

Techniques for Enhancing Sustainability of Industrial Operations

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Abstract--Reducing the consumption of energy from non-renewable energy sources is critical in reducing global warming and making a company's operations sustainable in the long term. Sustainable companies make a top-level managerial commitment to reducing energy usage and establish environmental management systems (EMS) with this goal in mind. More is required than this commitment. Companies serious about reducing their energy consumption must establish a culture that empowers all employees to identify and eliminate waste, identify their points of consumption, and implement effective energy usage reducing techniques. Some of these techniques are well-known; however, some are less obvious but should not be overlooked.

As part of a broad study of the synergistic relationship between Lean Production Systems and Green Operations Systems, we have shown that application of techniques usually associated with Lean programs also result in improvements in waste generation and energy consumption. Here we present techniques that are applicable to a wide variety of industries for the reduction of energy used in facilities, fleets, and process systems as well as suggestions for changes in policies and procedures to support this effort and opportunities for incorporation of alternative energy sources in these areas.

INTRODUCTION

Global warming is clearly a colossal threat to the future of humanity as well as the general global environment. The foundations of the advanced industrial societies of the current millennium are unsustainable in the long run [1]. If society does not move away from a fossil-based economy in a planned, systematic way, society will be forced by natural catastrophes and fuel depletion to do so in the midst of a monumental crisis [2].

The twin threats of global environmental collapse and fuel depletion present compelling reasons for academic researchers, corporate executives, politicians, and members of the general public to view re-orientation of the global economy to a non-fossil-fuel basis as a primary goal of the first half of this century.

The goal of changing the energy foundation of the future is achievable and is the most important step in creating a fully sustainable global society that can continue to achieve outstanding accomplishments [1]. Every company that plans to exist in 2050 or beyond must begin to determine how it will change its production and operations processes

to eventually eliminate its reliance on any forms of fossil fuels. While society does not yet have the complete solution to this difficult dilemma, there is significant knowledge of how to move industries of all types much closer to the lofty and absolutely necessary place of enhanced sustainability.

ENVIRONMENTAL MANAGEMENT SYSTEMS

The journey to corporate sustainability begins with top and middle management. The visionaries and planners of the enterprise must be courageous in understanding the reality of the existing industrial reliance on practices that are not sustainable in the long term. These managers must accept the necessity of reformatting their business processes so that their companies can avoid the very high costs of purchasing fossil-based fuels when the supplies of these fuels dwindle in the middle and latter parts of this century.

The U.S. Environmental Protection Agency (EPA) states that companies working to reduce their environmental impacts must put in place effective environmental management systems (EMS) [3]. To be effective an EMS must be integrated into the company's policies and procedures as part of the overall management system. The most effective EMS is one that meets requirements for certification pursuant to International Standards Organization's ISO 14001 standard [4]. Such an EMS will provide the direction and leadership to move the company towards the environmental goals. It must also empower employees to make quick decisions to act to keep the production processes operating within appropriate environmental parameters.

Leadership is established in several ways. First, management should publish a policy statement outlining management's commitment to environmental issues. Second, the company's policies and procedures must be reviewed and adjusted to provide the framework for accomplishing the environmental goals. Third, company employees must be convinced of the importance of acting in support of these goals. Employees are likely to need some education, training, and reinforcement to be able to play their necessary role in the environmental program [5]. It is employees at all levels of the company who will make the operational decisions and take the actions needed to achieve the goals.

APPLICATION OF TECHNIQUES FOR

REDUCTION OF ENERGY USAGE

Once the company has established a viable EMS and communicated the new environmental position of the company to employees, the real work of reducing and eventually eliminating fossil-fuel-based energy from the company's production and operations systems can begin.

Determining the Company's Energy Demands

The company needs to measure the amount of energy used by the company in fulfilling its mission. This is no trivial task as traditional accounting methods have not given much emphasis to tracking energy usage. Energy may be consumed in dozens of different ways within a company. Major consumers fall into three main categories: facilities, transportation, and processes.

The facilities used by the company in carrying out its operations need to be heated or cooled, ventilated, and lighted. These basic facility operating needs are estimated to account for over one-third of energy consumption in the U.S. [6]. Unless a company has all-new facilities designed and outfitted under the strictest LEED standards of the U.S. Green Building Council [7], the opportunity for saving a significant portion of this energy is great.

