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Energy and Productivity, Two Sides of a Coin in the U.S. Auto Industry

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ABSTRACT

Productivity is a significant issue in the US auto industry that is often viewed as the success or failure that a vehicle assembly plant can make or break their production schedule. In other words, productivity is often looked at in terms of the number of assembled vehicles produced per year. While high production volume is an important indicator in a manufacturing environment, it certainly does not necessarily imply high productivity. By definition, Productivity is the ratio of output (number of vehicles produced) divided by all input resources such as labor, material, capital, overhead, health and energy costs. Improvement in productivity can be achieved in two ways: a reduction of inputs while output remains constant, or an increase in output while inputs remain constant. Energy is the single most controllable cost parameter in the input parameters of the productivity equation. In today's competitive marketplace, energy efficiency can provide means to improve productivity through reducing the manufacturing energy cost. This paper addresses this missing link between energy and productivity in U.S. auto industry. Furthermore, it outlines a methodological approach for driving improvements in energy usage in a major vehicle assembly plant in US. It is hoped that efforts in this direction would pave the road to better understand role of energy as an important factor in the assembly plant's vision to productivity improvement.

INTRODUCTION

The four major challenges facing the US auto industry nowadays are; 1) dramatic rise in oil prices, 2) the resulting change in auto industry sales mix, 3) the continued increase in interest rates, and 4) the lack of progress in addressing the U.S. trade deficit. In response to these challenges, researchers should focus their efforts to drive improvements through reducing the total manufacturing cost (structural cost and material cost). The major key drivers of structural costs are labor, health care plans, and utility costs. In this paper, the author will focus on the last key driver in an effort to contribute to the US Auto Industry turnaround plan to improve its productivity.

THE SCIENCE OF PRODUCTIVITY

Production is the creation of goods and services [1]. This creation requires changing resources into goods and services. Productivity is the measure of how efficiently this change is made. Single-factor productivity is defined as the number of units produced per labor-hour as summarized in the following equation [1]:

$$P = \frac{Q}{LH} \qquad (1)$$

A broader view of productivity is multifactor productivity which is calculated by combining all the input parameters to the production system as shown in the following equation [1]:

$$P1 = \frac{Q}{LC + MC + OC + HC + EC} \qquad (2)$$

Use of productivity measures aid managers in determining how well they are doing. Improving productivity means improving efficiency. As the above equations suggest, this improvement can be achieved in two ways: a reduction of inputs while output remains constant, or an increase in output while inputs remain constant.

PRODUCTIVITY IN AUTOMOBILE INDUSTRY

Productivity in the U.S. automobile industry is a concept that lots of people have very strongly held views about, few people can firmly define and none can persuasively measure. Often times, productivity is viewed as the direct labor hours per vehicle (HPV) [2]. Other times, productivity is conceived as the success in getting as much production units as possible during a given production shift. Applying these widely-agreed-upon definitions to the U.S. auto industry, though, is problematic [3]. The direct labor hours per vehicle (HPV) used for assembly would not be an accurate measure of productivity. If the machinery that replaces the labor gets expensive enough, it will be more efficient to hire more labor even if this drives up the factory wage. Further

clouding matters, some assembly plants also include stamping facilities in which the body parts are formed while others bring such parts in from outside the factory, and some assembly plants include their own paint shops while others do not. Add to all this the fact that many plants produce multiple products so attributing the fraction of capital costs to each particular product is tricky at best [3]. Moreover, the success of achieving the production schedule goals may not necessarily mean high productivity. Inefficient manufacturing system with uncontrolled resources and waste can be an added burden to the manufacturing cost associated with producing more vehicles, driving down productivity of the manufacturing system.

To achieve optimal productivity, each related manufacturing process must operate at peak performance and the overall management of these processes must be integrated. Production throughput, labor hours per vehicle and manufacturing cost (including energy cost) must be viewed together as the multifactor productivity definition suggests.

