in re-forestation programs or buying offsets in a cap and trade system.

Companies have the opportunity to explore each of these four levers to find cost effective mechanisms for carbon reduction. In 2008, Ford Motor Company, for example, began purchasing electricity for its manufacturing facility in Cologne, Germany from a hydroelectric producer in Scandinavia[2]. The car maker has pursued different strategies in other plants. Three wind turbines at its diesel engine manufacturing plant in Dagenham, United Kingdom, provide enough energy to operate the factory. At a U.S. facility in Kansas City, Missouri, Ford has committed to the purchase of carbon offsets equivalent to the entire energy consumption of the operation.

Most companies will need to deliver CO_2 savings within tight budgetary constraints. For many, spending their way to a smaller carbon footprint is simply not an option. Our analysis suggests, however, that organizations in this position can deliver significant emission reductions while simultaneously reducing their operating costs.

In some situations, these parallel savings are obvious. Energy costs money after all, so investments in technologies that reduce energy consumption are likely to pay back over time. However, one important source of emissions reduction requires little or no investment: modifying operating practices to maximize the productivity of the energy that is consumed. This second dimension for reduced emissions has been the focus of our recent work.

[2] Source: http://world-wire.com/news/0804210001.html

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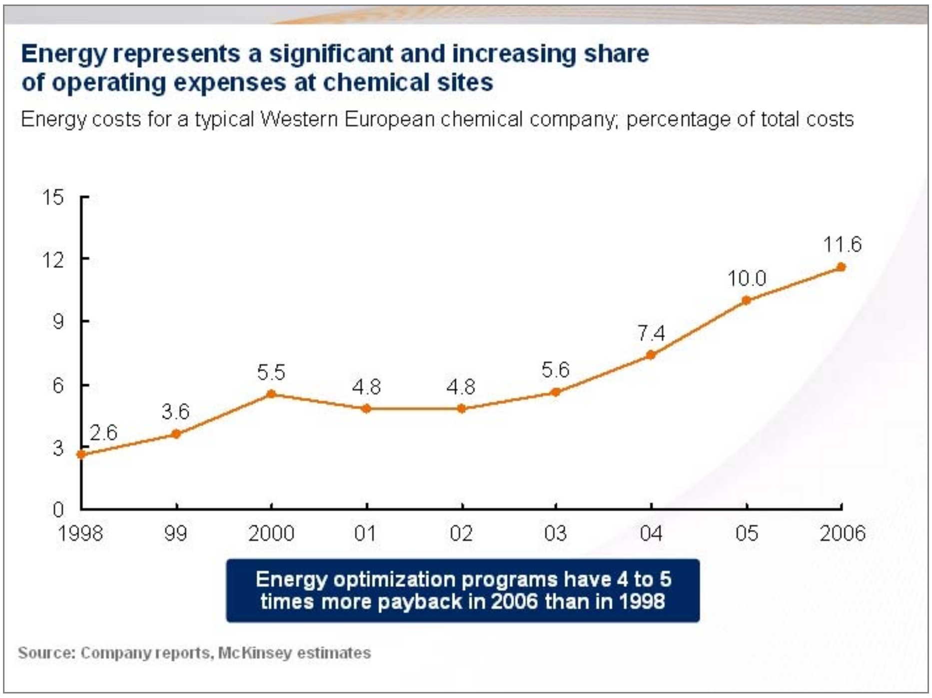
The road to energy efficiency

Why is there such an important untapped opportunity to improve energy efficiency? We believe that many companies fail to deliver here for three reasons:

1. in the past, energy prices were too low to place efficiency high on the management agenda
2. the focus for most firms was on volume increase and quality optimization
3. energy consumption is difficult to manage as it is very sensitive to externalities such as throughput and product mix.

Exhibit 1: Energy costs are increasingly important in many industries



Better energy efficiency can not be imposed on a production system from the outside the way that applying a new technology or source of energy can be applied. Instead, it must be painstaking built into every aspect of manufacturing operations. To do this takes time, commitment and a new way of working.

Fortunately, many companies already have the foundations they need to maximize energy efficiency. 'Lean' organizations that use integrated processes to optimize their quality, productivity and flexibility already have the key skills required to improve energy efficiency. They are used to examining their processes in detail, identifying potential sources of waste and inefficiency, designing countermeasures and evaluating their ideas using hard data.

In fact, many standard lean practices improve energy efficiency as a side effect. The wastes that lean processes reduce: overproduction, transportation and quality errors, for example, all have associated energy consumption that will disappear as those wastes are eliminated.

Likewise, idle assets often consume considerable energy waiting for production. Approaches that improve overall equipment effectiveness (OEE) will also reduce CO_2 production here by improving uptime and maximizing production when the equipment is fully charged.

