



Addis Ababa University

Addis Ababa Institution of Technology

School of Electrical and Computer Engineering

**Studies on Energy Utilization and Efficiency Improvement
Opportunities of Messebo Cement Factory**

BY: Lemlem Haftom

June, 2015

Addis Ababa, Ethiopia



Addis Ababa University

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Electrical and Computer Engineering Department

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of Messebo Cement Factory**

**A thesis Submitted to the School of Graduate Studies of Addis Ababa University in
partial Fulfillment of the Requirement for the Degree of Masters of Science in
Electrical Power Engineering**

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Declaration

I hereby declare that the work which is being presented in this thesis entitled “Study on energy utilization and efficiency improvement opportunities of Messebo cement factory) ” is original work of my own, has not been presented for a degree in this or other universities and all sources of materials used for this thesis work have been fully acknowledged.

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Abstract

Adequate and reliable supply of energy is required to ensure sustainable development of any country. However, the use and conversion of primary energy results in energy waste, high cost energy and emission. In addition, developing countries (like Ethiopia) have low awareness on energy conservation and faced to generate more energy rather than to use the existing energy efficiently. This studies on energy utilization and efficiency improvement opportunities of Messebo cement factory. It aims to improve the energy efficiency of the factory by proposing energy conservation options such as improving energy intensive equipments such as lighting system and electric motors of the factory.

For the purpose of data analysis, a historical data regarding their energy consumption and energy intensive equipments, such as electric motors and lighting systems were collected. Energy efficient cement plants were selected as a benchmark to compare the energy efficiency of the factory. As the result of data analysis the factory loses 34% of their total energy (electrical and fuel) due to inefficient consumption and pays 45,197,841.70 birr per annum. The factory accomplishes its activities with excess and inefficient lamps and also with low efficiency of electric motor due to under load operating of the motor for the specific application.

By optimizing the illumination of the existing lighting system 49.87MWh of energy is saved per annum. The respective annual cost saving is 24,936.80 birr. Another way of improving the lighting system is through replacement of existing lamps with energy efficient lamps 49.02 MWh/year of energy is saved and the respective annual cost saving is 24,510.5 birr.

In this study, MotorMaster + international software used to select a proper electric motor in terms of efficiency, cost effectiveness & energy saving potential. The simulation result from MotorMaster + international also shows that through replacing low energy efficiency of electric motors 275.5MWh of energy is saved and the respective annual cost saving is 218,970 birr per annum with small payback period.

Key Word: Cement industry, energy utilization, energy efficiency, energy efficiency improvement opportunities, MotorMaster + international software and energy saving

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Acronyms

E.C	Ethiopian calendar
Ton	Tone
Loe	Liters of Oil Equivalent
Lits	Liters
TJ	Terajoule
GJ/t	Gigajoule per tone
tCO ₂	Total CO ₂
ES	Energy Saving
DS	Demand Saving
ASD	Adjustable Speed Drive
NEMA	National Electrical Manufacturers Association
TP	Total Power Rating of Lamps
ENL	Existing Number of Lamps
TLu	Total Lumen Output of the lamp
E	Illumination produced by the installed lamps
RA	Room area of each department measured in square meter.
ALP	Actual Number of Lamps needed to post
RSE	Required Standard illumination
EU	Energy Utilized
RE	Required Energy

CHAPTER ONE

Introduction

1.1. Background and Statement of the Problem

Energy shortage is one of today's major problems. Due to this human beings increase dependency on fossil fuel supplies to accomplish their day to day activities, while the use of those fossil fuels causes' energy waste in conversion of primary energy and major global challenges. Thus, efficiently use of energy is an essential step towards all overcoming the rising problems of the worldwide energy and environmental crisis [1]. Most industrial processes are characterized by low energy efficiency, which indicates that there are significant opportunities for improving energy efficiency in the sector [2]. Improving energy efficiency means identifying wasteful energy use and taking actions to reduce or illuminate that waste. Production levels should not be affected, only the amount of energy and the expense incurred in generating that production. This implies in reduce energy costs and consequently increase profitability. This is the most important step towards achieving the three goals of energy policy: security of supply, environmental protection and financial growth/ energy costs reduction. Nearly a third of global energy demand and CO₂ emissions are attributable to manufacturing, especially the big primary materials industries such as chemicals and petrochemicals, iron and steel, cement, paper and aluminum. Understanding how this energy is used, the national and international trend and the potential for efficiency gains, is crucial [3]. Changing how energy is managed by implementing an organization wide energy management program is one of the most successful and cost-effective ways to bring about energy efficiency improvements. Energy management refers to the strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems. A detail studying on energy utilization, efficiency improvements, energy management and implementing of cost

effective technologies for the specific application can often lead to save energy and ensure minimal wastage, consequently promoting environmental sustainability.

Industrial sector accounts around 40% of the commercial energy [4]. It uses both the electrical and thermal energy in various equipments like motors, pumps, boilers, compressors, furnaces, diesel generating engines, refrigerators, etc. Some industries (best practices) around the world have reduced their energy intensities by implementing and developing energy efficient technologies and management strategies. This is a justification for their high energy end-use and high contribution to energy related environmental problems. However, most industries in developing countries like Ethiopia are lagging behind in the implementation of energy efficiency and management measures [5]. In addition there are many problems in the industry sectors to efficiently use their energy. They are mostly limited to some critical factors, such as a combination of market failures (number of products) and not well informed on the concept of energy conservation.

There are different more energy intensive industrial sectors in Ethiopia which suffer to incredible energy consumption and costs, such as cement industries, sugar industries, textile industries, etc. Cement industries are one of these plants that use mostly electrical and fuel energies. A lot of attention is being paid to generate enough electricity by government and individuals to serve its consumer. But little is being done to check that the amount of energy presently being generated is efficiently used and on awareness of energy conservation especially for the industry sectors. Industries have been able to maintain better efficiency in their usage of electricity due to the improved monitoring of these places by Ethiopian Electric and Power Corporation (EEPCO). But this approach has yet to be used [6]. Due to this they lose lots of money on energy bills, causes problems on the environment, industries will not be competitive, etc.

Most studies occur on energy utilization and efficiency of several industries focus on the thermal energy efficiencies but the electrical energy has also major impact on the industries. New energy improvement opportunities are necessary to detail study including on new technologies for implementing energy efficiency and energy cost savings to reduce high consumption of energy and energy costs. [1] In addition 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. Energy improvement on reactive power compensation and harmonic can achieve a significant energy saving of industries. [6][7]

Cement sector is one of the major energy intensive industries while playing an important role in the economy of a country. Ethiopian cement industry consists of four integrated cement plants. Three of these are located in the central area of Oromia, with one in the north of the country. These have been installed with a total capacity of about 1,366,000 million tons of ordinary Portland cement per annum in Ethiopia.[8] Table 1.1 presents the installed capacities and locations of the cement plants of Ethiopia. The cement industry is energy-based which constitutes 45 % of the cost of production. The total average annual consumption of furnace oil by these factories based on their installed clinker capacity and average oil consumption is estimated to reach 120 million liter or around 30 million dollar in value. [8]

Table 1--1: Ethiopian cement plants [8]

Regional state	Name of Cement plant	Operating	Year	Installed Cement
		unit	Established (E.C)	Capacity (tone/year)
Tigray	Mosobo cement	Line 1	1992	900,000
		Line 2	2002	900,000
Oromiya	Mugher cement	Line 1	1977	350,000
		Line 2	1982	350,000
Dire Dawa City Council	Dire Dawa	Line 1	1936	36,000
Addis Abeba	Addis Abeba	Line 1	1964	70,000

Messebo Building Materials Production (MBMP) factory is one among the outstanding and more energy intensive factory in Ethiopia. This is a private sector owned with Development Tigray Association (TDA)'s factory, and erected with the support of Denmark Company and China. The company is located in northern part of Ethiopia i.e about 800 km far from Addis Ababa. The factory has two large mostly separated lines which produce the same product. These are line one and line two. The first line started operation in 1992E.C. Each line was proposed to produce a maximum 2000 tons of clinker per day. It was also proposed to produce a maximum 900,000 tons of Portland pozzolana Cement (PPC) per year [9]. The raw materials for the company are limestone, shale, silica sand, iron ore, gypsum and other additive. The different raw materials that are important for the plant operation are extracted from different places. These all are nearly closed to the company and supplied by itself.

Paper sack plant of this factory was established in year 2002E.c with the objective of producing and supplying paper sacks which are to be used for packing cement, lime, fillers and other products. The production capacity of the plant is 60 million pieces of 50kg capacities per year. The cement production is continuously monitored and the cement product of the factory includes:

- ✓ Ordinary Portland Cement(OPC)
- ✓ Portland Pozzolana Cement(PPC)
- ✓ Portland limestone cement (PLC)

The main difference between the three different cements is the clinker proportion. Clinker is the combination of the four materials i.e. limestone, shale, iron ore and silica sand when it passes through a series of steps. Clinker is pure cement without gypsum. Therefore OPC is a type of cement with proportion of 95% clinker 5% gypsum; whereas PPC is a type of cement with the proportion of 70% clinker and 25% pozzolana and 5% gypsum. But in the case of PLC it is a type of cement with the proportion of 80%clinker and 15 to 20 high grade lime stones. The type of kiln technology used by Messebo cement factory is a dry process five stage preheater kiln with rotary cooler [9].

