Energy Utilization Assessment in Ethiopian Industries (Case Study at Mughar Cement Factory (MCF))

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Abstract: **The cost of energy as part of the total production cost is significant in most manufacturing industries. They spend millions of dollars annually on electric power and fuel oil for their energy requirement. Hence, considerable work of efficiency improvement on energy utilization is important. The aim of this paper is to assess the energy sources and utilization in the selected factory. And also, it is to study and identify energy utilization efficiencies of the different utilities of the factory. Finally, based on measurements, collected data and benchmarked cement factories experiences, the energy losses at the selected factory have been assessed.**

Keywords—Energy, Energy Intensity Mughar Cement Factory, Electric Motors, Industrial Energy.

I. Introduction

Energy is an integral part of a modern economy. It is an essential ingredient in nearly all goods and services, but its use exacts heavy financial, environmental, and security costs. The key method of reducing energy costs while retaining its benefits is to use it more efficiently. The industrial sector accounts around 40% of the commercial energy. It uses both the electrical and thermal energy in various equipment like motors, pumps, boilers, compressors, furnaces, diesel generating engines, refrigerators, etc. But there are many problems in the industry sectors to efficiently use their energy. They are not well informed on the concept of energy conservation. Due to this they lose lots of money on energy bills, causes problems on the environment, industries will not be competitive, etc. [3]

Industries use energy for equipment such as motors, lightings, pumps compressors, boilers, etc. These important utilities require regular maintenances, good operation and replacement when necessary. Thus, a critical element of the plants energy management involves the efficient control of crosscutting equipment or utilities that powers the production process of the plant. A second important area is the proper and sufficient operation of the process. Process optimization and ensuring the most efficient technology is in place a key energy savings in plant’s operations.

Industrial power systems are often characterized as large consumers of reactive powers and also significant generators of harmonics because most of the loads are generally composed of induction motors and static power converters. Reactive power compensation and harmonic control have a vital role to improve the electrical energy efficiencies in industries.

II. INDUSTRIAL ENERGY SYSTEMS AND EFFICIENCY

A. Industrial Energy Efficiency

Energy efficiency is a means of using energy more efficiently, either through change of behavior, improved management or the introduction of new technology. By increasing efficiency, energy demand can be reduced without reducing structural changes or adversely affecting economic growth. [14].

Replacing failed electric motors with energy efficient or premium efficient electric motors; Scheduled and proper greasing of electric motor bearings, reducing electric motor system friction losses, properly sizing electric motors to the load; testing questionable equipment before and after repair, improving the fuel consumption efficiency, improving lighting systems; and other measures that can be immediately implemented or implementation plan after energy losses assessment. These examples and other related activities can improve the factories over all energy efficiency.

There are many reasons why we should use energy efficiently some of these are:

- ❖ Most energy sources are non- renewable, so increasing energy conservation will extend the availability of energy sources.
- ❖ Investments in energy conservation will provide a better return than investments in energy supply. Increased energy conservation will therefore improve the general efficiency of the economy.
- ❖ Energy conservation will reduced the negative environmental consequences of energy production and use.
- ❖ Cost effective energy conservation techniques can save industries from 10 to 30 percent of industrial energy consumption.

Depending on the industry, energy expenditures can reach 70 percent of the total production costs. The higher the share of energy costs as a proportion of total costs, the more important that energy management become. [15]

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The table below shows the share of energy costs in the total production costs of some of the industrial sectors.

Industrial sectors	Share of energy costs
Ice	70%
Cement	55%
Ammonia	50%
Steel	30%
Glass	30%
Fertilizer	25%
Paper	25%
Ceramics	20%
Metallurgical	15%
Textile finishing	12.5%
Food products	10%
Oil refining	7.5%

Table 1. Energy costs relative to total production of different industrial sectors [15]

B. Industrial energy systems

Every industrial process is unique, and has its own specific areas where energy efficiency can be improved. There are a few common to many industries, which have opportunities for energy efficiency improvement. All plants are designed with at least one form of energy conversion systems. It is very important that the systems are efficient and reliable and that the environmental impacts are considered. Some of the utility systems in industrial set up are:

