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Investigation of Industrial Energy Efficiency: A Case Study

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ABSTRACT

Developing economies are mostly unaware of the actual savings potential of energy conservation and are additionally restricted due to the application of outdated technology in their industrial production. This is partly because their industries have not been checked for proper energy use and conservation. Therefore, it is the intention of this paper to provide and apply tools on the procedure and methods involved to firstly assess possible deficiencies suspected of irrational consumption of energy bill. Also steps to be taken to raise possible required investment for energy conservation measures and their financial analysis like payback period will be included. The status of Industrial Energy Efficiency in Ethiopian Industries has been analyzed with a special focus on the leather sector taking Batu Tannery a case study. The various energy utilization and saving practices of the plant and its potential saving areas are identified. Though higher saving is possible through the introduction of modern technology, this study focuses on housekeeping and low investment measures that will gain fast results and will motivate the management for more in – depth energy conservation measures. This approach is found suitable for developing countries who suffer from lack of funds for higher investment in energy conservation programs and the use of renewable energy sources.

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INTRODUCTION

Energy conservation dates back to the beginning of energy use. Fires were built in enclosed spaces and later replaced by ovens; man learned to build shelters for protection but also to provide warmth with less fuel. This movement towards improved efficiency in energy use, however, has often been overshadowed by increasing demands for energy services – to produce more products, to travel further and faster or to be more comfortable. Both trends continue – as they should. But over the past few decades there has been a new effort to examine broadly the potential economic and social benefits of energy conservation, Worrel et al. (2003), Dumas (1999). This examination has led to the recognition of energy conservation, for the first time, as an essential national and international objective. Energy conservation means using energy more efficiently, weather through behavior, improved management or the introduction of new technology. It has sometimes been associated with efforts to curtail energy use at the cost of economic activity and living standards, but it should be concerned exclusively with energy conservation as a means of increasing economic benefits. This curtailment mostly being advocated by the Green Parties Movement in Industrialized Countries has a serious background, however, Thunmann and Younger (2008), Wulfinghoff (1999).

Principally the rational use of energy is based on two issues. Firstly, to limit the production of Greenhouse gases (GHG) to the utmost possible extent, secondly, to improve the economies of countries as yet not applying the rational use of energy. Whereas the first issue may not be the dominating factor for African countries while the second item being of prime interest for developing countries like ours, because much money could be saved for each and every one there, again without restrictions to everyone's life and wellbeing only with a little consideration where energy could be saved, Karekezi and Mackenzie (1993), Sarker and Singh (2010), Jebaraj and Iniyan (2006). This commences with a keen eye on good housekeeping practices with no or little investment involved, to proceed to improvements on various industrial appliances after assessment of pay-back periods for the investment required, up to the exchange of

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complete production facilities with up to date installations consuming less energy per product unit after a thorough investment of the financial viability (pay-back period for a first rough assessment, followed by a financial analysis for Internal Rate of Return (IRR), Net Present Value (NPV) etc.

It is the intention of this paper to provide a tool on the procedure and methods involved to firstly assess possible deficiencies suspected of irrational consumption of energy and secondly show what implications this has on the energy bill and steps to be taken to raise possible required investment for energy conservation activities. The status of Industrial Energy Efficiency in Ethiopian Industries has been analyzed with a special focus on the leather sector taking Batu Tannery a case study. Batu tannery is located in Addis Ababa Ethiopia, established on January 2000. The plant enjoys locational advantage and has the proximity both to the source of raw material and market. 77% of the projects output is aimed for export while the balance of 23% of the output is for the local market that is suffering from the acute shortage of finished leather supply. The selection of machinery and equipment is based on standard selection criterion like production capacity, cost, availability of spare parts, ease of maintenance, familiarity to the local technicians etc. Above all the facility is equipped with a modern waste water treatment technology to avoid water, air and environmental pollution. The projects establishment is, therefore, friendly to the surrounding vicinities which is a major concern for the establishment of tanneries.