Messebo cement factory uses fuel and electricity as major energy inputs to accomplish their activities. Coal and oil is a very important input in Messebo cement production and is mainly used in kiln for production of heat (thermal energy) which is used for clinker production. This industry uses domestic washed coal to reduce its ash content coal, transported from mines in Jimma. It also uses lignite blended with coal to the extent possible. Pet coke, which has proved to be an excellent alternate fuel to coal, is a residual product from oil refinery with high calorific value and insignificant ash content but often with high sulphur content as compared to coal. Imports of coal with a higher heat and lower ash content were effectively prohibited with high tariffs from South Africa. The frequent variations in the quality of coal, inadequate supplies and transportation bottleneck have rendered it imperative to import coal from countries like South Africa, Kenya etc. However, import of coal is costly and a drain on our national exchequer even though it has helped cement industry getting quality coal. Deteriorating and inconsistent quality of coal has become a limiting factor in improving energy efficiency, productivity and clinker quality. The use of these coals results in a number of operational problems such as improper and inefficient burning and higher per unit consumption of coal as well as lower operational efficiencies which tend to further increase the emission of green house gases. [8]

1.2 Objectives of the Thesis

The main objective of this thesis is to study electrical energy utilization and energy improvement opportunity, as the results of energy audit, which optimize the energy system of Messebo cement factory. Specific objectives

- To Survey the working condition of the Messebo cement to take relevant data for the thesis
- To analyze the energy losses of the Messebo cement factory as compared with selected energy efficient cement plants.
- To analyze the major causes of energy losses of energy intensive equipments
- To recommend possible energy saving opportunities on:

- Electrical motors, operation and maintenance efficiency and kiln process.
- Lighting systems
- fuel consumptions reduction
- Reducing the amount of imported fossil fuel used for cement production.
- Achieving greenhouse gas emission reductions through energy efficiency improvement in cement manufacture.

The study focuses on the detailed analysis of energy use by process, specific energy technologies and measures to reduce energy consumption and to improve the energy efficiency without affecting the production potential of the cement industry.

1.3 Methodology

The following methods were used to assist the way of energy utilization and efficiency of the energy intensive equipment of the factory.

Site Identification

Out of the four currently operating cement factories in Ethiopia, the selected factory for this thesis work is Messebo cement factory.

Data Collection

To achieve the objective of the thesis different type of data were collected.

These data's includes the following:

- List of electrical motors with different horse powers and operating parameters
- Measurement on specification operating parameters on various equipments under different conditions and maintenance procedures of the equipments, to estimate their operating efficiencies of the factory.
- The electrical energy and fuel consumptions required to produce a unit product.

- The production energy cost of the factory, energy bill, including lighting data of the factory.

The data collection involved walk-through surveys of work place of the factory, direct observation, in depth interviews with the decision makers on the factory. This is for the purpose of having better understanding on the general picture of the plant energy use, operation, and energy losses.

Data Analysis

Data analyses based on the collected information were done. The analysis of these data provides background information on the cement industry like motor load and identifies of the energy saving potential of the industry. It also forwards general energy use and production patterns, specific energy saving potential, energy efficient and cost reduction opportunities of the factory. MotorMaster+ international software was used which helps to determine the proper efficient motor size, based on commercially available energy efficient motors.

1.4 Related Works

T. Ashokkumar, P. Raja and Rahmath Ulla Baig, were studied on energy conservation for both electrical and thermal. From this study, they concluded in three ways, effective use of electrical equipment, effective and change in operation of existing operational equipment without investment, change of the existing equipment with latest technical up gradation system equipment with investment. From the energy study 16 numbers of energy conservation opportunities amounting to a net saving in specific energy consumption 14 kWh / ton of clinker (11.67%) was identified. On successful implementation of the suggestions given for each ECO's, there will be net saving of 473958 kWh/ month. Out of the net saving (14 kWh / ton of clinker), 9.56 kWh/ton of clinker (7.97 %) can be realized without any major investment. The monthly energy savings will be 323645 kWh. Eco's, which are investment oriented, contribute to the remaining portion of saving i.e. 4.44 kWh/ton of clinker (3.7%) the monthly energy saving will be 150312 kWh. The total

investment required to implement the proposal can be implemented within an overall payback period of 16.3 months [10].

Ernst Worrell and Christina Galitsky examined over 40 energy efficient technologies and measures and estimated energy savings, carbon dioxide savings, investment costs, and operation and maintenance costs for each of the measures. The report describes the measures and experiences of cement plants around the world with these practices and technologies. The analysis of cement kiln energy-efficiency opportunities is divided into technologies and measures that are applicable to the different stages of production and various kiln types used in China: raw materials (and fuel) preparation; clinker making (applicable to all kilns, rotary kilns only, vertical shaft kilns only); and finish grinding; as well as plant wide measures and product and feedstock changes that will reduce energy consumption for clinker making. According to their study they provide the following information for each technology: fuel and electricity savings per ton of cement; annual operating and capital costs per tonne of cement or estimated payback period; and, carbon dioxide emissions reductions for each measure applied to the production of cement [11].

Jatin Gupta has studied on the master of “Electrical Energy Audit of Induction Motors in Textile Plant”. The preliminary study of the textile was explored the possible energy saving areas such as induction motors, power factor improvements and optimized parallel loading of transformer. Jatin Gupta after doing analysis on the rewound induction motors for its efficiency, it was founds that rewound motors if replaced by new motors the payback period had got in the range of 2 year to 6 months [12]

1.5 Organization of the Thesis

This thesis is organized in to five chapters. The first chapter presents the introduction of the study i.e about the background of the study, statement of the problem, the general overview of the existing Ethiopian cement industry, objective, methodology and related works to this thesis. The second chapter presents energy utilization and efficiency improvement of cement factory discusses about cement production process, energy utilization of cement factory and energy efficiency improvement opportunities of cement factory (technologies

and measures). The third chapter gives the data collection and analysis discussions i.e shows the overall energy intensity of the factory, energy loss assessments and data analysis. Chapter four is presents about the energy efficiency improvements of Messebo cement factor i.e shows energy efficiency improvement of energy intensive equipments of Messebo cement factory and how using MotorMaster + software to select efficient electric motor. The chapter five is presents about the simulation result discussions; conclusion and recommendation i.e shows the summary of the study. It also shows the forwarded conclusions and recommendations of the study. Finally, also includes future work, i.e studies on recovering the waste heat with cogeneration system around kiln area of Messebo cement factory to generate electricity.

CHAPTER TWO

Energy Utilization and Efficiency Improvement of Cement Factory

2.1 Cement Industry Production Process

Cement is an inorganic, non-metallic substance with hydraulic binding properties, and is used as a bonding agent that holds particles of aggregate together to form concrete. It is a fine powder, usually gray in color. The main general processes involved in cement manufacture are raw materials preparation, clinker production, and finish grinding. Figure 2.1 shows the general describes of cement production process. These main general processes discussed as follow.

2.1.1 Raw Materials Preparation

Extraction and Transport of Raw Material: The production process of cement starts with raw material supply, which involves such as detonation of rocks, transportation the raw material from quarries with dump trucks, crushing the rock on site and transporting it to the cement plant by conveyer belts. The most common raw materials used for cement production are limestone, chalk and clay. The major component of the raw materials, the limestone or chalk, is usually extracted from a quarry very close to the plant. Limestone provides the required calcium oxide and some of the other oxides, while clay, shale and other materials provide most of the silicon, aluminum and iron oxides required for the manufacture of Portland cement.

Crusher: The crusher contains apron (a shield or plate attached to a machine that protects the user) feeder, hammer crusher, belt conveyors. Apron feeder is used for horizontal, inclined transportation of bulk materials that come from quarry in to crusher roller inlet. The apron feeder is driven through drive shaft by two frequency controlled geared motors which are mounted directly on the shaft. The hammer crusher is of a single rotor type, without in let grates and inlet rollers and is designed for large reduction in one stage.

Hammer crusher used for crushing of raw materials like, limestone, shale, silica and gypsum. The raw material is reduced in size by processing through a series of crushers. Primary size reduction is accomplished by a jaw or gyratory crusher, and followed by secondary size reduction with a roller or hammer mill. The crushed material is screened and stones are returned. Belt conveyors are used to transport the crushed raw materials to the raw materials storage. Once the rocks have been reduced to a small size, which is appropriate to carry by the belt conveyor it is conveyed to the raw materials storage.