Over 28% of energy used in the U.S. is used to move people and goods [8]. Usage of energy in transportation is largely in shipping the company's products or in traveling to clients in order to provide services. Additional travel may be needed for employees to attend meetings, obtain supplies or services, or otherwise represent the company in off-site situations. One significant and often overlooked use of energy is in material handling within the company's process areas. Fork trucks, automated stacker-retriever systems, and conveyor systems all require power for operation.

Depending on the industry, processes may simply require office equipment or they may require extensive systems heated by a fuel such as natural gas. Virtually all manufacturers have a large variety of processes operating on several types of fuel. Producers of Green technology may still have this large range of processes.

Total company demand may be obtained by auditing the company's payments to energy providers, but almost no company can accurately allocate that energy to the specific internal user. Exceptions would be large users of a fuel that is unique within the company. These are relatively rare and often non-existent in individual firms. Companies can make realistic estimates of internal users or make special efforts to isolate users through adding internal metering systems. These efforts can provide significant visibility of energy use patterns for small investments.

Actions for Reducing Energy Usage

Once a picture of a company's energy usage is available, it becomes feasible to determine where opportunities to significantly reduce energy usage exist. Then, empowered employees can begin to make system changes that reduce the power required to meet the company's mission. The type of action to be taken will depend on the type of energy used and on the user. Different energy reduction techniques may be applied in facilities, transportation, and processes.

Techniques for Reducing Energy Usage in Facilities

A number of powerful techniques for reducing the requirements for energy to operate a company's facility exist (separate from the requirements associated with processes). These are discussed below.

- **Insulation:** Since a major portion of the energy used in facilities is required for heating the facility in the winter and cooling it in the summer, much energy can be saved by reducing heat transfer between the facility interior and the environment, thus reducing the requirement for heating and cooling. Adding insulation in walls, attics, and floors can significantly reduce heat loss or gain and thus allow the interior to stay comfortable with less operation of the heating and cooling equipment.
- **Insulated Windows and Doors:** Similarly, replacing single-paned windows and doors with triple-paned glass reduces the heat passing out through the glass in cool or cold weather or coming in during hot weather. This keeps the building comfortable with less operation of the heating and cooling systems.
- **Exploit Solar Gains:** Solar energy falling on a building can be used to bring heat into the building and to provide natural (and free) lighting. Solar gains may be welcomed by adding windows to south-facing walls or by adding skylights in the roof. In cooler climates, the added heat will be a significant bonus in winter. In warmer climates, steps will be needed to preclude heat gain in the summer. One excellent way of exploiting solar heating in the winter while limiting it in the summer is to plant deciduous trees in front of south-facing windows. Because these trees maintain their leaves in the summer, they shade windows. Because they drop their leaves in winter, they allow full sun to fall on windows when heating is desired.
- **Reduce Nighttime Heat Loss:** Because heat radiates into the night sky, heating systems may be particularly active over night. To reduce the heat loss and thus the energy required for heating, windows, doors, and skylights should be fitted with insulated coverings that can be closed at sunset.
- **Lighting Efficiencies:** Lighting may account for up to 60% of facility electricity requirements [9]. Lighting may be made more efficient in three ways: use natural lighting whenever possible, perform a lighting audit to determine optimal lighting levels for different activities and reduce levels where indicated, and replace standard incandescent and fluorescent bulbs with modern energy-miser bulbs. These are relatively inexpensive actions and may save up to about 75% of lighting energy [10].
- **Use Passive Solar Designs:** Since the 1970s, passive solar designs for buildings have been developing. New facilities built with passive solar features such as Trombe walls, adobe or brick construction, and greenhouses may be much more

energy efficient than more standard buildings [11]. Since these are significant changes to building architecture, they may not be possible except in new construction or significant remodeling projects. The company should develop a policy to include passive solar features in all new construction.

- **Equipment Efficiencies:** Obtain the greatest possible efficiencies from equipment by replacing outdated equipment with new more efficient models. Replacement of older heating and cooling systems may yield especially good energy savings. Older refrigerators, stoves, copy machines, and power tools may also be excellent candidates for replacement. A second form of improving equipment efficiencies is to institute and enforce policies requiring employees to shut down all equipment that is expected to be unused for more than 10 minutes (with certain exceptions granted when the equipment has long or power-hungry start-up).