(a) Electric power systems

Electric motors and drive systems are common to most industrial processes. Motors are prime movers of such equipment as pumps, conveyors, compressors and various industrial production equipment. In fact, electric motors account for approximately 70 percent of industrial energy use. Motors can consume up to 20 times their purchase value in electricity each year. Properly sized, energy efficient motors with electronic variable speed controls, and improved gears, belts, bearings and lubricants, use only 40 percent as much energy as standard systems while their prices are 15-20 % more than standard motors.[12]

There are several occasions in industries that motor systems are oversized due to consideration of successive safety factors in the design of the systems. Motors that are oversized present high losses, lower efficiency and also low power factor. In such a situation oversized motors have to be changed by the correct sized motors.

Distribution cables are used to supply currents to motors and these cables produce I*I*R losses. Correct sizing of the cables will allow cost effective minimization of those losses and it will also reduce voltage drops in the distribution cables.

(b) Lighting systems

Lighting accounts for up to seven percent of industrial energy costs. The installation of energy – efficient lighting systems can cut lighting bills by as much as 40 %. With lighting, it’s a question of choosing long life and low maintenance technology to suit the requirements of the industry. For instance, in a warehouse, significant savings can be achieved by the installation of translucent roof panels or skylights, which reduces the need to operate artificial lighting during the day. Light colored ceilings and flooring reflect light and reduce the number of lights needed.

(c) Compressed air system

Compressed air, widely used throughout industries, is the most expensive industrial utility. About 10 percent of all electrical energy used by industry is employed in compressed air. Only 5% of input electrical energy is converted into useful energy and the rest is wasted as heat. This is an area which offers large potential for energy savings through simple measures.

Regular maintenance program for the compressed air system can reduce electricity consumption by identifying air leaks, reduce intake air temperature, optimize system pressure, manage compressor operation and eliminate inappropriate uses of compressed air.

It’s likely that a typical plant will have a leak rate of at least 20 percent. As well as wasting energy, leaks cause a drop in system pressure, which can cause equipment to operate less efficiently. Repairing air leaks can save between 25 and 40 percent of energy costs.

(d) Heat energy

This is the primary path of energy conversion i.e. from the chemical energy of fossil fuel to the thermal energy of the steam. Steam is produced by boilers, usually located far away from steam using equipment. The steam must be distributed by piping arrangements and valves. The use of large pipe means unnecessary heat loss and higher cost of piping and installation and if the pipe is too small there will be excessive noise in the pipe line due to excessive velocity as well as loss of pressure and capacity.

The main types of fuels used in the boilers include coal, oil and gas. A decision on which fuel to use in a particular case must be made in the context of the complete plant and with the knowledge of the current market prices of fuels and the likely trend in prices within the lifetime of the plant.

III. DATA COLLECTIONS AND ENERGY LOSS ASSESSMENTS

A. Data Collections

For undergoing the research work on industrial energy utilization efficiency assessment at Mughar cement factory, data has been collected from many sources; documents, interviews, direct observation and questionnaires.

Generally two types of data have been collected: primary data and secondary data. Primary data is obtained from the researchers and it is the result of the researcher’s studies of the problem. It includes the collection of information through direct observation, personal interviews, and conducting conversation. The secondary data, on the other hand, is the result of other people’s research in the same problem area, or

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from other related problem areas. It includes the study of documents, web-sites and other historical and documentary records relevant for the study.

The following tables provides the factory four years of cement production and energy consumption data and also shows the specific energy consumption, costs of energy per year, energy costs of MCF as well as the standard plants taken as a benchmark. And there are electric motors data and lighting data obtained from the selected factory.