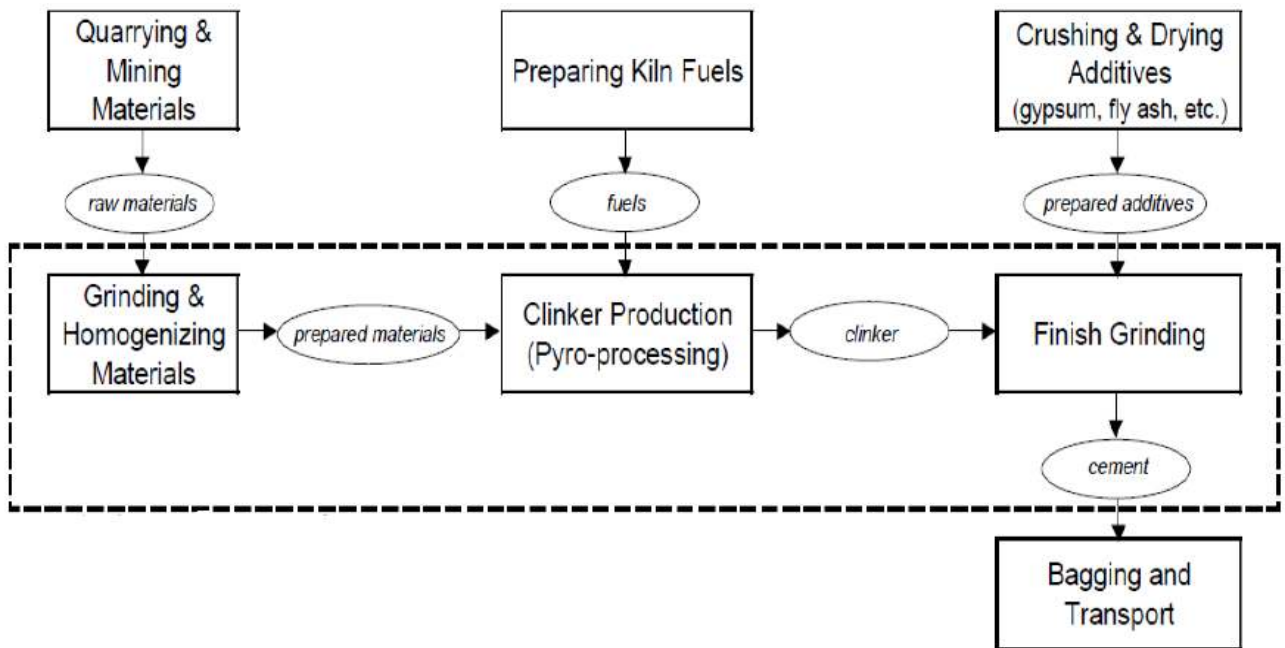


Figure 2-1: Describes the general cement production process [13]

Raw Materials Storage: The raw materials that are transported through a belt conveyor from the crusher department are stored in the raw material storage. They are deposited in a number of loads in the store using a stacker. The stacker is used stack raw materials in a number of loads in a store. After the raw materials are arranged in piles the bridge scraper is used for homogenizing of particulate materials at longitudinal store and for conveyance of the homogenized materials from the piles to the outgoing conveyor. Reclaiming of limestone and shale will be executed by separate bridge reclaimers. Silica is to be loaded on the outgoing belt conveyor by loaders. The raw materials that are coming from the raw

material storage are entered to the proportioning unit or four raw meals feed bins through different belt conveyors. The amounts of raw materials that are feed to the raw mill are arranged in the proportioning unit.

Raw Mill: The dosed raw materials are dried and finely ground in the raw mill to form an intermediate product, called “raw meal”. The grinding provides an increased surface area to enhance the heat exchange in the downstream heating process.

HomoSilos: The “raw meal” is then stored in a homogenizing silo in which the chemical variation is reduced. This homogenizing process is important to stabilize the downstream sintering process as well as to provide a uniform quality product. The “raw meal” is then transferred to the Preheater Tower. Raw meal is obtained by grinding the homogenized raw material. The raw meal is pre-heated in cyclone heaters, calcined and sent to the kilns.

2.1.2 Clinker Production

Pre heater and Kiln:

In clinker production the raw mix is gradually heated in the kiln until it reaches a temperature of about 1450 °c. All processes have in common that the kiln feed in four basic steps:

- ✓ In the first (drying and preheating) zone of the kiln, the raw mix is heated to 100-120 °c, to evaporate all moisture. After this the temperature increases to about 450 °c to Liberate more firmly bound water of hydration from the used day. [1]
- ✓ In the second (calcining) zone, the calcium carbonate is thermally decomposed in a temperature-range of 450-1100 °c to form calcium oxide, accompanied by the liberation of carbon dioxide. In this zone any present organic material is burned and present alkalies partially vaporize.
- ✓ Sintering (clinkerisation) process is formation of clinker minerals at temperatures up to 1450°c. A series of reactions between the calcium oxide and the other raw material components, results in the formation of tricalcium silicate, dicalcium silicate, tricalcium aluminate and tetracalcium alumino-ferrite. These products are

the four main clinker minerals. The characteristics of produced cement clinker depend on the relative concentrations of these different compounds

- ✓ The kiln internal cooling, in which crystallization of calcium aluminates and calcium ferrite occurs in the temperature range of 1,350-1,200°C. The clinker formed enters the grate cooler for cooling purpose. The burnt product clinker is cooled down with air to 100-200° C and is transported to intermediate storage.

Conditioning and Electrostatic Precipitator: The flue gas exiting the preheater is directed to the raw mill for drying. Before it enters the electrostatic precipitator ("EP") for its final dust removal process, its temperature and humidity is regulated in a conditioning tower. This process is essential as it affects the dust collecting efficiency of the electrostatic precipitator ("EP").

Electrostatic precipitator is commonly used as the final dust removal device for flue gases. It consists of chambers each of which contains a series of collection plates and an overhead framework of suspended rigid high-voltage electrodes. Particles in the gas stream are charged by a high-voltage, direct current field which is generated from the discharge electrodes, suspended between the collector plates.

Grate Cooler: The residual heat from the clinker leaving the kiln is recovered by a grate cooler (consisting of rows of grates). Cooling air is injected from the bottom of the grate, and is forced into the clinker which is travelling slowly on the grate. The heated air is then recycled as secondary air for combustion in the kiln. The clinker is stored and then finely ground. Gypsum is added to control setting time, along with supplementary cementing materials, such as fly ash or slag, to obtain a fine powder called cement, with the desired properties of strength and chemical resistance.

2.1.3 Finish Grinding

Cement Mill: The final process of cement making is called cement grinding. Clinker dosed with controlled amount of gypsum is fed into a cement mill. Typically, a cement mill is a horizontal steel tube filled with steel balls. As the tube rotates, the steel balls are lifted, tumble and crush the clinker into a super-fine powder. The particle size is controlled by a

high efficiency air separator. The raw materials, a mixture of clinker, gypsum and additive are fed via three separate weigh feeders, one for each material, in preset proportion to the common reversible feed belt feeding the total feed to the mill inlet. The fine materials leaving the mill are transported to the bag filters with the ventilation air. However, the coarse material leaving the mill is transported two air slides, an elevator and another air slide to the inlet of the sepal separator. Then the cement meal product is transported to the cement silos by elevator and stored in the silos as a final product. The dust filtering units are bag filters. Cement transport to packing and bulk loading (air slides, bucket elevator or a combination of appropriate transport means) [14]

Packing and Loading: The department is used to packing the final result of cement in order to be sold to the customers by transporting it to different market place. It is packed through two systems packing unit and bulk loading units. In packing unit the cement is packed using rotary bag packing machine through manual bag feeding. Transport of bags to the loading through roller conveyor and belt conveyors equipped with brake and speed controller. Dust filtering unit is bag filters or any other unites. Bulk loading unit uses loading device with brake and speed controller.

2.2 Energy Utilization of Cement Factory

2.2.1 Energy Requirement of Cement Factory

Factory uses a wide array of energy sources as compared with the commercial. This is to power a diverse range of manufacturing and resource extraction processes [15]. It consumes natural gas, petroleum, electricity, coal, and renewable, as well as many derivatives of these fuels.

The petroleum products are particularly varied. They include distillate fuel oil, residual fuel oil, gasoline, petroleum coke and lubricants. To operate electric motors, fans, pumps, conveyors, rotate the kiln to crash, grind raw materials and lightings etc. Most cement factories use rotary kilns with five-stage pre-heaters technologies. Rotary kilns represent the largest energy consumer and carbon dioxide emission source of the cement industry than their activities of production and lead to less competitiveness with the world market.

The kiln process consumes approximately 90% of the energy uses in the cement manufacturing sector. Four different basic clinker production processes can be shortly characterized by dry raw meal (dry process), semi-dry process (dry raw meal), semi-wet process (raw slurry) and wet process (the raw slurry). The dry and wet kilns have different heating and cooling temperatures and thus, they need different amount of electric and fuel. In simple terms, wet kilns takes less electricity to run since all the drying functions occur within the kiln itself, but do require significantly more fuel to burn. The reverse is true for dry kilns [13].

