

Energy Conservation through Productivity Enhancement in Manufacturing Facilities

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ABSTRACT

The goal of this research work is to explore the energy savings that may result from productivity improvement recommendations. The productivity improvement recommendations on setup time reduction and finished goods inventory reduction were taken from Industrial Assessment Center (IAC-WVU) and Industries of the Future (IOF-WVU) databases at West Virginia University (WVU) and analyzed to evaluate the corresponding energy savings. A simulation analysis was performed to compare the peak energy demands (kW) in the present and proposed scenarios for the setup time reduction recommendation. It was found that productivity improvement recommendations can result in significant energy savings (2% to 4%).

INTRODUCTION

PRODUCTIVITY IMPROVEMENT - Many manufacturing companies are under pressure from international competition to reduce product lead times and total costs, while increasing product complexity and customization. The need for productivity improvement was felt by the U.S. industries during the 70's and early 80's when the Japanese manufacturing industry was able to deliver high quality and reliable products at lower costs. Various manufacturing philosophies like Just-in-Time (JIT) manufacturing [Hall 1983, Hay 1988], lean manufacturing [Womack and Jones, 1994], time-based competition [Stalk and Hout, 1990], the agile enterprise [Goldman et al., 1995; Nagel and Bhargava, 1994], and kaizen [Masaaki Imai, 1986] were introduced to focus on the one primary goal of productivity improvement [Montaban et al., 1997]. Even though most of these techniques encompass all the input to the processes for increasing the productivity, the consideration to the

impact of energy cost savings has not been given proper attention in the past. Multi-factor productivity indicates the ratio of many or all resources to the goods and services produced [Heizer et al., 2000] and is defined as:

$$\text{Multi-factor Productivity} = \frac{\text{Output}}{\text{Labor} + \text{Material} + \text{Energy} + \text{Capital} + \text{Miscellaneous}}$$

It may be noted that energy is one of the basic inputs to any process but has not been given enough attention in the past during the productivity improvement projects. This research briefly introduces the relationship between productivity improvement philosophies and associated energy conservation opportunities.

LEAN MANUFACTURING - Taiichi Ohno and Shigeo Shingo at Toyota originated lean manufacturing, which is also known as the Toyota Production System (TPS) [Pavnaskar et al., 2003; Connstep, 2001; Zimmer, 2000]. Lean manufacturing is simply a group of strategies for elimination of waste by identification and elimination of the non-value added activities inside the value stream. The seven major categories of production wastes that were identified are overproduction, extra inventory, defects, inappropriate processing, waiting, excessive transportation, and wasted motion [Sullivan, et al., 2002; Kaizen for the Shopfloor, 2002]. Generally, the reasons for these wastes are lengthy setup times, low labor/machine effectiveness, poor equipment maintenance, lack of communication, improper facility layout, inefficient policies and procedures, poor process documentation and inaccurate forecasting systems. Setup or changeover time reduction is very important to companies seeking to be more responsive to their customer needs. Shigeo Shingo

methodology for setup reduction, the Single Minute Exchange of Dies (SMED) [Shingo, 1985].

ENERGY CONSUMPTION IN THE U.S. - Until 1950, the U.S. produced enough energy to cater for the needs in the country but as consumption started increasing, the gap between production and consumption increased; and by 1970, the gap was quite significant (Figure 1) [Web: eia.doe]. Traditionally energy is consumed in four broad sectors in the U.S., namely residential, commercial, industrial, and transportation with industry being the highest consumer. About 60% of the industrial sector energy is used for manufacturing [Web: eia.doe].

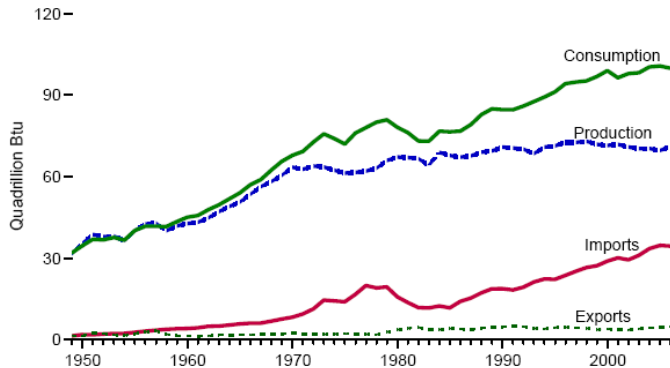


Figure 1: Overview of Energy Production and Consumption

Natural gas is the most commonly used energy source in manufacturing. Energy consumption by end use between 1949 and 2006 is illustrated in Figure 2 [Web: eia.doe].