No	Items	Unit.	Years			
			2010	2011	2012	2013
1.	Cement pro.	ton	712,372	662,278	654,250	727,000
2.	Clinker pro.	ton	603,458	610,000	590,745	600,000
3.	Elec. consump	kwh	84,452, 500	77,918, 048	65,609, 144	76,297, 000
4.	Fuel consump	Lit.	63,061, 361	62,464, 000	59,842, 467	64,164, 000
5.	Specific consump	Kwh /ton cem nt	118.5	117.6	100.3	104.9
6.	Specific fuel consump	Lit/t on clink er	104.5	102.4	101.3	106.9
7.	Energy intensity (el)	KJ/Kg cement	426.6	423.36	361.08	377.64
8.	Energy intensity (fuel)	KJ/Kg clinker	4,193.6	4,109.3	4,065.2	4,289.9

Table 2.Review of cement production and energy consumption at MCF [12]

Items	units	years			
		2010	2011	2012	2013
Furnace oil	birr	260,308,2 08	257,074,0 33	294,261,968	382,957, 949
Elect. Energy	birr	34,431,7 81	29,270,1 55	42,899,377	31,750, 770
total	birr	294,739,9 89	286,344,1 88	337,161,345	414,708, 719

Table 3. Energy Costs at MCF for both electrical and furnace oil [12]

Plant	Spec. electric consump.	Spec. Fuel consump.	Energy intensity (elect.)	Energy intensity (fuel)
	Kwh/ton cem.	lit/ton clinker	KJ/kg cement	KJ/Kg clinker
1.	82.75	78.25	297.90	3140.00
2.	87.79	58.81	316.04	2360.00
3.	101.83	91.95	366.59	3690.00
4.	88.65	90.75	319.14	3641.80
5.	78.99	65.54	284.36	2630.00
6.	87.20	54.07	313.92	2170.00
7.	94.60	71.27	340.56	2860.00
8.	78.56	56.07	282.82	2250.00
9.	82.42	55.57	296.71	2230.00
10.	86.69	59.06	312.08	2370.00

Table 4. Cement production and energy consumption of 10 different plants in china (selected as bench marks) [15]

B. Energy losses Assessment at MCF

(a) Computation of energy intensity of the plant

Energy intensity is the amount of energy consumed to produce a unit amount of product and is a measure of the energy efficiency of the plant. The following graphs show the plot of the energy intensity of the mughar cement factory from year 2010-2013, and the energy intensity of the selected cement plants taken as a benchmarks. The graph also compares the specific energy of the MCF and the selected benchmark cement plants.

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The selected benchmarks have used fuel oil for their clinker production which is the same as mughar cement factory and also they have same kiln technology as MCF. These cement plants have comparatively higher energy efficiency performance as compared to other cement factories.

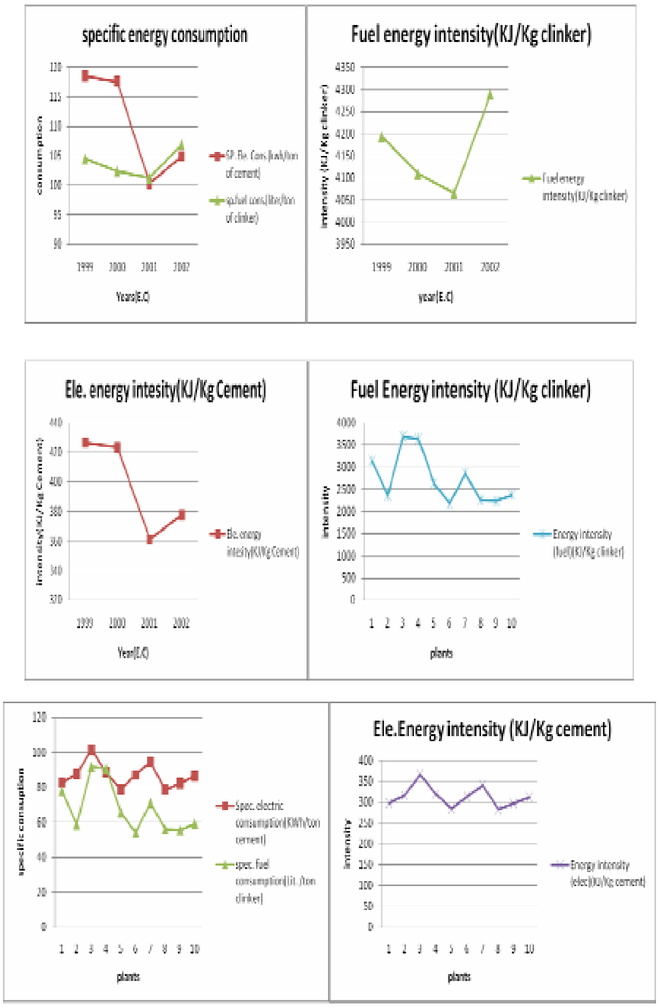

Fig. 1 comparison of energy consumption between MCF and the selected benchmark factories