Each cement production process step uses electricity to power electric motors, fans, pumps, conveyors to crash and grind the raw materials. And also in finish grinding mills, to operate fans and blowers in preheating facilities, to cool the clinker and rotate the kiln as well as building operations such as lighting and ventilation systems (see figure 2.1). In addition to electricity however, the core function of turning the raw materials into clinker is accomplished through the consumption of large amounts of fuel(oil and coal). This is to generate heat in kiln areas for clinker burning (pyroprocessing) system. The thermal energy demand for clinker production is ruled by endothermic reactions of the raw materials with required temperatures of up to 1450oc for formation of stable clinker phases. Therefore, a theoretical energy demand of 1650 to 1800 MJ/t clinker is needed for this process. [13]

This study focus on the major energy resources of the factory fuel (oil & coal) energy (use for clinker production) and electricity use for raw material preparation (fuel, raw material), grinding (raw, cement). This is because Messebo cement factory uses fuel and electricity as major energy inputs to accomplish their activities. Electric motor systems, lighting systems, heat energy systems, compressed air systems, refrigeration and HVAC are the main energy intensive/required equipments in this factory.

2.2.1.1 Electric Motor Systems

An electric motor is an electromechanical device that converts electrical energy to mechanical energy. This mechanical energy is used for, for example, rotating a pump, fan or blower, driving a compressor etc. Electric motors are used in most industrial systems

and sometimes called the “work horses” of industry because it is estimated that motors use about 70% of the total electrical load in industry.[17]

The general working mechanism is the same for all motors such as:

- ❖ An electric current in a magnetic field will experience a force.
- ❖ If the current carrying wire is bent into a loop, then the two sides of the loop, which are at right angle to the magnetic field, will experience forces in opposite directions.
- ❖ The pair of forces creates a turning torque to rotate the coil. (note: a “torque” is the force that causes the rotation)
- ❖ Practical motors have several loops on an armature to provide a more uniform torque and the magnetic field is produced by electromagnet arrangement called the field coils.

Industrial electric motors can be broadly classified as induction motors, direct current motors or synchronous motors. All motor types have the same four operating components: stator (stationary windings), rotor (rotating windings), bearings, and frame (enclosure). Depending on the industrial structure, electric motor systems account for about 60 to 70% of industrial electricity consumption [16]. Pumping, compressed air and fan systems are some of the most electricity-consuming motor systems. When considering energy efficiency improvements to industries’ of motor systems, it is important to optimize the energy efficiency of entire motor systems (i.e., motors, drives, driven equipment such as pumps, fans, and compressors, and controls), not just the energy efficiency of motors as individual components. It is necessary to analyze both the energy supply and energy demand sides of motor systems as well as how these sides interact to optimize total system performance, which includes not only energy use but also system uptime and productivity. To optimize the energy efficiency of entire motor systems typically involves the following steps: [18].

- ✓ All applications of motors in a facility should be located and identified.
- ✓ The conditions and specifications of each motor should be documented to provide a current systems inventory.

- ✓ The needs and the actual use of the motor systems should be assessed to determine whether or not motors are properly sized and also how well each motor meets the needs of its driven equipment.
- ✓ Information on potential repairs and upgrades to the motor systems should be collected, including the economic costs and benefits of implementing repairs and upgrades to enable the energy efficiency improvement decision-making process.
- ✓ If upgrades are pursued, the performance of the upgraded motor systems should be monitored to determine the actual costs savings.

2.2.1.2 Lighting System

Lighting is used either to provide overall ambient throughout the manufacturing, storage, and office space or to provide lighting to a specific areas. High-intensity discharge (HID) sources including metal halide, high-pressure sodium, and mercury vapor lamps are used for manufacturing and storage areas. Fluorescent, compact fluorescent (CFL), and incandescent lights are typically used for task lighting and offices. Lighting controls should be used in all areas of the plant. Lighting demand is measured by a quantity of lumen of visible light needed at a certain point of time. The term efficacy is used to describe the energy efficiency of a lamp. It is described by the amount of light it produces in lumens with respect to the power it consumes in Watts (lumens/Watt). The term efficacy is used, rather than efficiency, because it is comparing dissimilar units. The term luminous flux is used to measure the visible light output of lamps, being emitted from a light in all directions.

Illuminance is the term used to describe the level of light on a surface in lumens/square meter or lux. When a ray of light hits a solid surface, the process is known as illumination. The illuminance E at a point on a surface is defined as the luminous flux F (lumens) incident upon a small element of the surface divided by the area A (m^2) of the element.

Illuminance = (Luminous flux (lumens))/(area (m^2))

$$E=F/A \text{ (lux)}$$

For fluorescent tubes (and CFLs) lamp performance, the most important aspects of their performance are efficacy- the energy efficiency of a lamp (lumens/Watt), lifetime - the average operating hours (OH), luminous flux - used to measure the visible light output of lamps, being emitted from a light in all directions (lumens) and illuminance - used to describe the level of light on a surface in lumens/square meter or lux. The relationship between the watt and the lumen (lumen/watt) is important as it is possible to calculate the luminous flux a particular lamp will produce by considering the radiated power at each wavelength and the corresponding eye sensitivity at that wavelength.[19][25]

Only a small part of the energy used in a lighting fixture results in lighting; the remainder is lost as heat. Even energy use in lighting is very small in the cement industry still, energy efficiency improvement opportunities may be found that can reduce the energy use cost effectively. This may achieved through using more efficient lighting systems.[19]

2.2.1.3 Compressed Air Systems

Compressed air systems are used in different parts of the plants, i.e. mixing of slurry (in wet process plants) and in the bag house or dust collector filters and other parts. Total energy consumption by compressed air systems is relatively small in cement plants, however, it can amount to a considerable expense if the systems run continuously and end users are offline. Still, energy efficiency improvement measures may be found in these systems. Compressed air is probably the most expensive form of energy available in a plant because of its poor efficiency. Typically overall efficiency is around 10% for compressed air. [18]

Inadequate maintenance can lower compression efficiency and increase air leakage or pressure variability, as well as lead to increased operating temperatures, poor moisture control, and excessive contamination. Improved maintenance will reduce these problems and save energy. This is an area which offers large potential for energy savings, might be improved through simple measures such as: monitoring, reduction of leaks (in pipes and equipment) and reduction of the inlet air temperature, and operating pressures, control strategies, leak detection, and demand reduction in its evaluation and compressor efficiency

upgrades which would lead to energy savings and cost savings. 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 %of energy costs. [5]

2.2.1.4. 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 way 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.

2.3 Energy Efficiency of Cement Factory

2.3.1 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. [19].

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

- Most energy sources are depeletable, so increased 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% of industrial energy consumption.

There are several energy efficiency improvement opportunities (technologies and measures) that can reduce the energy consumption (i.e. the electricity or fuel consumption per unit of output) of the various process stages of cement production. This section provides energy efficiency improvement opportunities of technologies and measures of cement factory.

2.3.2 Energy Efficiency Improvement Opportunities in Electric Motors

In understanding a motor it is important to understand what a motor load means. Load refers to the torque output and corresponding speed required. Characteristics of loads can generally be categorized into three groups [17]:

- ✓ Constant torque loads are those for which the output power requirement may vary with the speed of operation but the torque does not vary. Conveyors, rotary kilns, and constant-displacement pumps are typical examples of constant torque loads.
- ✓ Variable torque loads are those for which the torque required varies with the speed of operation. Centrifugal pumps and fans are typical examples of variable torque loads (torque varies as the square of the speed).
- ✓ Constant power loads are those for which the torque requirements typically change inversely with speed. Machine tools are a typical example of a constant power load.

Motor performance depends on how well these operating characteristics match the load. The load on a motor is not always constant, and the response of the motor to changes in load is a fundamental factor in selecting the right motor for an application.[20] These load characteristics are particularly important in deciding whether speed control method is an option.

Energy efficiency of industrial electric motors can be improve through properly sizing electric motors to the load, 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, testing questionable equipment before and after repair and other measures with immediately implemented or implementation plan after energy losses assessment. [22]

Sizing to Variable Load: Industrial motors frequently operate under varying load conditions due to process requirements. A common practice in this situation is to select a motor based on the highest anticipated load. But this makes the motor more expensive as the motor would operate at full capacity for short periods only, and it carries the risk of motor under-loading. An alternative is to select the motor rating based on the load duration curve of a particular application. This means that the selected motor rating is slightly lower than the highest anticipated load and would occasionally overload for a short period of time. This is possible as manufacturers design motors with a service factor (usually 15% above the rated load) to ensure that running motors above the rated load once in without causing failure under certain conditions. The biggest risk is overheating of the motor, which adversely affects the motor life, efficiency and increases operating costs. A criterion in selecting the motor rating is therefore that the weighted average temperature rise over the actual operating cycle should not be greater than the temperature rise under continuous full-load operation (100%). [23] Overheating can occur with:

- ❖ Extreme load changes, such as frequent starts / stops, or high initial loads
- ❖ Frequent and/or long periods of overloading
- ❖ Limited ability for the motor to cool down, for example at high altitudes, in hot environments or when motors are enclosed or dirty

Adjustable Speed Drives (ASDs): Where loads vary substantially with time, speed control methods can be applied in addition to proper motor sizing. Horsepower of a motor is the product of its torque and speed. A properly specified motor will match the power requirements of the load over the expected range of operating conditions. However, to correctly specify a motor/drive system, it is usually not sufficient just to match the motor horsepower to the load horsepower. The speed and torque requirements of the driven

equipment and the ability of the motor to respond to load changes are important factors in determining how well a motor performs.