ENERGY USAGE PATTERNS IN VEHICLE ASSEMBLY PLANT

To study the opportunities for energy systems improvement, it is important to understand how energy is used in auto assembly plant. This should include the distribution of each type of energy stream and the total amount of energy used in each operation as well as a thorough study of the load curve of the given plant. The main energy sources in a typical auto assembly plant are fossil fuels (natural gas and sometimes coal), and electricity. Fuels are mainly used for space heating, steam generation, and in the curing ovens of the painting lines. Electricity is used throughout the facility for many different purposes, e.g. compressed air, lighting, ventilation, air conditioning, motors, materials handling and welding. Estimates of the energy usage in vehicle assembly plants may vary among plants based on the processes used in that facility [4]. This variation presents a challenge when trying to benchmark the energy use between auto assembly plants [4]. However, in this paper, we provide a methodological approach that is applicable to U.S auto industry in general. For this purpose, the differences between plants are not as much of importance; noting that the approach developed may still apply to other assembly plants. Figures 1, 2, 3, and 4 summarize the patterns of energy usage in a typical U.S auto assembly plant.

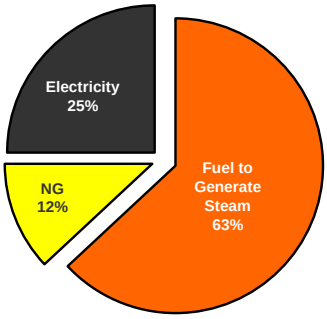

Fig. 1 Energy Distribution by Type in a Typical Auto Assembly Plant

As shown in Fig. 1, Fuels represent 75% of the energy use, while the electricity represents the remaining 25% of the total energy use in a typical auto assembly plant. About two-thirds of the energy budget in assembly plants is spent on electricity due to the difference in prices between fossil fuels and electricity. This demonstrates the importance of the electricity in the fuel mix [4].

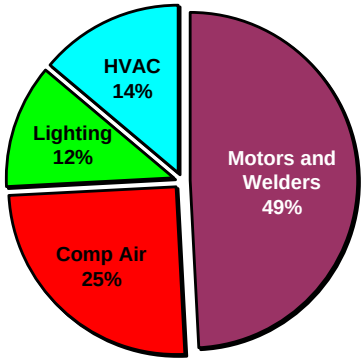

Fig. 2 Main Electrical Energy Consumers in a Typical Auto Assembly Plant

Fig.2 shows that the electric motors and welding machines account for nearly 50% of all electricity used to drive the different pieces of equipment in the plant and metal welding operations. This emphasizes the importance of motor system optimization and adopting technologies such as high efficiency welding systems including power factor improvement techniques in the energy efficiency improvement strategies. Compressed air system accounts for 25% of all electricity used underlying the importance of repairing air leaks, and using more efficient air assisted equipment as an interim step to minimize the dependency on compressed air to lowest level possible through upcoming emerging technologies.

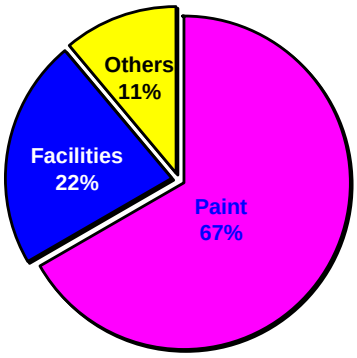

Fig. 3 Steam Usage in a Typical Auto Assembly Plant

Fig. 3 suggests that paint is the major consumer of steam in a typical assembly plant underlying the importance of addressing the saving opportunities in paint steam system. Reduction of airflow in paint booths, and repairing steam traps in paint process steam system are the biggest saving opportunities. Mostly, other uses of steam are in space heating, car wash, and other non-manufacturing purposes.

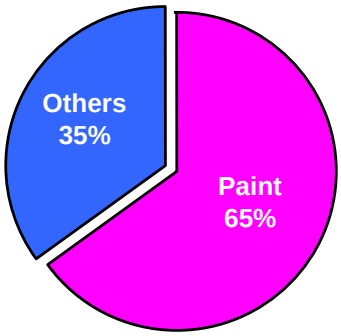

Fig. 4 Natural Gas Usage in a Typical Auto Assembly Plant

Paint is another major consumer of Natural gas in a typical assembly plant underlying the importance of looking for energy saving opportunities in paint cure ovens including burner combustion efficiency improvement [5], minimizing ovens stabilization period, Insulation, and Heat recovery. This is in addition to considering technologies such as Infrared paint curing, Ultraviolet paint curing, and Microwave heating.

