Electrical Energy intensity as a Cleaner Production measure for resource usage optimisation: An investigation into a tobacco manufacturing company in Zimbabwe

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ABSTRACT

This paper presents a study on electrical energy intensity as a cleaner production measure for resource use optimisation. The aim of this research was to analyse the economics of cleaner production measures for electrical energy intensity. The researchers carried out an electrical energy audit at a typical tobacco manufacturing company in Zimbabwe. An energy matrix was administered to analyse the responsiveness of the sector to electrical energy efficient programs. Interviews with critical members were carried out as well as a review in the historical data. The company's performance indicators used in this paper are electrical energy consumption, maximum demand, production output, load factor and power factor. Results reviewed inconsistencies and poor performance in terms of electrical energy efficiencies. The researchers' recommended Demand Side Management (DSM) programs for energy efficiency and the cost effectiveness of these were evaluated. The result was a 10% reduction in electricity costs. Improving the electrical energy efficiency offers many cost reduction opportunities.

Keywords*:* Electrical energy intensity, Cleaner Production Demand side Management (DSM), Eco-efficiency

1. INTRODUCTION

Competing and succeeding in today's business environment requires clear strategies for managing a variety of expenses incurred on a daily basis and electrical energy is no exception. As energy prices continue to rise, manufacturers are coming under increasing pressure to be proactive and manage their energy consumption while also maintaining compliance with evolving sustainable requirements. Electrical energy intensity gives an indication of the effectiveness with which electrical energy is being used to produce added value. It is defined as the ratio of electrical energy consumption to production output. Electrical energy performance indices include maximum demand, load factor and power factor. Managing these indices ensure reduction of costs.

Maximum demand is the largest value of the kW demand in a given period (month, quarter or year). The Bureau of Energy Efficiency explains that considerable savings can be realised by monitoring power use and turning off or reducing non-essential loads during such periods of high power use. Load factor is defined as the ratio of average active load (kW) to the maximum kW demand over a day, month or year and serves as an indicator of the effectiveness with which electricity demand is managed. The power factor level of an industrial plant is an indication of the amount of reactive power the plant demands. Power factor is the ratio of the real power flowing to the load to the apparent power, and is a number between 0 and 1. Utilities typically charge additional costs to customers who have a power factor below some limit (which is typically 0.9 to 0.95).

Implementing cleaner production strategies will help industry to lower production costs, increase productivity, facilitate efficient resource use, develop safer and improved products, reduce pollution levels for humans and the environment and assist in compliance with environmental management systems for certification and performance or recognition in global markets. Industry across all sectors always aspires to increase production capacity and enhance competitive advantage.

2. LITERATURE REVIEW

Cleaner Production is defined as the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase eco-efficiency and reduce risks to humans and the environment [1], [9]. It serves economic and ecological efficiency ('eco-efficiency') and contributes to realisation of the environmental risk reduction and management objectives for humans and the environment. According to the World Business Council for Sustainable Development (WBCSD) eco-efficiency is 'reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's carrying capacity'[4]. For production processes, Cleaner Production aims in particular at conserving raw materials and energy, eliminating toxic raw materials, and reducing the quantity and toxicity of all emissions and wastes before they leave the process.

Demand Side Management (DSM) replaced energy conservation in the mid-1980s as the umbrella term for the science and policy of reducing the demand for energy [8]. The semantic evolution has continued in recent years to "market transformation" and "energy efficiency on the demand side." The amount of energy used to produce a unit of output is termed energy efficiency. Energy efficiency is using less energy to provide the same level of energy service.

Energy efficiency and energy conservation are very closely related to each other. With increase in demand of energy and due to uncertainties in oil supply and fluctuating price of conventional fuels, efficiency and conservation of energy has become an important aspect of industrial development [6]

Demand Side Management is the process of managing the consumption of energy, generally to optimize available and planned generation resources [10]. It also refers to "actions taken on the customer's side of the meter to change the amount or timing of energy consumption [10]. DSM also refers to cooperate activities to implement options for increasing the efficiency of energy utilization with resulting benefits to the customer, utility and society as a whole. These measures can be directly linked to cleaner production

DSM programs are aimed at reducing the energy used by specific end- use devices and systems, typically without affecting the services provided. These programs reduce overall electricity consumption, often without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technologically more advanced equipment to produce the same level of end-use services with less electricity.