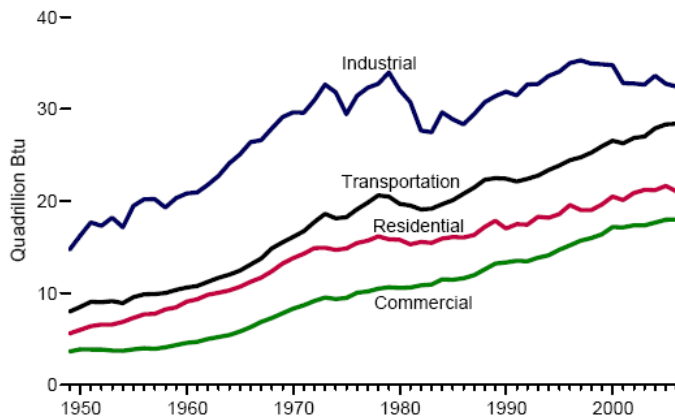


Figure 2: Energy Consumption by End Use

Energy has a significant impact on the U.S. economy. Rapid escalation of fuel costs, the instability of supplies and predicted future limitations have made manufacturers re-think on energy use. Looking at these trends, the U.S. Department of Energy (DOE) has started various programs like Industrial Assessment Centers (IAC), Industries of Future (IOF), and BestPractices to help companies save energy and increase overall efficiency in energy utilization [Web: BestPractices, ITP]. Energy auditors have traditionally considered energy conservation opportunities as being independent of other industrial opportunities, such as

waste reduction/pollution prevention, and other management issues [Kasten et al., 1997].

PRODUCTIVITY IMPROVEMENT AND ENERGY MANAGEMENT - Energy management is the judicious and effective use of energy to maximize profits (minimize costs) and to enhance competitive positions [Thumann et al., 1995]. Any productivity improvement recommendation can be classified either in terms increasing pieces/person/hour or decreasing cost/piece. The main objective of the productivity improvement is to optimize the use of resources involved in producing products. Some of the most commonly suggested productivity improvement recommendations are explained as [Muller et al., 1996]:

- Increase Pieces/Person/Hour
 - Bottleneck mitigation
 - Defect reduction
 - Quick Changeovers
 - Labor optimization
 - Preventive/predictive maintenance
- Decrease Cost/Piece
 - Purchasing
 - Floor layout
 - Inventory
 - Burden/overhead
 - Scheduling

Space Optimization - Space is an important resource that gets overlooked in many facilities. To optimize the space utilization, there are four basic recommendations that can be considered [Muller et al., 1996].

- to optimize existing floor layout
- lease excess space to outside interests
- reduce leased space requirements and
- avoid new construction for future expansion or demolish the dilapidated space to reduce tax and insurance expenses.

All the recommendations in terms of optimizing space were pure productivity improvement recommendations but other possible opportunities would be to reduce or avoid operating costs for the space (lighting, HVAC, etc.) thus resulting in energy savings.

Setup Time Reduction - Quick Changeovers - Setup time reduction has a very high impact on customer satisfaction as shorter production runs mean more frequent changeovers, more frequent production of the wide product mix, and therefore, faster response to the customer demands [Szatkowski et al., 1991]. Reducing setup time results in making the same number of products in much less time or making more products in the same time (increasing throughput).

Inventory Reduction - During the process of energy assessments, most of the times, excess inventory is observed in the manufacturing facilities. Inventory is one of the expensive assets of many manufacturing

industries, representing as much as 40% of the total invested capital [Heizer et al., 2000]. Some of the reasons for excess inventory are lack of workplace organization, frequent machine breakdowns, excessive manufacturing lead times, communication problems, reward systems, quality problems, unreliable equipment, supplier deliveries, long setup/changeover times, and unreliable market forecasts. It can easily be proved that every productivity improvement has an associated energy gain and/or a reduction in the waste.