Many motor in cement plants have high operating hours with variable loads and consume large power. Drives are used with a motor to reduce the overall system power consumption by adjusting motor speeds in applications that do not need to operate constantly at full speed. This adjusting enables the motor power and energy consumption to follow the load variation, rather than unnecessarily operating continuously at full speed. Most of the time adjustable speed drives (ASDs) can mainly applied to cement plants, which helps the motor to draw only the actually required power as the load requirement. This is done through adjusting of the motor speed (rpm) and/or torque (Newton meter [Nm]) to the immediate condition/load variations that occur. For example, in many conveyor systems, lines are controlled by energizing and de-energizing a series of motors. These frequent starts and shutdowns are tough on motors and line components because of repeated stresses from starting currents and acceleration and deceleration of mechanical components.

In addition due to conveyors also continuously in operation there is always a risk of damaging the belt by overstretching, slipping or breaking. To reduce operational costs, it is important to extend the belt lifetime and availability. Using variable speed drives can smooth out line motion for more efficient and effective operation. This drives provide accurate torque and speed control of conveyors and reduces the stress on mechanical equipment such as gearboxes, pulley and belts, especially during start-up and stopping, but also during operation and maintenance. These drives control the speed of the conveyors to match the production capacity and as such reduce wear and save energy. [24][25]

The overall result is significantly lower energy consumption than with fixed drives of similar performance using mechanical control principles in partial load operation. When loads vary, VSDs motors can often reduce electrical energy consumption in centrifugal pumping and fan applications by 50% or more.[26] However, understanding of the characteristics/types of the load that can be used by the plant is particularly important, in deciding whether speed variation control is an option. The largest potential for electricity savings with variable speed drives is generally in variable torque applications, for example

centrifugal pumps and fans, where the power requirement changes as the cube of speed. Constant torque loads are also suitable for VSD application.

Rewinding: It is common practice in industry to rewind burnt-out motors. The number of rewound motors in some industries exceeds 50% of the total number of motors [2]. Careful rewinding can sometimes maintain motor efficiency at previous levels, but in most cases results in efficiency losses. Rewinding can affect a number of factors that contribute to deteriorated motor efficiency: winding and slot design, winding material, insulation performance, and operating temperature. For example, when heat is applied to strip old windings the insulation between laminations can be damaged, thereby increasing eddy current losses. A change in the air gap may affect power factor and output torque.

However, if proper measures are taken, the motor efficiency can be maintained after rewinding, and in some cases efficiency can even be improved by changing the winding design. Using wires of greater cross section, slot size permitting, would reduce stator losses and thereby increasing efficiency. However, it is recommended to maintain the original design of the motor during the rewind, unless there are specific load-related reasons for redesign.

The impact of rewinding on motor efficiency and power factor can be easily assessed if the no-load losses of a motor are known before and after rewinding. Information of no-load losses and no-load speed can be found in documentation of motors obtained at the time of purchase.

An indicator of the success of rewinding is the comparison of no load current and stator resistance per phase of a rewound motor with the original no-load current and stator resistance at the same voltage. When rewinding motors it is important to consider the following:

- Use a firm that ISO 9000 certified or is member of an Electrical Apparatus Service Association.
- Motors less than 40 HP in size and more than 15 years old (especially previously rewound motors) often have efficiencies significantly lower than currently available

energy-efficient models. It is usually best to replace them. It is almost always best to replace non-specialty motors under 15 HP.

- If the rewind cost exceeds 50% to 65% of a new energy-efficient motor price, buy the new motor. Increased reliability and efficiency should quickly recover the price premium [2][21].

When repairing or rewinding a motor, it is important to choose a motor service center that follows best practice motor rewinding standards in order to minimize potential efficiency losses. Such standards have been offered by the Electric Apparatus Service Association (EASA). When best rewinding practice are implemented, efficiency losses are typically less than 1%. [27]

The criteria or choice of employing an energy motor strongly depends on motor operating conditions and the payback period associated with the investment. In general, new motors are most economically attractive when replacing old motors with annual operation exceeding 2000 hours/year or rewind motors. Sometimes, even replacing an operating motor with a premium efficiency model may have a low payback period. [21]

Improving maintenance: Most motor cores are manufactured from silicon steel or de-carbonized cold-rolled steel, the electrical properties of which do not change measurably with age. However, poor maintenance can cause deterioration in motor efficiency over time and lead to unreliable operation and high operating costs. For example, improper lubrication can cause increased friction in both the motor and associated drive transmission equipment. Resistance losses in the motor, which rise with temperature, would increase. Ambient conditions can also have a detrimental effect on motor performance. For example, extreme temperatures, high dust loading, corrosive atmosphere, and humidity can impair insulation properties; mechanical stresses due to load cycling can lead to misalignment.

Good maintenance of motors essential to prolong motor life and to foresee a motor failure. Motor maintenance measures can therefore be categorized as either preventative or predictive. Preventative measures, include voltage imbalance minimization, load consideration, motor alignment, lubrication and motor ventilation. Motor maintenance through preventative measures avoids increased motor temperature which leads to

increased winding resistance, shortened motor life, and increased energy consumption. The purpose of predictive motor maintenance is to observe ongoing motor temperature, vibration, and other operating data to identify when it becomes necessary to overhaul or replace a motor before failure occurs. The savings associated with an ongoing motor maintenance program could range from 2% to 30% of total motor system energy use. [21]

Appropriate maintenance is needed to maintain motor performance. A checklist of better maintenance practices would include:

- ✓ Inspect motors regularly for wear in bearings and housings (to reduce frictional losses) and for dirt/dust in motor ventilating ducts (to ensure proper heat dissipation)
- ✓ Check load conditions to ensure that the motor is not over or under loaded. A change in motor load from the last test indicates a change in the driven load, the cause of which should be understood. Lubricate appropriately. Manufacturers generally give recommendations for how and when to lubricate their motors. Inadequate lubrication can cause problems, as noted above. Over-lubrication can also create problems, e.g. excess oil or grease from the motor bearings can enter the motor and saturate the motor insulation, causing premature failure or creating a fire risk.
- ✓ Check periodically for proper alignment of the motor and the driven equipment. Improper alignment can cause shafts and bearings to wear quickly, resulting in damage to both the motor and the driven equipment
- ✓ Ensure that supply wiring and terminal box are properly sized and installed. Inspect regularly the connections at the motor and starter to be sure that they are clean and tight
- ✓ Provide adequate ventilation and keep motor cooling ducts clean to help dissipate heat to reduce excessive losses. The life of the insulation in the motor would also be longer: for every 10°C increase in motor operating temperature over the recommended peak, the time before rewinding would be needed is estimated to be halved.

Motor management plan: Implementing a maintenance program that incorporates both predictive and preventive measures as part of a motor management plan facilitates anticipating and preventing motor failure before it occurs. With this information available, facility managers have the opportunity to reconfigure, repair, or replace components before failure occurs, or to predict when motor failure is likely and prepare accordingly.

A motor management plan is an essential part of a plant's energy management strategy. Having a motor management plan in place can help companies realize long-term motor system energy savings and will ensure that motor failures are handled in a quick and cost effective manner. The Motor Decisions Matter SM Campaign suggests the following key elements for a sound motor management plan: [21]

- Creation of a motor survey and tracking program.
- Development of guidelines for proactive repair/replace decisions.
- Preparation for motor failure by creating a spares inventory.
- Development of a purchasing specification.
- Development of a repair specification.
- Development and implementation of a predictive and preventive maintenance program.

Improving power quality: There are several electrical disturbances that commonly affect industrial processes. Such as: voltage sags, capacitor switching, surges, and harmonics. Since the owners of industrial processes also have experienced unexplained process interruptions and unplanned equipment shutdowns, this results reduction of process/system power quality which implies low overall system of energy efficiency. Many process interruptions can be prevented with a little knowledge of power quality issues, owners of industrial processes can learn to identify causes of electrical disturbances & action to prevent their return and inadequate electrical grounding or wiring, or to connections between loads within the premises.

In a typical process industry, the primary loads are motor-driven. Low-voltage and medium-voltage induction motors, medium-voltage synchronous motors, and motors

controlled by electronic AC or DC drives make up the motor loads in a plant. Motors ranging from a few horsepower to thousands of horsepower directly connected to the utility system or connected through a variable-speed drive provide a variety of process and auxiliary functions. Motor failures can have a significant effect on facility operation and unscheduled downtime. Many times, premature failure of motors is associated with system voltage unbalances. Failures are also related to motors controlled by adjustable-speed drives. An understanding of how motors are affected by these system voltage unbalances conditions can be important in preventing motor failures.

Voltage unbalance can be even more detrimental to motor performance and occurs when the voltages in the three phases of a three-phase motor are not equal. This is usually caused by the supply different voltages to each of the three phases. It can also result from the use of different cable sizes in the distribution system. An example of the effect of voltage unbalance on motor performance is shown in table 2.1. The voltage of each phase in a three-phase system should be of equal magnitude, symmetrical, and separated by 120°.