3. JUSTIFICATION

Changing electricity markets in the developing and the developed countries face several challenges, largely due to the uncertainties in the load growth investments required in capacity addition, declining fuel sources and its associated environmental costs. The concept of Demand Side Management (DSM) was developed in response to the potential problems of global warming and the need for sustainable development, and the recognition that improved energy efficiency represents the most cost effective option to reduce the impacts of these problems.

The trends in the supply of energy in Southern Africa encourage companies to analyse and review their energy consumption by adopting appropriate strategies. At the heart of the energy predicament in Zimbabwe and the Southern African Development Community (SADC) region is the fact that demand for electricity outstrips supply. The Zimbabwe Electricity Supply Authority (ZESA) being the sole electricity generating company in Zimbabwe is faced with challenges of ensuring the supply of electricity.

Energy conservation and energy efficient programs are essential to overcome mounting problems of the worldwide energy crisis, and are a necessary contribution to the sustainable transition. Reducing energy usage does more than save money; it reduces a company's effect on the environment by consuming fewer finite resources and reducing the generation of harmful greenhouse gases. Demonstrating good environmental credentials will not only be increasingly required by law, but will have a beneficial effect on a company's public image and on customers. Additionally, monitoring of greenhouse gas emissions, maintaining an accurate carbon footprint inventory, and providing source accountability for carbon cap and trade credits is becoming essential.

4. RESEARCH METHODOLOGY

Some companies have not factored energy consumption into their tactical production planning, execution decisions and strategic planning because they do not have the right data in the appropriate context. Timely visibility to energy consumption at a local level (manufacturing area, equipment, and product) does not exist, so companies are unable to optimise their production-related energy consumption. With a detailed understanding of the energy consumption for specific production areas, equipment, and products, manufacturers can better manage production planning and execution as well as strategic contracting in an informed and responsible manner.

Energy management is much more than simply carrying out an energy study or audit of the plant. Energy audits may be useful in the plant in gaining an appreciation of where the major energy losses are and what kind of solutions is required. The researchers performed an energy audit to ascertain the load types and losses. An energy matrix was administered to analyse the responsiveness of the sector to energy efficient programs. An assessment of the energy matrix was done to identify and describe the current priority attached to different aspects of energy management in the organization. The matrix was made up of six elements:

1. Policy and systems
2. Organization
3. Motivation
4. Information systems
5. Training and awareness
6. Investment

The rows of the matrix represent increasing levels of complexity or sophistication in dealing with six key management issues. Level 0 is the lowest and level 4 is the highest. Moving up the matrix signifies an increasingly mature and formal approach to handling energy management activities and implies increasing 'good' practice.
Interviews with critical members were carried out as well as a review in the historical data on the sector's performance in terms of energy consumed, maximum demand, production output, load factor and power factor.

5 FINDINGS

5.1 Energy Matrix assessment.

The research reviewed that in the absence of a formal energy management policy the company however carries out some energy management activities as a spin off from the environmental policy in place. The informal energy team gathers and tracks energy data (electricity, coal and water). The data is processed and reported to top management for informed decision making. Top management provides feedback on the way forward. There is no extensive marketing of energy management within and outside the organisation but simply ad hoc staff awareness and training. There is, however, very little which is done to motivate staff to save energy or to encourage staff to come up with ideas to save energy. The results obtained during the assessment are displayed in Fig. 1.