ENERGY ASSESSMENTS - Traditionally, energy auditing consisted of recommendations dealing with energy only improvements. But once productivity, waste and other opportunities were incorporated, the audit process became more effective and beneficial to the facilities. The IAC program began incorporating productivity recommendations into their assessments in 1997 and since then, these recommendations account for 10%-15% of all the recommendations. Of the \$853 million total dollar savings for all recommendations since 1997, productivity recommendations account for \$423 million i.e. almost 50% of the dollar savings [Kyriaki et al., 2003].

Presently, the recommendations in the areas other than energy savings do not show the real impact of the recommendations on the energy efficiency. In many cases e.g. in the areas of productivity improvements, the amount of energy used may be increased. In these cases, the recommendation reflects negative energy savings while in reality; the overall energy usage per unit is reduced. If the indirect energy savings are not accounted for in the total savings, some of the recommendation may even be rejected because of more energy consumption. This research work aims to bridge this gap and develop some metrics to relate the savings from productivity improvements to the energy savings.

LITERATURE REVIEW

PRODUCTIVITY IMPROVEMENT MEASURES - Energy costs for the U.S. manufacturers typically represent only 1-7% of the total product cost [Hopkins et al., 1995]. Thus, even with achieving significant energy efficiencies, their impact on the total product cost will be fractional and it may not drive the management to implement energy related recommendations. Therefore, it is wise to invest the resources in projects that address productivity and throughput issues while considering the related energy efficiency and waste reduction opportunities.

A productivity-training manual prepared by OIT (Office of Industrial Technology) staff, is a very helpful tool in providing various productivity improvement recommendations and gives a brief idea on how the productivity savings can be linked to energy savings [Muller et al., 1996].

Often the impact of productivity projects on energy use in plant is ignored or underestimated. It is quite clear that the appropriate metric in evaluating energy impacts of

productivity related projects would be improvements in energy intensity [Kyriaki et al., 2003].

PRODUCTIVITY IMPROVEMENT AND ENERGY CONSERVATION - The Total Assessment Audits (TAA) implemented by Iowa energy center is explained by Haman (2000). The TAA methodology partners the upper management team of a company with multi-disciplined team of industry-specific specialists to collectively ascertain the core opportunities for improvement in the company and then formulates a company oriented continuous improvement plan. Productivity, waste reduction, and energy efficiency objectives are seamlessly integrated into a single service delivery with the TAA approach [Haman, 2000]. The four critical elements for a successful TAA are: first, company should be willing to change and an audit should be seen as something that brings in continuous improvement in the company. Second, the company should be able to benchmark and analyze their operations quickly. Third, the company should believe in teamwork and should work well in teams. Fourth, and the most important element is to have credibility in the entity offering assistance.

Various productivity measures for energy management are explained by Turner et al., 1981. This article researches energy productivity monitoring and control measurement systems. Various indices of BTU/unit of production, BTU/square foot of conditioned space, and BTU/direct labor hour are examined with their relative advantages and disadvantages. After the analysis, new indices like BTU/sales dollar, \$energy/\$sales (\$profit) (\$value added) are proposed with their relative advantages and disadvantages. This paper examines energy accounting starting with a look at "one shot" productivity measures expanding into more sophisticated accounting systems by analyzing General Motor's, Carborundum's, and Ace Manufacturing Company systems in detail.

The relationship between energy efficiency improvement measures and productivity in various industries is explained by Laitner et al. (2001). The authors studied the iron and steel industries in the U.S. and found that including productivity benefits directly in the modeling parameters would double the cost effective potential for energy efficiency improvement, compared to an analysis excluding those benefits. A framework for evaluating the productivity benefits of energy efficiency is laid out and is explained in the following 4 steps [Laitner et al., 2001; Worrell et al., 2003]: first, to identify and describe the productivity benefits associated with a given measure; second, to quantify these impacts as much as possible; third, to identify all the assumptions needed to translate the benefits into cost impacts; and fourth, to calculate cost impacts of the productivity benefits. By following the above framework, the cost evaluation of productivity benefits is formalized and by using bottom-up energy conservation supply curve (CSCs), they can be incorporated into an energy scenario analysis. The relationship between energy efficiency improvement

measures and productivity in industry (considering 77 case studies from available databases) is explained by Worrell et al., 2003. A total of 52 case studies that monetized non-energy savings and an additional 25 case studies that qualitatively documented non-energy benefits were analyzed during this course of study and a framework was laid out as explained above. Of the 52 monetized case studies, the dollar ratio of savings from non-energy benefits to savings from energy efficiency ranged from 0.03 to over 70, initially indicating a wide range of added value derived from the non-energy benefits. However, in 63% of these case studies, the non-energy benefits were equal to or greater than the energy savings. In nearly 30% of these case studies, the non-energy savings were more than four times the energy savings [Worrell et al., 2003]. Several authors have studied the relation between productivity and energy efficiency and found a direct relationship using different methodologies and datasets. [Boyd et al., 2000; U.S. DOE, 1997; Hodayah, 2001]