Table 2-1: Effect of voltage unbalance in induction motors [2]

	Example 1	Example 2	Example 3
Unbalance in voltage (%)	0.30	2.30	5.40
Unbalance in current (%)	0.4	17.7	40.0
Increase in temperature (C°)	0	30	40

Voltage unbalance degrades the performance, shortens the life of a three-phase motor and increases distribution system losses. Voltage unbalance at the motor stator terminals cause phase current unbalance far out of proportion to it. Unbalanced currents lead to torque pulsations, increased vibrations and mechanical stresses, increased losses, and motor overheating, which results in a shorter winding insulation life. Voltage unbalances may be caused by faulty operation of power factor correction equipment, an unbalanced transformer bank, or an open circuit.

Common causes of voltage unbalance include:

- Faulty operation of power factor correction equipment.
- Unbalanced or unstable utility supply.
- Unbalanced transformer bank supplying a three-phase load that is too large for the bank.
- Unevenly distributed single-phase loads on the same power system.
- Unidentified single-phase to ground faults
- An open circuit on the distribution system primary.

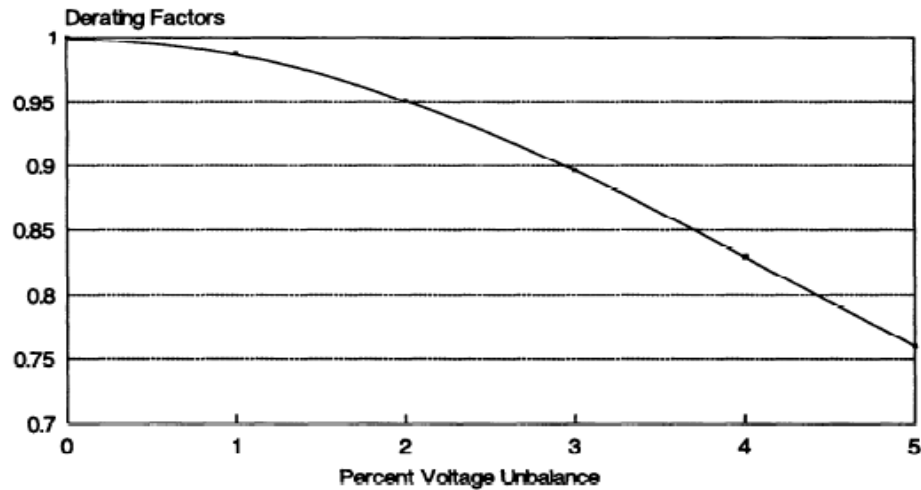


Figure 2--2: Motor derating due to voltage unbalance

Voltage unbalance is defined by the National Electrical Manufacturers Association (NEMA) as 100 times the absolute value of the maximum deviation of the line voltage from the average voltage on a three-phase system, divided by the average voltage.

$$\text{Unbalance voltage in \%} = (\text{maximum deviation from mean voltage} / \text{mean voltage}) \times 100$$

For example, if the measured line voltages are 462, 463, and 455 volts, the average is 460 volts.

$$\text{The voltage unbalance is: } = [(460-455)/460] \times 100\%$$

It is recommended that the voltage unbalances at the motor terminals not exceed 1%. A voltage unbalance of only 3.5% can increase motor losses by approximately 20%.

Imbalances over 5 percent indicate a serious problem. Unbalances over 1% require derating of the motor, and will void most manufacturers' warranties. A voltage imbalance of 2.5 % would require a derate factor of 0.925 to be applied to the motor rating. Derating factors due to unbalanced voltage for integral horsepower motors are given in Figure 4.4 above. The NEMA derating factors apply to all motors. There is no distinction between standard and energy-efficient motors when selecting a derate factor for operation under voltage unbalance conditions. [2][21]

Voltage unbalance can be minimized by:

- ✓ Check the electrical system single-line diagram to verify that single-phase loads are uniformly distributed
- ✓ Regularly monitor voltages on all phases to verify same power system that a minimum variation exists.
- ✓ Install required ground fault indicators
- ✓ Segregating any single phase loads which disturb the load balance and feed them from a separate line / transformer.

Power factor correction: An induction motor requires both active and reactive power to operate. The active or true power, measured in kW, is consumed and produces work or heat. The reactive power, expressed in kVARs, is stored and discharged in the inductive or capacitive elements of the circuit, and establishes the magnetic field within the motor that causes it to rotate.

The electric utility must supply both active and reactive power loads. A low or "unsatisfactory" power factor is caused by the use of inductive (magnetic) loads and can indicate a possible low system electrical operating efficiency. Inductive loads like transformers, electric motors, and HID lighting may cause a low power factor. Induction motors are generally the principal cause of low power factor because there are so many in use and they are not fully loaded. When motors operate near their rated load, the power

factor is high, but for lightly loaded motors the power factor drops significantly. This effect is partially offset as the total current is less at reduced load. Thus, the lower power factor does not necessarily increase the peak KVA demand because of the reduction in load.

Many utilities, however, charge a penalty or surcharge if a facility's power factor drops below 95 or 90%. In addition to increased electrical billings, a low power factor may lower your plant's voltage, increase electrical distribution system line losses, and reduce the system's capacity to deliver electrical energy. Low power factors can be corrected by installing external capacitors at the main plant service or at individual pieces of equipment. Power factor can also be improved and the cost of external correction reduced by minimizing operation of idling or lightly loaded motors, and by avoiding operation of equipment above its rated voltage [21].

2.3.3. Energy Efficiency Improvement Opportunities in Lighting System

Electricity used to operate lighting systems represents a significant portion of total electricity consumed in industries. Fluorescent lamps, compact fluorescent lamps (CFL) and incandescent lights are typically used for task lighting and offices in industries. The two objectives of the lighting designer are considered:

- ✓ To provide the right quantity of light, and
- ✓ Supply the right quality of light

Although lighting is often a small component of industries energy uses, efficiency improvements to lighting systems leads a significant energy saving. Through implementing of lighting energy-efficiency improvement opportunities like illumination optimization, replacement of T-12 Tubes with T-8 Tubes, lighting controls, high-intensity fluorescent lights, day lighting, turning off Lights in unoccupied areas and replace magnetic ballasts with electronic ballasts.

Lighting Controls: Lights can be shut off during non-working hours by automatic controls, such as occupancy sensors that turn off lights when a space becomes unoccupied. Occupancy sensors can save up to 10% to 20% of facility lighting energy use. [28] Manual

controls can be used in conjunction with automatic controls to save additional energy in smaller areas. One of the easiest measures is to install switches to allow occupants to control lights. It is also important to make employees aware of the importance of turning off lights in unoccupied spaces. Other lighting controls include daylight controls for indoor and outdoor lights, which adjust the intensity of electrical lighting based on the availability of daylight.

High-Intensity Fluorescent Lights: Traditional HID lighting can be replaced with high-intensity fluorescent lighting. These new systems incorporate high-efficiency fluorescent lamps, electronic ballasts and high-efficacy fixtures that maximize output to the workspace.

Advantages of the new system are many; they have lower energy consumption, lower lumen reduction over the lifetime of the lamp, faster start-up, better color rendition, higher pupil lumens ratings, and less glare. High-intensity fluorescent systems yield 50% electricity savings over standard metal halide HID. [29] In addition to energy savings and better lighting qualities, high-intensity fluorescents can help improve productivity and have reduced maintenance costs.

Day Lighting: Day lighting can be combined with lighting controls to maximize its benefits. Because of its variability, day lighting is usually combined with artificial lighting to provide the necessary illumination on cloudy days or after dark. Day lighting technologies include properly placed and shaded windows, atria, angular or traditional (flat) roof lights, clerestories, light shelves, and light ducts. Clerestories, light shelves, and light ducts utilize angles of the sun and redirect light with walls or reflectors. Not all parts of a facility may be suitable for the application of day lighting. Day lighting is most appropriate for those areas that are used in daytime hours by people. In office spaces, day lighting may save between 30 and 70% the savings will vary widely depending the facility and buildings. [29]

Turning off Lights in Unoccupied Areas: An easy and effective measure is to encourage personnel to turn off lights in unoccupied building spaces. An energy management program

that aims to improve the awareness of personnel with regard to energy use can help staff get in the habit of switching off lights and other equipment when not in use.

Replace Magnetic Ballasts with Electronic ballasts: Ballast regulates the amount of electricity required to start a lighting fixture and maintain a steady output of light. Electronic ballasts can require 12% to 30% less power than their magnetic predecessors. New electronic ballasts have smooth and silent dimming capabilities, in addition to longer lives (up to 50% longer), faster run up times, and cooler operation than magnetic ballasts. [29]

2.3.4. Opportunities to Improve the Use of Fuel oil Consumption of Cement Factory

A critical element of plant energy management involves the efficient control of crosscutting equipment that powers the production process of a plant. A second and equally important area is the proper and efficient operation of the process. Table 2.2 shows lists of energy-efficient practices and technologies in cement production. Not all measures of this table will apply to all plants. Applicability will depend on the current and future situation in individual plants. For example, expansion and large capital projects are likely to be implemented only if the company has about 50 years of remaining limestone reserves onsite. Plants that have a shorter remaining supply are unlikely to implement large capital projects, and would rather focus on minor upgrades and energy management measures. [30]

2.3.4.1 Clinker Production

This section provides fuel oil consumption reduction technologies and measures, their costs, and potential for implementation in the cement industries.