Design for greener production

While going lean helps companies to go green, a few organizations are taking an important next step. By including energy efficiency in their lean thinking, they are beginning to design their entire production system to include environmental considerations. To do this, they include green in their technical system, their management infrastructure and their mindset. These companies integrate green into their lean management systems to create a 'green' operational transformation that parallels the lean transformation.

Technical system

By modifying some of their lean tools to examine and optimize energy efficiency as well as labor productivity, these companies are discovering significant opportunities for CO_2 reduction. The eight sources of waste, for example, can be translated completely into their energy counterparts (Exhibit 2). On top of these, two additional levers can be used: system integration/optimization (reuse of waste heat between different processes, for example) and technological improvement (high efficiency motors, for example).

Exhibit 2: Wasted energy

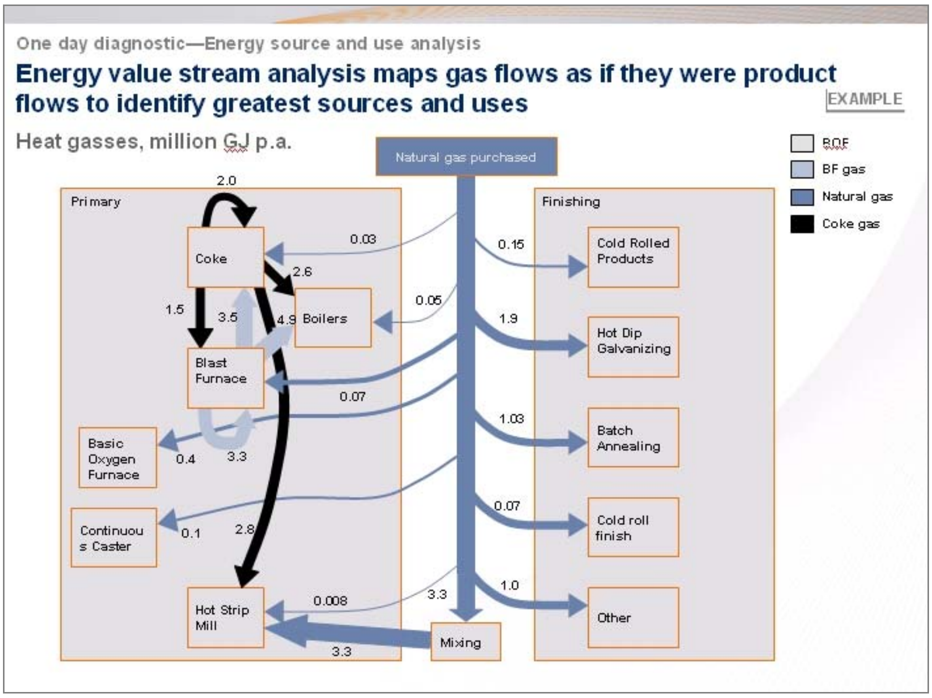
Lean waste concept can be translated into energy terms and is strengthened by 2 additional levers

	Types of waste	Definition	Example
A	I Overproduction	Producing excess energy (input energy that is unused)	Heating of empty ovens
A	II Waiting	Consuming energy while production is stopped	Unused conveyor belts keep running
A	III Transportation	Inefficient transportation of energy	Redundant compressed air networks
A	IV Over-specification	Process energy consumption deliberately higher than necessary	Furnace operated at higher then required temperature
A	V Inventory	Stored goods use/lose energy	Crude steel cools in storage, is then reheated for rolling
A	VI Rework/scrap	Insufficient reintegration in upstream process when quality is inadequate	Inefficient mixing of insufficient production charges in upstream processes
A	VII Motion (inefficient processes)	Energy-inefficient processes	Fixed motor running below optimal efficiency
A	VIII Employee potential	Failure to use employees potential to identify and prevent energy waste	Employees not involved in developing energy saving initiatives
B	System	Failure to optimize system as a whole	Waste heat from process A that could be used in process B
C	Technology	Lack of TCO based investment decisions	Avoid purchasing frequency convertors despite amortization time of 5 months

Energy consumption is often hard to track down. To find where energy is wasted in a process, another powerful technique from lean can be used: value-add analysis. Traditional value-add analysis is used to determine the efficiency of, for example, equipment maintenance. The time spend by the technician is measured and classified in three categories: value-added time (working on the machine), incidental waste (walking from the shop to the machine) and waste (waiting for the machine to be made available for maintenance). A similar logic can be used for energy: energy that is thermodynamically required to make the product, energy that is wasted because of technical set-up and energy wasted due to management practices. Applying this logic helps users understand the real sources energy loss in their processes and can help in the setting of aspirational targets for efficiency improvement.