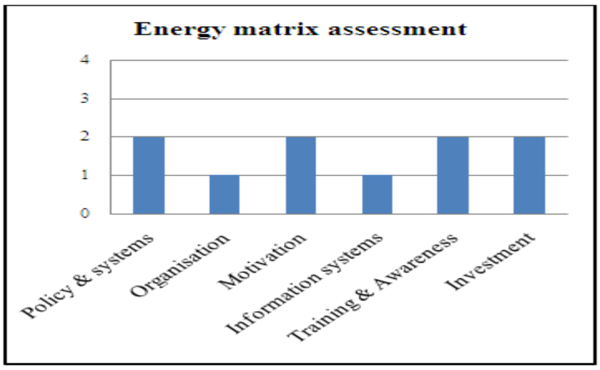

Fig 1, Energy management matrix assessment results

5.2 Electrical energy intensity

Electricity consumption is not consistent with production as shown by the graph in Fig. 2. Since energy is relative to production, it is therefore necessary to normalise energy consumed by the amount of production.

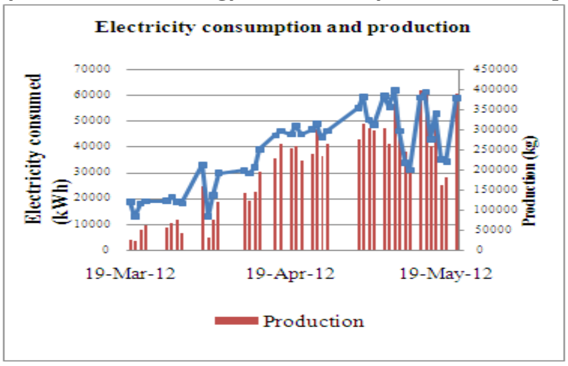

Fig. 2, Electricity consumption and production output

Fig. 3 shows the electrical energy intensities in the operations in terms of electricity usage per kilogram of tobacco. The minimum and maximum values of energy intensity are 0.31 and 1.52kWh/kg respectively. The inconsistencies in the values could be due to the production output and overall plant system efficiency. The average value of energy system is 0.24kWh/kg.

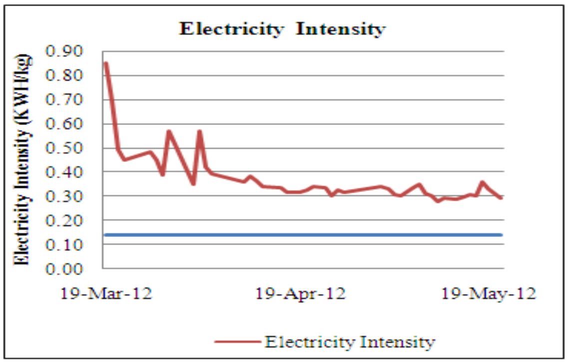

Fig 3, Electricity intensity

The target electricity intensity for the plant is 0.14kWh/kg; this can be assumed as the potential value of intensity that is possible by the application of low cost measures that include awareness and proper machine maintenance. Using moderate targets the following savings were calculated as in Table 1.

Table 1, Savings in electrical intensity

Average electricity intensity	0.24	kWh/kg
Targeted electricity intensity	0.14	kWh/kg
Average production	205 020	Kg
Average energy = (average production * average intensity)	49204	kWh
Targeted energy = (average production * targeted intensity)	28702.8	kWh
Potential Energy savings per month	20501.2	kWh
Weighted average cost of energy during production	0.08125	USD/kWh
Potential cost savings (Energy saved *Cost of Energy)	1665.72	USD

USD1,665.72 can be saved per month if the average electricity intensity is reduced to 0.14kWh/kg

5.3 Maximum demand

Demand is a measure of the instantaneous apparent power (real and reactive) drawn by the plant. Since the maximum demand is instantaneous, it is difficult to control unless there is a maximum demand controller. This unit can be used to warn personnel of high demand by raising an alarm and also it can shed off non-essential loads to maintain a targeted maximum demand.