Sintering and fusing the ground materials into clinker is the most energy-intensive stage of the process. It accounts for approximately 80 percent of the energy used in cement production. Improving the efficiency of the pyroprocessing system can reduce energy consumption and hence CO₂ emissions (tCO₂/t) considerably. Measures to improve energy

efficiency (fuel oil consumption reduction) in clinker production may include the following:

Kiln combustion system improvements: Fuel combustion systems in kilns can be contributors to kiln inefficiencies with such problems as poorly adjusted firing, incomplete fuel burn-out with high CO formation, and combustion with excess air. Many techniques are developed in world wide. One technique developed in the U.K. of flame control resulted in fuel savings of 2-10% depending on the kiln. This combustion technology improves combustion through the use of better kiln control. The average fuel savings of up to 10% have been demonstrated for the use of flame design techniques to eliminate reducing conditions in the clinkering zone of the kiln [30].

Use of Waste Derived Fuels: Waste fuels can be substituted for traditional commercial fuels in the kiln. Waste derived fuels may replace the use of commercial fuels, and are hence accounted as energy savings. The carbon dioxide emission reduction depends on the carbon content of the waste derived fuel, as well as the alternative use of the waste and efficiency of use (e.g. incineration with or without heat recovery). The addition of scrap tyre as fuel can put cement industry and environment in a better position for sustainable development of infrastructure. Most of the worldwide generated tyres (65.5%) are simply dumped in the open or in the landfill. Land filling is very common these days but number of waste tyres is increasing faster every year. It is well known that scrap tyres possess high volatile and low ash content, with a high heat value than coal or biomass. The calorific value of tyres is between some 6450kCal/kg and 8000kCal/kg. To substitute 1 ton of coal (some 6100kCal/kg) around 0.76 - 0.95 ton of scrap tyres is needed. The net CO₂ emission factor is approximately 59t of CO₂/TJ for tyres and incineration of coal has emission factor of 96t CO₂/TJ. Based on the ultimate and proximate analysis it can be said that tyre is a feasible option to be used in cement kilns, while paying attention to heavy metal concentration. Performance of OPC is largely unaffected by small additional quantities of heavy metal or certain non metallic's. There is an upper limit (in the 1% by weight of clinker range 10,000 ppm) above which these compounds start to affect the setting and hardening properties of cement. [31]

Kiln Shell Heat Loss Reduction (Improved Refractories): There can be considerable heat losses through the shell of a cement kiln, especially in the burning zone. The use of better insulating refractories (for example Lytherm) can reduce heat losses. Refractory choice is the function of insulating qualities of the brick and the ability to develop and maintain a coating. The coating helps to reduce heat losses and to protect the burning zone refractory bricks. Refractories protect the steel kiln shell against heat, chemical and mechanical stress. The choice of refractory material depends on the combination of raw materials, fuels and operating conditions. Extended lifetime of the higher quality refractories will lead to longer operating periods and reduced lost production time between relining of the kiln, and, hence, offset their higher costs. The use of improved kiln-refractories may also lead to improved reliability of the kiln and reduced downtime, reducing production costs considerably, and reducing energy needs during start-ups. Estimates suggest that the development of high-temperature insulating linings for the kiln refractories can reduce fuel use by 0.12 to 0.4 GJ/t of clinker. Costs for insulation systems are estimated to be \$0.25/annual tonne clinker capacity. Structural considerations may limit the use of new insulation materials. [32]

Seals: Seals are used at the kiln inlet and outlet to reduce false air penetration, as well as heat losses. Seals may start leaking, increasing the heat requirement of the kiln. Most often pneumatic and lamella-type seals are used, although other designs are available (e.g. spring-type). Although seals can last up to 10,000 to 20,000 hours, regular inspection may be needed to reduce leaks. Energy losses resulting from leaking seals may vary, but are generally relatively small. Philips Kiln Services reports that upgrading the inlet pneumatic seals at a relatively modern plant in India (Maihar cement), reduced fuel consumption in the kiln by 0.4% (or 0.01 MBtu/ton clinker) (Philips Kiln Services, 2001). The payback period for improved maintenance of kiln seals is estimated at 6 months or less. [30]

Conversion to Grate Cooler: Four main types of coolers are used in the cooling of clinker: shaft, rotary, planetary and grate cooler. The grate cooler is the modern variant and is used in almost all modern kilns. The advantages of the grate cooler are its large capacity (allowing large kiln capacities) and efficient heat recovery (the clinker leaves the cooler at 83°C, instead of 120-200°C). Modern grate coolers recover more heat than do the other

types of coolers. For large capacity plants, grate coolers are the preferred equipment. For smaller plants the grate cooler may be too expensive. Grate coolers are essential if a precalciner is installed, as the grate cooler produces the required tertiary air, except in the case of through the kiln calciner systems. When grate coolers compared to a planetary cooler, additional heat recovery is possible with grate coolers at an extra power consumption of approximately 3 kWh/tonne clinker. The savings are estimated to be up to 8% of the fuel consumption in the kiln. In our analysis we estimate an energy savings of 0.3 GJ/t.

A cooler conversion probably is economically attractive only when installing a precalciner, which is necessary to produce the tertiary air. The cost of a cooler conversion is estimated to be \$0.4 - 0.5/t clinker capacity with annual operation costs increasing to \$0.1/t clinker capacity. [31]

High Temperature Heat Recovery for Power Generation: Waste gas discharged from the kiln exit gases, the clinker cooler system, and the kiln pre-heater system all contain useful energy that can be converted into power. In the U.S., only in long-dry a kiln is the temperature of the exhaust gas sufficiently high to cost-effectively recover the heat through power generation. Cogeneration systems can either be direct gas turbines that utilize the waste heat (top cycle), or the installation of a waste heat boiler system that runs a steam turbine system (bottom cycle). This measure focuses on the steam turbine system since these systems have been installed in many plants worldwide and have proven to be economic. Heat recovery has limited application for plants with in-line raw mills, as the heat in the kiln exhaust is used for raw material drying. While electrical efficiencies are still relatively low (18%), based on several case studies power generation may vary between 11 and 25 kWh/t clinker. Electricity savings of 22 kWh/t clinker are assumed estimate installation costs for such a system at \$2.2 to 4.4/annual tonne clinker capacity with operating costs of \$0.22 to 0.33/t clinker. In 1999, four U.S. cement plants cogenerated 486 million kWh. In China, most high temp waste heat is recycled to the preheated and Precalciner. [32]

Table 2--2: *Energy-efficient practices and technologies in cement production [31]*

<p>Raw Material Preparation</p> <p>Efficient transport system</p> <p>Raw meal blending systems(dry process)</p> <p>High – efficiency roller mills (dry cement)</p> <p>High – efficiency classifiers (dry cement)</p>	
<p>Clinker production (wet)</p> <p>Kiln combustion system improvements</p> <p>Kiln shell heat loss reduction</p> <p>Use of waste fuels</p> <p>Conversion to modern grate cooler</p> <p>Conversion to pre – heater, pre – calciner kilns</p> <p>Conversion to semi – wet kilns</p>	<p>Clinker production (dry)</p> <p>Kiln combustion system improvements</p> <p>Kiln shell heat loss reduction</p> <p>Use of waste fuels</p> <p>Conversion to modern grate cooler</p> <p>Heat recovery for power generation</p> <p>Low pressure drop cyclones for suspension pre – heaters</p> <p>Long dry kiln conversion to multi stage pre heater-kiln</p>
<p>General measures</p> <p>Preventative maintenance (insulation, compressed air losses, maintenance)</p> <p>Reduced kiln dust wasting</p> <p>Energy management and process control</p> <p>High efficiency motors</p> <p>Efficient fans with variable speed drives</p>	<p>Product changes</p> <p>Blended cements</p> <p>Reducing the concentration of C3S in cements</p> <p>Reducing fineness of cement for selected uses</p>
<p>Finish grinding (applies to both wet and dry cement production)</p> <p>Improved grinding media (ball mills)</p> <p>High – pressure roller press</p> <p>High efficiency classifiers</p> <p>Improve mill internals</p>	

Installation of pre-calciners on dry pre-heater kiln: An existing preheater kiln may be converted to a multi-stage preheater precalciner kiln by adding a precalciner, when possible an extra preheater. The addition of a precalciner will generally increase the capacity of the plant, while lowering the specific fuel consumption. Using many features of the existing plant and infrastructure as possible, special precalciners have been developed by various manufacturers to convert existing plants. e.g. Pyroclon®-RP by KHD in Germany. Generally, the kiln, foundation and towers are used in the new plant, while cooler and preheaters may be replaced. Cooler replacement may be necessary in order to increase the cooling capacity for larger production volumes. The conversion of a plant in Italy, using the existing rotary kiln, led to a capacity increase of 80-100%, while reducing energy use from 3.56 to 3.06 GJ/tonne clinker, resulting in a saving of 11-14%. Fuel savings will depend strongly on the efficiency of the existing kiln and on the new process parameters (e.g. degree of precalcination, cooler efficiency). The average savings of new calciners can be 0.4 GJ/tonne of clinker. It is assumed a cost of \$15/annual tonne of clinker. The increased production capacity is likely to save considerably in operating costs, estimated around \$1/tonne of clinker. [30]

Conversion of long dry kilns to dry pre-heater, pre-calciner kilns: In some cases it may be feasible to upgrade a long dry kiln to the more current state of the art multi-stage preheater, pre-calciner kiln. The average energy saving is 1.3 GJ/t clinker for this conversion. This savings reflects the difference between the average dry kiln fuel intensity (4.5 GJ/t clinker) and the energy intensity of a modern preheater, pre-calciner kiln (3.2 GJ/t clinker) based on a study of the Canadian cement industry and the retrofit of an Italian plant. The estimated investment costs of \$28/t clinker capacity [13].