Improving energy efficiency requires companies to cross-departmental and business unit borders and to use a holistic approach for the entire plant along the energy value chain. Energy value streams (Exhibit 3) use the principles of materials and information flow analysis (MIFA) to see exactly where energy is consumed in plant. These diagrams help to identify sources of waste, opportunities for recovery and re-use of energy (for example, using heat exchangers to transfer waste heat to incoming material flows) and decide where improvement efforts are likely to have the biggest impact.

Exhibit 3: Energy value stream maps highlight major sources of CO_2 emissions



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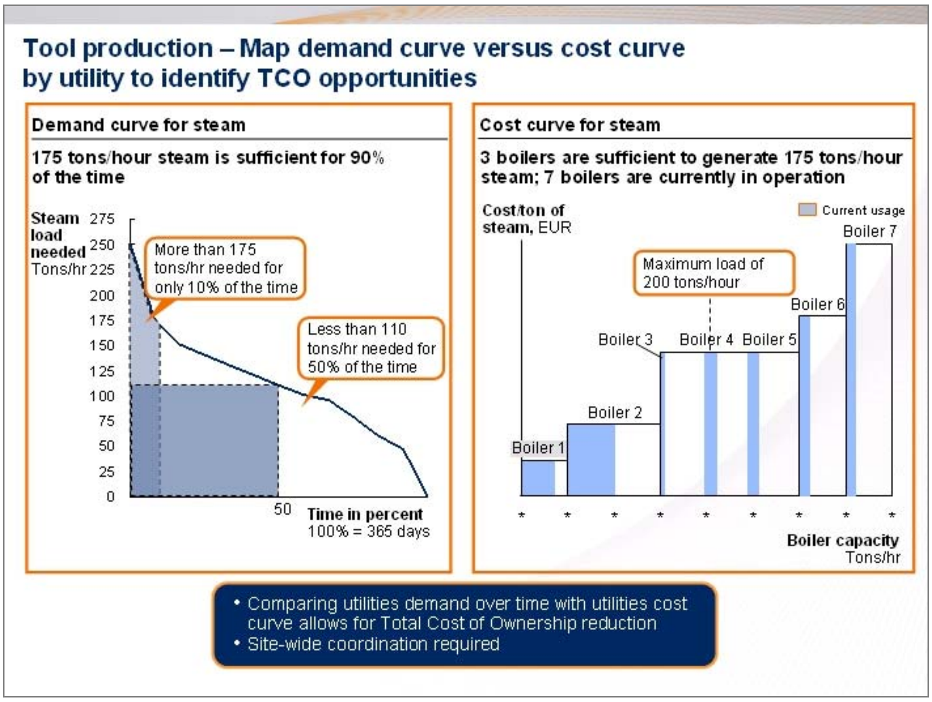
Flow balancing and sequencing can help to reduce unnecessary energy consumption caused by running plant at part load. Plants often run extra equipment just to handle peaks in throughput. By changing schedules to flatten those peaks, efficiency can be substantially improved and part loaded equipment taken offline (Exhibit 4).

Exhibit 4: Flow balancing reduces peak energy demands



Smart sequencing is also extremely effective at eliminating extra heating and cooling cycles. In aluminum production, for example grouping loads that require processing at a similar temperature together can reduce heating loads by 10 to 15 percent per transition. Strategies to reduce process variability also help to cut energy use, by ensuring that all batches in a process receive the minimum required energy inputs.

Two steel plants recently applied these techniques to their own operations. 48 percent of the energy opportunities identified could be implemented with minimal capital investment and with payback periods of less than one year. One example of this improvement was to connect separate compressed air networks around the site. Connecting three of the four networks led to a 30 percent reduction in the number of compressors required and an annual saving of $1.2 million, paying back the investment in just over one year. Across a number of industries, sites have been able to reduce total energy consumption 10 to 20 percent within two years of the initial effort.

Management systems and mindsets

Successfully exploiting operational CO_2 reduction opportunities requires management systems that measure green performance and motivate improvement, along with a culture that encourages people to think creatively about CO_2 reduction.

Powerful tools are helpful, but as important are the processes that to support the desired change. Most companies have substantial energy savings potential hidden in the thousands of small energy consumers spread all over the plant. These devices, such as motors, pumps and heaters, are often over-designed, inefficient, and poorly aligned with the actual demands placed upon them. Companies can often reduce overall energy consumption by 5 to 10 percent over time by introducing a Total Cost of Ownership concept in supporting departments such as purchasing and maintenance. By searching not for the lowest capital cost, but for the lowest cost over the lifetime of a piece of equipment, these functions can simultaneously cut energy use and reduce other overheads, such as maintenance. For example, low cost transformers may seem appealing at the time of purchase, but over their lifetime they are likely to cost a company 10 times the initial savings in energy consumption compared to more efficient alternatives. Installing these processes at maintenance and purchasing will help to correct mistakes from the past, but a similar effort is required for engineering, to ensure that best practices are carried forward into new designs.