Methodology:

Without an energy audit it is difficult to find out how to conserve energy, and to measure the success of an energy management program also financially. The first technical step in the energy management program is the energy audit, which is made from a series of surveys and assessments and shows where and how energy is being used and/or wasted. An ideal audit lists each process step, the minimum practical or theoretical energy requirement for each step (benchmarking), the actual energy used and the variance between the minimum and actual use. The flue gas analysis of the boiler in Batu tannery is carried out using a flue gas analysis as part of the energy audit. The plant has only one boiler with a capacity of 2.1 MW, steam production of 3,000 kg/hr, thermal efficiency of 89% and fuel consumption rate of 156 kg/hr at a working pressure of 10 bar. The boiler pressure is adjusted according to the current plant requirement with minimum and maximum limits of 4.5baar and 5.5 bar respectively. i.e. the burner starts when the pressure falls below 4.5 bar and it shuts down when the steam pressure goes beyond 5.5bar. A thermal efficiency analysis is carried out on the boiler using a flue gas analyzer (Shown in Figure 1) and the amount of excess air, percentage constituent of H_2O, CO_2 , O_2 and CO as well as the flue gas temperature was determined.

Fig. 1: Exhaust analyzer.

The auditing process has three phases, namely the pre-site work, the site visit and the post site work. The pre-site work phase of the energy audit in the selected case study plant involves collection of fuel and electricity bills, collecting information on production (quantity and product type), preparing a simple floor plan of the facility, preparation of audit data forms, estimating the specific energy consumption of the facility during the last few years and benchmarking the same with global best practice. During the site visit the actual system was inspected and data on the various thermal and electrical energy utilization was collected. Measuring equipment used include thermometers and infrared thermometers (to measure liquid temperature, surface temperature and air temperatures), and exhaust analyzer.

RESULTS AND DISCUSSIONS

The simplest analysis that is employed is to produce a percentage breakdown of annual energy consumption and cost data. It is selected since it enables the overall energy performance of a building or facility to be assessed quickly and easily. The electrical, heavy furnace fuel (HFF) and Gas oil consumption of Batu Tannery for three consecutive years is given in table below. The energy utilization analysis on the case study plant is presented in terms of annual energy consumption (Table 1) and energy input by type and share of energy costs (Table 2). To help in the comparison of the relative consumption of the electricity and fuel energy types and their share of the total energy cost, both the HFF and Gas Oil consumption were converted to the KWh unit using their calorific value per liter as shown in Table 2.

Table 1: Annual Energy Consumption.

Year	Electricity [KWH]	Heavy Furnace Fuel [lt]	Gas oil [lt]
2005	580,494.3	110,607	2,600
2006	1,079,988	156,926	2,721
2007	1,270,486	323,399	10,820

Table 2: Energy input by type and share of energy cost, 2007.

Energy Type	Purchased Unit	Consumption		Cost	
		kWh	%	Ethiopian Birr	%
Electricity	1,270,486KWh	1,270,486	24.63	734,783	37.41
Gas Oil	10,820 lt	114,220.25	2.21	81,150	4.13
HFF	323,399 lt	3,773,290.17	73.16	1,148,066	58.45
Totals		5,157,996.42	100%	1,963,999	100%

The specific energy consumption is calculated for each year by accounting for the total energy consumption and total production of the specific year. The data for production output of each year is collected and summarized as shown in Table 3.

Table 3: Specific energy consumption.

Item #	Year [E.C.]	Energy Consumed [KWh]	Production of finished leather [ft2]	Specific Energy Consumption [KWh/ft2]
1	2005	1,898,459.17	5,099,657.5	0.372
2	2006	2,939,661.74	5,343,918	0.55
3	2007	5,157,996.42	8,440,900.8	0.611

Although only three years data might not be enough to draw any plausible conclusions, it can be observed that there is an increase in specific energy consumption of the facility in the consecutive years. This is partly due to increased shift work to satisfy the high demand combined with the low thermal efficiency of shift operation as a result of lower efficiency of boilers and other equipment at part load. In addition, this expansion increased the energy consumption in the form of steam/hot-water and electricity. For example the plant used to dry the finished leather using an overhead conveyor with the help of natural air circulation. On the mid of 2006 the plant has installed an overhead tunnel drier machine which consumes 600kg/hr of steam. However, more detailed study should be carried out to further investigate other possible causes. The specific heavy furnace fuel (HHF) consumption of the steam boilers and the specific electrical energy consumption of the plant are worked out and summarized in Tables 4 and 5 respectively.