The annual fuel energy intensity of MCF in the years 2010-2013 ranges from 4065.2- 4289.9 KJ/kg of clinker with average intensity of 4164.5 KJ/Kg of clinker. The energy intensity of various cement plants taken as bench marks shown above gives an average energy intensity of 2934.1 KJ/Kg of clinker. Hence a difference of 1214.5 KJ/Kg intensity exists between the average practice and what exists at MCF.

With regards to electricity energy intensity of MCF in the year 2010-2013, it ranges between 100.3 -118.5 kWh/ton of cement with average intensity of 110.33 kWh/per ton of cement. The energy intensity of various cement plants taken as bench marks shown above gives average energy intensity of 86.95 kWh/per ton of cement. Hence a difference of 23.38 kWh/per ton of cement exists between the average practice and what exists at MCF.

(b) Explanation of the results

From the analysis of the energy intensity of MCF, it can be seen that there is a significant difference between the energy intensity of the plant as compared to the selected benchmarks cement plant experience. This shows that there is actually a room for improving the energy efficiency of the plant. The following calculation shows clearly how much the company is actually spending for energy which actually was not necessary.

- Production (average)
  = 700, 000 ton of cement per year and
  600,000 ton of clinker/year.
- Cost of fuel oil = 4.1 birr/lit.(2011)
- Cost of electricity = 0.50 birr/kwh.
- Specific heat of fuel oil = 40,128KJ/lit.
- Difference in electricity energy intensity
  = 23.38kwh/ton cement
- Difference in fuel oil energy intensity
  = 1214.5KJ/Kg clinker
- Annual cost due to inefficient use of fuel oil energy
  = fuel in lit * cost of fuel.

$$= \frac{energy\ intensity\ \left(\frac{KJ}{Kg}\right) * production(ton)}{specific\ heat\ of\ fuil\ oil\ \left(\frac{KJ}{lit}\right)} * fuil\ cost\ \left(\frac{birr}{lit}\right)$$

= <u>72,453,000 (birr/year)</u>

- Annual cost due inefficient use of electrical energy

= electricity consumption in kwh * cost of electricity

$$= energy\ intensity\ \left(\frac{kwh}{ton}\right) * production(ton) * cost\ of\ electricity\ \left(\frac{birr}{kwh}\right)$$

= 8,183,700 birr/year.

- Total cost due to inefficient use of energy(both)
  = 80, 636,700 birr/year

As we have seen there is a huge energy loss at the Mughar cement factory. This inefficient use of energy in the MCF also caused many problems. Such as:

- High energy cost.
- Causes environmental pollution.
- MCF is not competitive with the world market.
- Also produce products with incomparable cost.

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IV. CONCLUSION

In Ethiopian industries proper attention is not given to improve energy consumption efficiency, but for the sake of survival and to contribute their part to the country's energy development and also to save foreign currency due to the imported furnace oil, the factories must assess their energy losses and they have to save energy losses.

- As we have seen on the energy loss assessment part, 15 – 20 % of cost of energy is due to inefficient use of energy both electric and furnace oil. So, by reducing these losses the factories will reduce their energy costs.
- Reducing energy consumption without affecting the production means reducing carbon dioxide emission – reduces environmental pollution.
- By reducing their energy intensity, the factories will be competent with the world market. Which means the factory will produce products with minimum cost.

The high cost or capital intensive measures may need further detailed audit and analysis. However, the results of the study should be used as a guide line for future expansions and purchases of new machineries.

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