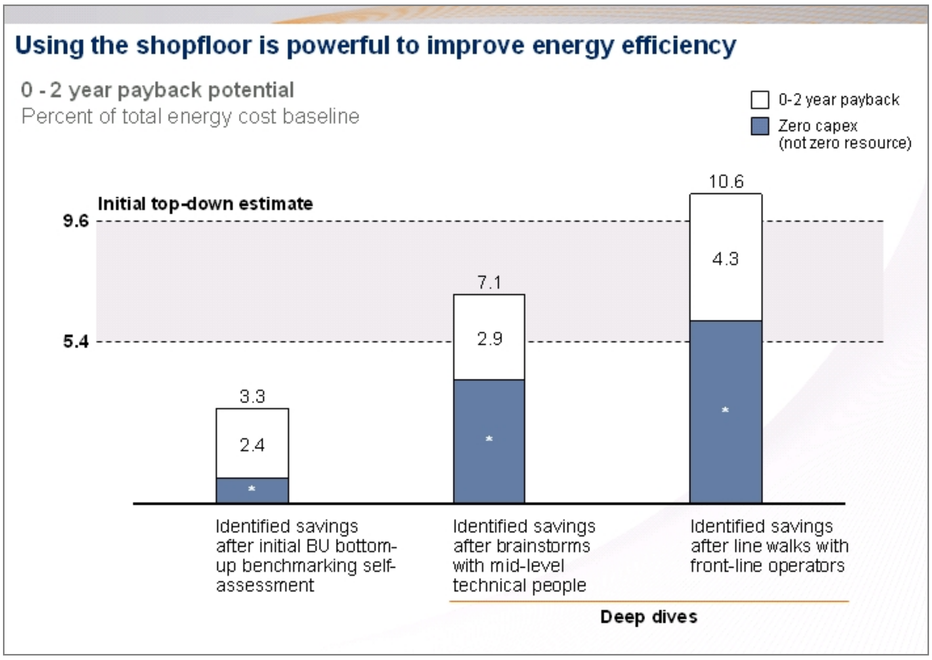
Management systems should include targets and incentives for overall CO_2 reduction. Companies should also take care to modify existing incentives to encourage improved energy efficiency. Some quality or productivity metrics, for example, can motivate staff to consume unnecessary energy by leaving equipment at idle or operating plant away from its most efficient conditions. Such metrics must be balanced with efficiency measures to encourage optimum performance.

Managing energy is still a relatively new domain for the majority of companies and many find it very difficult. Energy consumption is load and product dependent, so setting up a meaningful metric is an exercise that needs to be undertaken with care. One approach, based on the Overall Equipment Effectiveness (OEE) concept in lean, is to manage energy by focusing on, and striving to reduce, losses. The definition of energy losses can be made to match those of OEE: availability, speed, quality or energy lost while the line was not producing, energy lost because the line was not producing optimally, or energy lost because the product was rejected.

The mindsets of employees and energy efficiency performance are strongly linked. For example, we analyzed the energy efficiency mindset of the various departments in a Chinese steel factory. The results of this survey showed clearly that the department with the weakest energy mindset also showed the weakest performance on the floor. Improving the performance of this department would require substantial effort to change the attitude of the employees, in addition to any technical changes.

Given sufficient encouragement, the shop-floor staff can be the richest source of ideas for reducing energy consumption. A NAFTA example showed that going closer to the shop floor increased savings from 3 percent to 11 percent (Exhibit 5). The best companies have effective systems in place to capture these ideas, filter them and track their implementation. In many companies improving environmental performance is something that can create considerable enthusiasm among staff. Some companies have even made use of interest in environmental improvement to drive engagement with a wider lean transformation program.

Exhibit 5: Employee input identifies improvement opportunities



How to get there

The first step towards an integrated CO_2 program is to understand where the greatest improvement potentials exist. Simplified diagnostics can be completed within a week, comparing current usage to industry norms and qualitatively benchmark the current state of CO_2 management practices. More detailed analyses investigate carbon-offset options, the impact of lean and operational improvements and develop site-specific carbon abatement offset curves.

A pilot area is chosen using all of the above analysis as the target area for improvement efforts. The pilot team addresses management and capability deficiencies locally and crafts the broader set of tools for site-wide implementation. In parallel to the implementation effort is a series of communication efforts that state the case for change. These efforts are critical in driving the behavioral changes needed throughout the organization in order to sustain the improvements after the initial surge of interest and activity.

Lastly, as companies target the least-cost means for carbon abatement, they can prioritize energy efficiency efforts to create self-funding programs. Many firms could reduce their CO_2 emissions by 10 to 15 percent simply by altering operating and management practices. These changes, when fully integrated into process improvements, deliver both 'lean' and 'green' improvements: growing profits as the carbon footprint shrinks■

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