Integrating productivity improvement, pollution prevention, waste minimization and energy conservation opportunities has always proved beneficial and effective on a corporate level as energy-only recommendations can have little or no-impact on productivity [Kasten et al., 1997]. With their immense knowledge on energy assessments, the members of Industrial Assessment Center (IAC) program at Rutgers University explain how different elements in a manufacturing firm have to be incorporated in the traditional energy auditing. They give examples of three different manufacturing companies (plastic cup, bottle making, and tire making companies) who were recommended to implement both energy and productivity savings together which made them save both energy and get cost benefit by improving productivity. As energy auditing is becoming more and more comprehensive, the auditors should analyze the effects of a recommendation on the entire manufacturing process. Sometimes, the actual energy use may in fact increase, resulting in increased paybacks and misleading indications about energy efficiency. It is the auditor's responsibility to show quantifiable results to the industrial management client.

A new methodology proposed by the members at IAC, Rutgers to calculate the overall productivity improvement and to calculate corresponding improvements in energy intensity is explained by Kyriaki et al., 2003. This article explains a method to calculate effective energy savings (EES) in three-step process and takes four manufacturing company's case studies (corrugated cardboard, grey iron castings, lighting fixtures, and car and forklift battery manufacturer) as examples to explain how energy intensity can be optimized with energy consumption as the only variable (which can increase, decrease or remain same) with increased productivity. Therefore, the ultimate goal for any manufacturing facility would be to increase productivity and decrease energy intensity.

The articles discussed so far have proven, how significant improvements in energy management led to productivity improvements and waste minimization opportunities, but there is not enough work done to support these ideas. This research is an effort to bridge the gap and come up with metrics to relate energy efficiency and productivity.

JUSTIFYING EFFICIENT PROJECTS TO MANAGEMENT - THE CORPORATE VIEW POINT - Traditionally energy auditing was considered as recommending pure energy conservation opportunities independent of waste reduction/pollution prevention and productivity improvement to management. If a recommendation cannot be shown to have a secondary or even tertiary benefit to the company, the project cannot be "sold" to the management [Kasten et al., 1997]. In order for any recommendation to be approved by management, it has to be shown financially viable. A corporate audience responds more readily to a dollar-and-cents impact than to a discussion of plant utilities such as steam, motors, and compressed air [Russell, 2001].

There are various publications that discuss, on how to convince management for efficient projects and on "how to sell ideas". Lindo explains how management can approve a good idea given that, it is introduced at the right time and the person can actually sell it [Lindo, 1996]. Lindo says, in order for a project/idea to be approved, there are six steps that have to be followed by the person who is presenting it. First, a proper conception of the idea is required as to give a clear picture of what it would be once the project is completed; second, to be concise and clear while presenting the idea; third, to present the idea in such a way that the supervisor will feel the essence of implementing it; fourth, to keep the attention of the audience by highlighting important points; fifth by summarizing the action-oriented summation pinpoints addressing specific actions for individuals; and finally, closing the scale by being confident, enthusiastic and respectful of the audience. By laying a proper foundation, a well-timed promising idea will definitely be sold.

Many people cannot sell an idea, as they fear rejection and some because of the reluctance to spend time and effort presenting it [Pollock, 2001]. Ted Pollock suggests ways on presenting new ideas to the management. It is the presenter's responsibility to spend, as much time as needed depending on the audience's age, position, technical skill, education and to explain until everyone in the room feels comfortable and confident on the subject. Audiences have to be given ample time to think and ask questions. After a very good presentation, audience responses have to be measured and if they do not seem to be impressed, then presenter has to change his tone in a way that is heard. An idea that has virtue will definitely be sold with continuous and constant effort.