APPROACHES TO DRIVE IMPROVEMENTS

First Approach "THE INSIDE-OUT APPROACH"

One of the approaches used was the protocol developed by Kissock, et al. [6] for identifying energy savings opportunities that begins at the heart of the production plant, with the equipment that actually manufactures the product, and works outward. The author has used this approach in a previous energy conservation study in a major auto casting plant in conjunction with other energy consultants [7]. According to this approach when seeking to reduce energy costs, we sequentially analyze the manufacturing equipment and processes, the energy distribution systems, the primary energy conversion equipment, and finally the utility services. By first looking for savings opportunities at the heart of the manufacturing process, and then working out toward the plant boundary, savings are multiplied because distribution systems, energy conversion equipment and waste treatment processes can be downsized or eliminated. Unlike the traditional approach the "Outside-IN Approach" where the analysis begins at the plant boundary and works incrementally inward toward the actual manufacturing processes. In many cases, the "analysis" will end here with the simple solicitation of quotes for higher efficiency equipment. In rare instances, the analysis may move beyond the primary energy conversion equipment (boiler, chiller, air compressor, and lighting) to consider the actual manufacturing equipment and processes. During the protocol of "THE INSIDE-OUT APPROACH", process flow diagrams are used to indicate the magnitude and location of energy-use, waste generation, and production costs of the manufacturing processes. Using these diagrams, specific systems, equipment, and processes are to be targeted for detailed analysis to identify, analyze and prioritize the most attractive energy savings opportunities.

Second Approach "THE KAIZEN TEIAN APPROACH"

Kaizen [8,9,10] is a widely known proven continuous improvement approach that concentrates on channeling employees' creative energies and hands-on insight. In few words, this approach focuses on People's participation in improvement as a key to success. Continuous improvement is essential for a company to survive in today's competitive global marketplace. Energy efficiency improvement directly impacts the productivity and the bottom line of the US auto industry. On that basis, It is imperative to create a common understanding of major energy challenges among the different plant levels. Awareness is an important dimension in any successful energy management program. Although technological changes in production process levels conserve energy, changes in staff and operators behavior and attitude can have a great impact. Through regular weekly meetings, almost daily verbal and written communications, staff becomes aware of the potential energy deficiencies, action plans to solve the deficiencies, and their role to put these plans to actions. Using this approach, attention should be given to improving energy shutdown methods and procedures during the non-production periods. Compressed air systems, lighting systems, building HVAC systems, and paint process equipment are among the shutdown items that should be given attention day after day. A shutdown goal of SD%, and SD1% of the electric demand through non production time during the working week and during the weekends, respectively, must be established and monitored closely. Deviations from these baselines have to be reported immediately and corrective actions must be taken instantly to achieve the established shutdown goals. This significantly reduces energy consumption during down times.

ENERGY, THE DIRECT IMPACT ON PRODUCTIVITY

Let's give an example of the direct relationship between energy and productivity over the course of five years utilizing the earlier definition of productivity. Assumptions will be made to explain the concept. Consider that the production volume of a given auto assembly plant is 185,000 assembled vehicles per year. According to the productivity definition, this is considered the plant output and will be given the symbol Q. Let's also assume that all the input items to the manufacturing system (Labor Cost, Material Cost, Overhead Cost, and Health Cost) would remain constant at a rate of $315 million per year during the five year study period would be associate it with the symbol Y. Lets, also, for the sake of this example, assume that the total energy cost over a period of one year is $17 million and symbolize it as X1. Hence, Multifactor Productivity (P1b) for the existing manufacturing system can be estimated as follows:

$$P1b = \frac{Q}{Y + X1} \qquad (3)$$

Assuming that an energy conservation program would result in a 25% accumulated savings in the five year study period (n=5) with an improvement of Z(i) = 5% per year. We will denote the cumulative reduction in energy usage over n-year period by $\sum_{i=1}^{i=n} X2(i)$, where:

$$\sum_{i=1}^{i=n} X2(i) = X1 - \sum_{i=1}^{i=n} Z(i) \times X1 \qquad (4)$$

How would this yearly 5% energy reduction for a projected period of five years translate into the company's productivity?