Table 2, Savings in demand by use of capacitor banks

Potential monthly savings	2382-2235.7	kVA
	146.3	kVA
Potential cost savings (1kVA = US$ 6.93)	1,013	US$/ month
Actual investment (Price + FOB @ 50%)	18,606	US$
Operation and maintenance cost/ annum	1,860	US$
IRR	30	%
NPV	4,902	US$
Profitability index	1.26	
Payback	20	Months

5.4 Power factor

Motors are significant energy consumers. In many industrial plants, motors and drive systems may consume over 50 per cent of the total electricity used. Poor motor performance is typically a major source of energy losses. A study conducted by Gujarat Energy Development Agency (GEDA) in India has indicated that a 5% improvement in overall efficiency of induction motor would save enough energy that would be comparable to energy produced by a new power plant of few hundred Mega Watts [11], [12].

Induction motors ranging in size from 0.1 to 100KW were identified in the plant. Installing a capacitor bank will lead to an annual saving of US$ 12,156 per annum in the first year. Assuming maintenance and operating costs of 10% of initial investment, an investment of US$ 18,606 will yield an IRR of 30 per cent with a positive NPV and a payback period of 20 months.

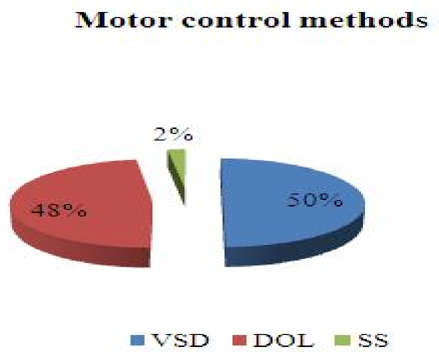

Fig 4, Motor Control methods

Table 3, Investment: Soft starters

Monthly kVA savings	2382-2235.7 Kva
	67.2 kVA
Monthly cost savings (1kVA = US$ 6.93)	466 US$
Actual investment	4 217.05 US$
Operation and maintenance costs	300 US$
Payback	10 Months

If a soft starter is used to start the fans instead of a star-delta starter, only 150% of the rated current will be used to overcome the starting torque. The motor is rated at 160A therefore only about 240A will be needed to start the motor instead of 348A. This will reduce the start-up current of the fans by at least 100A. This reduction in fan start-up current contributes to a demand saving of 67.2kVA or USD466 a month. With a saving of USD 466 a month, the payback period for installing a soft starter (which costs USD4 217.05) is 10 months.

One of the main motives of increasing the efficiency induction motor is to save our environment through the reduction of energy consumption. An improvement in energy efficiency will lead to reduction of CO_2 emissions. Electric drive systems are largely responsible for the largest part of the electricity consumption. Therefore an increase in efficiency in motor will result in large energy savings and reduction in CO_2 emission into our environment [13].

6 SAVINGS

Table 4 shows the amount of savings that result from various initiatives for the tobacco processing company. Awareness and training in energy intensity improvement result in the greatest savings, among the various initiatives.

Table 4, Summary of savings

Investment	Initiative	Savings US$/ month
Awareness & training	Improve energy intensity	1,665.72
Capacitor bank	Reduction in MD and power factor	1,013
Soft starters	Reduction in MD	466
Total savings		3,144.72

7 RECOMMENDATIONS

The following recommendations were made by the researchers

1. Demand Side Management programs are essential at the plant so as to enable continuity and compliance to the set standards of energy performance: without training these programs can prove difficult therefore personnel should be trained so that they are competent and skilled in identifying energy saving potentials. Formation of an Energy team headed by an Energy Champion is also vital for continuity and sustenance of DSM programs.
2. Install plant-wide maximum demand controller that do not stop machines but rather inhibits start-up for short periods of time. The controller will target only large loads.
3. Install power factor correction equipment. Avail information on installed power factor correction equipment to the actual users to maximize benefit from the equipment.
4. Installation of hardware and software to gather information on utility usage (electric, gas, water, steam) within the plant by use of sub metering. This will encourage an energy balance thus providing a way to manage utility costs.
5. Provision of proper start up procedures that enable staggering of equipment during start-ups or after load shedding to cater for problems of high power usages and high load factor.
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8 CONCLUSIONS

Demand Side Management (DSM) programs provide the means to economically manage energy resources and therefore control costs. The savings will result in a 12.6% reduction in the current total electricity bill of US$39 524 which represents monetary savings of US$3 144.72 per month.

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