These techniques for reducing facility energy usage are summarized in Table I. Clearly, not every technique discussed here will be suitable for every facility. However, a conscientious and comprehensive effort to make all company facilities energy efficient will yield startling results in almost every case. These changes involve the dedication of both time and investment funds, but do provide noticeable immediate payback in the form of lower power bills.

TABLE I
TECHNIQUES FOR REDUCING ENERGY USAGE IN FACILITIES

Techniques for Reducing Energy Usage in Facilities
<p style="text-align: center;"> Insulation Insulated Windows and Doors Exploit Solar Gains Reduce Night-Time Heat Loss Lighting Efficiencies Use Passive Solar Designs Equipment Efficiencies </p>

Techniques for Reducing Energy Usage in Transportation

Techniques for reducing energy required for the company's transportation needs are discussed below.

- **Fleet Efficiencies:** Depending on the company, the fleets may involve just a small number of cars or light trucks, a large fleet of long-distance tractor-trailer rigs, airplanes, ships, or trains. Material handling equipment may also be considered in this category. Regardless of the type of transport the company uses, the principle of improving the efficiency of the fleet is applicable. Improved driving skills of drivers and regular routine preventive maintenance can keep the existing fleet operating at or near peak efficiencies, resulting in

up to a 5-20% reduction in energy required [12]. Replacement of older models with newer models built to higher energy standards may also contribute significantly to reducing overall fuel requirements.

- **Travel Reduction:** Reducing the need to move materials and products or the need for employees to go outside the facility can result in significant reductions in energy required, not to mention reductions in time required and in annual costs. Improved work flow patterns in the facility may mean that less material handling is required. Logistics systems improvements may result in more efficient distribution routing or the choice of more efficient modes of transportation (perhaps shipping by rail or boat rather than truck or plane). In certain situations bicycles may be substituted for automobiles to allow employees to travel short distances. Encouraging employees to use mass transit systems whenever possible may significantly reduce the need for them to use automobiles. Using modern teleconferencing systems may reduce the need for employees to travel to meetings and conferences in distant locations. Most companies can reduce their costs as well as their carbon footprints by taking a serious look at reducing all types of travel within the company.

These techniques for reducing transportation-related energy use are summarized in Table II below.

TABLE II
TECHNIQUES FOR REDUCING ENERGY USAGE IN TRANSPORTATION

Techniques for Reducing Energy Usage in Transportation
<p style="text-align: center;"> Fleet Efficiencies Travel Reduction </p>

Techniques for Reducing Energy Usage in Processes

Since the type of processes existing in a facility may vary tremendously, there are many possible techniques for reducing energy consumed in the company's processes, but not all are necessarily applicable in all situations. The major techniques are discussed below.

- **Process Changes:** Explore the possibility of changing the parameters of a process (such as reducing the heat used or shortening the time) if possible without reducing product quality. Perhaps a heat treating process time can be reduced.
- **Process Substitutions:** In many cases there is more than one option for how to accomplish a needed transformation in a product. Reviewing choices may allow the company to switch to a process that accomplishes the tasks using less energy. Perhaps parts may be joining with rivets rather than welding.

TABLE III
TECHNIQUES FOR REDUCING ENERGY USAGE IN PROCESSES

<p>Techniques for Reducing Energy Usage in Processes</p>
<p>Process Changes Process Substitutions Material Substitutions Product Changes Purchasing Outside Equipment Efficiencies Exploit Co-Generation Opportunities</p>

- **Material Substitutions:** Many of the processes required to make a product hinge on the material that is used in the product. When this is the case, a change in material used for certain parts may allow a more efficient process to be selected.
- **Product Changes:** Design changes to a product may allow for the use of different materials or may allow more efficient processes to be used. Management should require consideration of environmental issues in the design of all products.
- **Purchase Outside:** If parts or subassemblies are available from outside vendors and substantial energy is required for their in-house manufacture, substantial energy savings may result from outsourcing to a more efficient supplier.
- **Equipment Efficiencies:** In the same way that more efficient equipment can make a facility more efficient to operate, more efficient processing equipment can also make the production system more efficient. Periodically employees should review alternatives for the process equipment in use to see if more energy efficient replacements have become available in the market. Even newer models of hand-held power tools such as portable drills may consume significantly less power than older models.
- **Exploit Co-generation Opportunities:** One of the biggest energy losses in some process systems is the loss of heated water or air that leaves a process location as a by-product of the process. If this air or water is allowed to cool down in the atmosphere the energy used to heat it previously is not recovered for other uses. Companies with particularly hot wastes should consider installing a unit to use the wastes to preheat make-up water or air or perhaps to warm the building. Co-generation equipment may also be used to generate electricity that can be fed into the power system to off-set the energy drawn from the utility. Co-generation processes may recover substantial energy loss and serve to reduce total power costs.