The plant cumulative Multifactor Productivity $\sum_{i=1}^{i=n} P2(i)$ that captures this reduction in energy usage can be estimated as follows:

$$\sum_{i=1}^{i=n} P2(i) = \frac{Q}{Y + \sum_{i=1}^{i=n} X2(i)} \qquad (5)$$

The following equation measures the change of Productivity as a result of energy improvement:

$$\sum_{i=1}^{i=n} \Delta Productivity(i) \uparrow = \frac{\sum_{i=1}^{i=n} P2(i) - P1b}{P1b}$$
$$\sum_{i=1}^{i=n} \Delta Productivity(i) \uparrow = \frac{(Y + X1)}{(Y + \sum_{i=1}^{i=n} X2(i))} - 1 \qquad (6)$$

Equation (6) tracks the productivity variation as a function of energy variation in auto assembly manufacturing system. It can be plotted using the assumed production parameters given at the beginning of this section as shown in Fig (5).

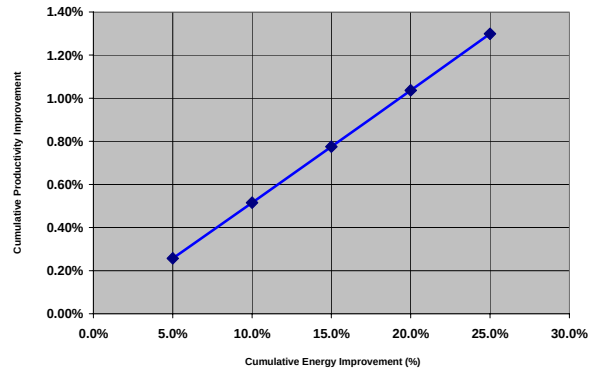

Fig. 5 Productivity Improvement Resulted from Energy Improvement over a Five Year Period

** Assuming Fixed Production Volume and Manufacturing Cost*

Fig. (5) Proves the relationship between energy and productivity. It is indeed remarkable to gain 0.22% in productivity by curtailing plant energy consumption by only 5% per year. In a typical auto assembly plant, this fraction of productivity gain can simply mean hundreds of thousands of dollars.

CONCLUSION

A major energy challenge is to identify manufacturers' embedded energy costs. Managers at each stage of manufacture may overlook energy waste because "energy is only four, or five or six percent" of production costs. But the prices of final products must absorb these layers of energy inputs. For example, the direct energy cost for assembling a vehicle might be only a few dollars—and a very small fraction of its retail cost. But in the big picture, there was energy consumed in producing different components such as engine, transmission, tires, in rubber and glass manufacture; in powerhouse fuels for the facilities that make plastics, paints, and dyes; which are energy commodities consumed directly as product ingredients. Any waste of energy in the manufacture of these intermediates, disguised in the cost of inputs, eats up profit margins at every step. In effect, consumers are "taxed" for any waste committed at all stages of the manufacturing process. Unprecedented vehicle profit curves and eroding shareholder value have provoked most automotive companies to undertake increased innovation efforts at significantly reduced cost. Energy cost is among the costs that can be easily controlled to contribute to US auto industry productivity.

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DFINITIONS, ACRONYMS, ABBREVIATIONS

P	Productivity
P1	Multifactor Productivity
LH	Labor-hour
Q	Production Volume
SD%	Non-Production Energy Shutdown Percentage
SD1	Weekend Energy Shutdown Percentage
P1b	Multifactor Productivity before Energy Reduction
$\sum_{i=1}^{i=n} P2(i)$	Cumulative Multifactor Productivity after Energy Reduction over n-years
i	Denotes a given year
n	Number of Projected Years
X1	Annual Energy Cost
$\sum_{i=1}^{i=n} X2(i)$	Cumulative reduction in energy usage over n-years
Y	Total manufacturing cost less energy cost.
Z	Fixed yearly percent energy reduction
$\sum_{i=1}^{i=2} \Delta \mathrm{Pr}oductivity(i) \uparrow$	Cumulative Productivity Improvement over n years.
MC	Material Cost
OC	Overhead Cost
HC	Health Cost
EC	Energy Cost
LC	Labor Cost