Table 4: Specific HHF consumption of steam boilers.

Year [E.C.]	HFF Consumption [lt]	Production Quantity [ft2]	Specific fuel consumption [lt/ft2]
2005	110,607	5,099,657.5	0.022
2006	156,926	4,343,918	0.029
2007	323,399	8,440,900.8	0.038

Table 5: Specific electricity consumption of the plant.

Year [E.C.]	Electricity Consumption [KWh]	Production Quantity [ft2]	Specific Electricity Consumption [KWh/ft2]
2005	580,494.3	5,099,657.5	0.114
2006	1,079,998	5,343,918	0.202
2007	1,270,486	8,440,900.8	0.15

It is required to carry out such analysis in other tanneries to compare the relative energy utilization efficiency of the different plants and to benchmark lower specific energy consumption for the leather sector in general.

Savings from condensate recovery:

Assessment of the current scenario of the plant indicates that condensate return is carried out only from the central hot water plant of the factory, with resulting boiler feed water temperature of 41^oC. Due to the proximity of the central hot water plant to the boiler house condensate rising is done with no pumping. No condensate return is done from the rest of steam using process machines and the discharge of the steam traps is simply drained to the effluent. The energy potential of condensate return in the plant in terms of condensate flow rate (kg/hr) and condensate temperature is shown in Table 6. The total amount of condensate available for saving is 1,106 kg/hr and the average condensate return temperature was determined to be 97.23^{o}C. Thermal analysis of this data showed that total annual heat energy of 2,889,500.21 MJ/year could be recovered which could be converted. Assuming a boiler efficiency of 86% and considering the price of HFF an annual saving of 375,987 Ethiopian Birr is available from condensate return alone.

Table 6: Potential of condensate return in the plant.

Item #	Process Equipment	Condensate Flow Rate [Kg/hr]	Condensate Temp. [^{o}C]
1	Vacuum Drier	286	78
2	Toggle Drier	100	87
3	Tunnel Drier/ overhead drier	600	113
4	Roller coater	24	60
5	Spray coater machine	96	76

Saving from Thermal Insulation:

The surface temperature of un-insulated and poorly insulated steam and hot water pipes was measured making use of infrared thermometer, and the length of non-insulated pipe was also recorded during the energy audit. Calculations showed that the annual heat loss due to lack of proper insulation and the equivalent annual fuel loss to be 134,026 MJ/Yr and 3,710.56 lt/Yr. In monetary terms the saving from insulation of steam and hot water pipes was calculated to be 18,552 Ethiopian Birr per annum.

In addition, some crucial observations were made regarding the condition of the boiler feed water. The temperature of the feed water is only 41oC, which indicates a need for additional heating of the feed water in order to assist removal of temporary hardness in feed water heater and to avoid thermal shock inside the boiler. The feed water softener plant is regenerated weekly, but water hardness tests carried out throughout the week showed that the effectiveness of the softener decreases after midweek implying the need for bi-weekly regeneration of the softening plant. In addition insulation of the feed water tank should be carried out and positioning of the boiler feed tank at a higher level should be sought in the future considering the possible rise in feed water temperature due to return of more condensate streams to avoid pump cavitation. In addition, the combustion efficiency of the boiler was measured making use of the exhaust analyzer, and lower operating efficiency of 86% as compared to a designed efficiency value of 89%. This indicates that further attention need to be given for periodic cleaning of scaling and soot on the inside and outside surface respectively of the fire tube pipes.

Conclusions and Recommendations:

The status of industrial energy efficiency in Ethiopian tanneries has been analyzed in the paper as a case study on a selected plant. The various energy utilization and saving practices of the plant and its potential saving areas are also identified. The study showed that there is a significant saving potential in Ethiopian industries in terms of small and medium conservation practices like steam line insulation and condensate return. It is recommended for Ethiopian industries to implement an energy management system that provides a systematic and structured approach to dealing with energy issues and to carryout regular energy audits. Determining the specific energy consumption of each industry sector and benchmarking with global best practice is also important in assessing the current energy efficiency status of the industries. Moreover, short and long term energy conservation measures should be planned, implemented and checked in the industries from time to time.

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