The choices as to which of these process efficiencies may be employed in a particular facility depend on the processes being used there. A comprehensive examination of the alternatives available to “business as usual” is likely to yield several opportunities to make a considerable reduction in the energy required for the company’s process lines. When combined with other waste reducing techniques popularized in Lean Production Systems, these process improvements can lead to substantially less costly systems. Oftentimes they also lead to increased production flexibility and reduced lead times for delivery. These techniques for reducing energy usage in processes are summarized in Table III.

Other Opportunities for Improving Energy Sustainability

A few other opportunities exist for reducing energy consumption. The main ones are discussed below.

- **Account for Energy Costs:** A company can assure that energy costs are accurately reflected in all company accounting procedures so that energy requirements of operations can be more visible. Accounting for energy costs also supports more energy-efficient decision-making throughout the company. Finance and accounting personnel should include both current and future energy costs in all financial decisions of the company.
- **Educate Employees:** Employees should be educated on the importance of energy efficiency and on specific techniques they can apply to reduce consumption. Management should develop, promote, and enforce a company-wide energy sustainability program.
- **Encourage Suppliers to be Energy Efficient:** This technique takes the concepts developed within the company back in the value chain to work with suppliers to help them adopt some of these techniques that are applicable to their operations. More efficient suppliers are likely to be able to give better prices to their customers and are more likely to be in business in the future. Better suppliers will be available to the company if energy efficiency is considered a criterion in awarding future contracts.
- **Develop Energy Efficient Products:** Let energy efficiency in both production and use be a major criteria in the development of all products the company sells. Develop a new product that will use substantially less energy than the one it replaces. Energy efficient products will be valued in the marketplace of the future and will provide a marketing edge to producers. Such products will contribute greatly to long-term company sustainability and to global environmental sustainability.
- **Add Renewable Energy Sources:** Most of the techniques mentioned here will serve to reduce total energy demanded by company operations. However, also in the spirit of creating both financial and environmental sustainability, a company should include renewable energy sources

wherever possible and practical. This would include projects such as adding solar photovoltaic or solar hot water systems to the roof of the factory if located in an appropriate area. Putting a wind turbine at the edge of the employee parking lot might make a major difference in the company's carbon footprint.

This last set of techniques (summarized in Table IV) reach beyond the obvious areas of direct energy reduction opportunities. Nevertheless, these areas do have significant opportunities to reduce the overall energy needs of a company. The truly environmentally conscious managers will investigate these opportunities.

TABLE IV
TECHNIQUES FOR REDUCING ENERGY USAGE IN FACILITIES

<p>Other Opportunities for Improving Energy Sustainability</p>
<p>Account for Energy Costs Educate Employees Encourage Suppliers to Be Energy Efficient Develop Energy Efficient Products Add Renewable Energy Sources</p>

CONCLUSIONS

We have looked at a wide range of generic techniques that can be applied to any type of industry in order to reduce the amount of energy required to accomplish the company's mission. The reduction in energy consumption translates to putting the company in a stronger financial position over time and to contributing to long-term sustainability of the global environment.

For companies engaged in the development of alternative energy products or Green technologies, whole-hearted participation in a serious energy reduction program is consistent with organizational mission and sustainability. Failure to build Green technology in highly efficient production systems would be seriously short-sighted.

Establishment of an effective Environmental Management System that sets challenging goals and empowers employees to reach them coupled with efforts to identify unnecessary energy use and implementation of techniques to reduce energy use can work together to assure a progressive company of long-term financial viability and can make a significant contribution to the reduction of greenhouse gases and improvement of Earth's environment.

It is incumbent on Green technology companies to set an example of sustainability that will encourage companies in every industry to undertake ambitious programs designed to contribute to company sustainability, societal sustainability, and environmental sustainability.

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