Low pressure drop cyclones for suspension preheater:

Cyclones are a basic component of plants with pre-heating systems. The installation of newer cyclones in a plant with lower pressure losses will reduce the power consumption of the kiln exhaust gas fan system. Depending on the efficiency of the fan 0.6-0.8 kWh/t clinker can be saved for each 50 mm VS the pressure loss is reduced. For older kilns this amounts to savings of 0.6-1.1 kWh/t. Installation of the cyclones can be expensive, since it

may often entail the rebuilding or the modification of the preheater tower, and the costs are very site specific. New cyclone systems may increase overall dust loading and increase dust carryover from the preheater tower. However, the dust carryover problem is less severe if an inline raw mill follows it. [13]

Low temperature Waste Heat Recovery power generation: A large amount of energy consumption for cement production occurs in the calcination process. This involves passing raw materials through a preheater stack containing cyclone heaters to a long rotating kiln to create clinker and then cooling clinker in the clinker cooler. In the clinker production process, a significant amount of heat is typically vented to the atmosphere without being used, resulting in wasted heat that can lead to heat pollution. If the waste heat is captured and used for power generation, it can significantly improve energy efficiency and reduce the amount of power imported from the electric grid. [13]

CHAPTER THREE

Data Collection and Analysis

3.1 Data Collections

Different types of relevant data are collected to have more understanding on the energy utilization and efficiency of the energy intensive equipment of Messobo cement factory. These data have been collected from many sources through direct observation of the factory auxiliary and major operating equipments and through conducting personal conversations and interviews. These data also collected from the result of other people's research in the same problem area, or from other related problem areas. It includes the study of documents and records obtained from the factory, web-sites and other historical and documentary records relevant for the research. That was done from utility bills, fuel purchase receipts and from individual departments or processes of energy meter.

From the collected data the following were included:

- Average energy consumption and energy intensity for the past 4 consecutive years from the factory billing,
- Their average production quantities
- Average energy costs from file of documentation department
- Energy use on electric motors from their motor name plates, measurement and calculations.
- Energy use on lighting system of the factory

3.1.1 Overall Energy Intensity

Energy intensity is defined as the energy consumption per ton of cement production. It depends on the type of fuel energy and its shares in total consumption. Many studies also calculate energy per unit of output in various sectors (e.g. specific energy consumed per unit of output) and compare these values with levels attained in other countries. Figure 3.1

shows fuel consumption to produce clinker in different countries abroad. And Japan has the most efficient clinker production with about 3.2 GJ per tonne of clinker [33].

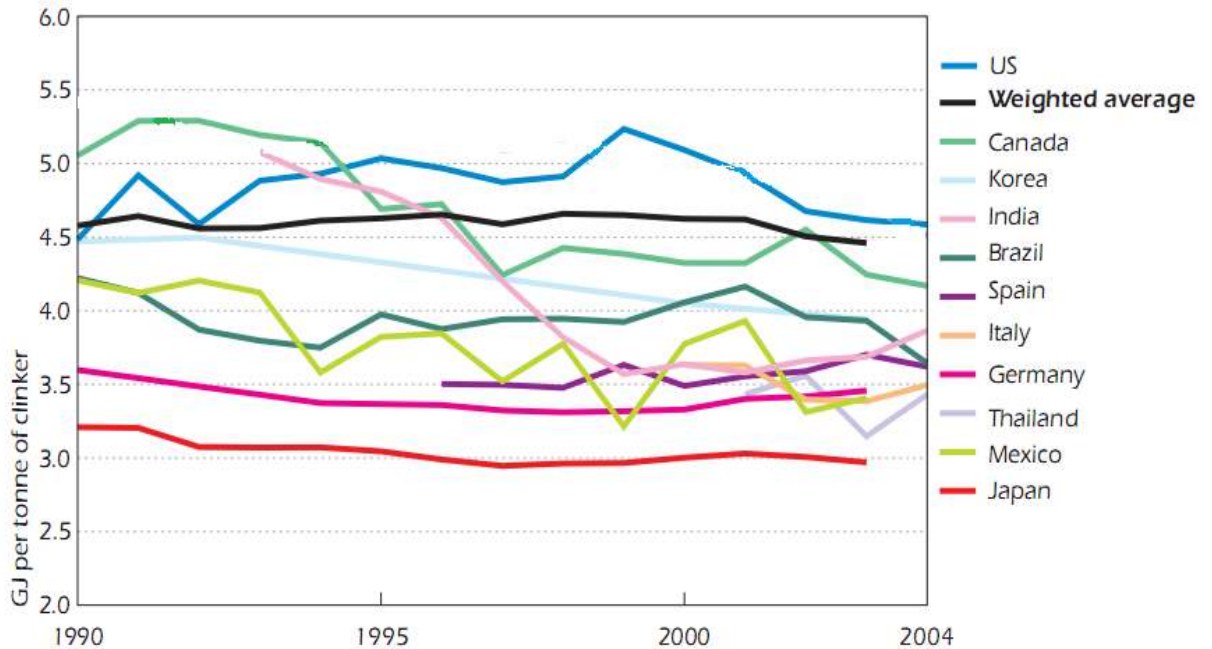


Figure 3--1: Energy consumption per tonne of clinker by country [33]

Messebo cement factory uses two main inputs of energies. Coal is mainly used in kiln for production of heat (thermal energy) which is used for clinker production and electricity to operate electric equipments in cement grinding and office. This study discussed the characteristic of specific energy consumption per unit output of the factory. And also it identifies energy efficiency opportunities suitable for industry. Table 3.1 shows the cement production and energy consumption data for four years of cement production.

Table 3--1: Cement Production and Energy Consumption Data for Four years of Cement Production of Messebo Cement Factory

No.	Items	Unit	Year of production			
			2009	2010	2011	2012
1	Cement production	ton	698,624.00	716,060.00	893,733.58	848,776.50
2	Clinker Production	ton	604,875.00	687,184.00	642,657.00	521,699.00
4	Electric Consumption	KWh	88,011,568.81	86,399,578.99	91,499,556.46	96,652,458.47
3	Coal consumption	ton	66,365.19	76,721.12	73,918.74	70,228.03
		Loe/ton	53,291,247.57	61,607,059.36	59,356,748.22	56,393,108.09
5	Fuel consumption(oil)	lits	3,940,890.00	6,013,100.00	4,930,540.00	3,124,290.00
6	Specific Ele. Consumption (cement)	KWh/ton	125.98	120.66	102.38	113.87
7	Specific coal Consumption(clinker)	ton coal/ton of clinker	0.11	0.11	0.12	0.13
8	Specific fuel oil Consumption(clinker)	Lits/ton	6.52	8.75	7.67	5.99
9	Energy Intensity (elec)	KJ/Kg	453.52	434.37	368.56	409.94
10	Energy Intensity (coal)	KJ/Kg	3080.00	3080.00	3360.00	3640.00
11	Energy Intensity (oil)	KJ/Kg	267.78	359.64	315.32	246.13
12	Total Specific Fuel Cons.	Loe/ton	94.62	98.40	100.03	114.08
13	Total Energy Intensity (Fuel)	KJ/Kg	3347.78	3439.64	3675.32	3886.13

Messebo cement factory average thermal (fuel) energy intensity consumption varies from 3347.78- 3886.13 KJ/Kg of clinker production with average intensity of 3587.22KJ/Kg of clinker production annually as shown in table 3.1. And also the average electrical energy intensity varies from 102.38 -125.98 kWh/ton of cement with average electrical energy intensity of 115.72 kWh/ ton of cement annually. Their energy Costs of the factor is also summarized in table3.2.

Table 3--2: Energy costs of Messebo cement factor for both electrical, and fuel (coal and furnace oil) [9]

Item	Unit	Year			
		2009	2010	2011	2012
Furnace oil	Birr	16,256,171.25	27,780,522.00	24,356,867.60	18,683,254.20
electricity Energy	Birr	49,092,853.08	52,600,063.69	34,815,581.23	54,540,982.31
coal Consumption	Birr	91,231,178.12	102,441,476.53	89,982,464.90	102,169,816.79
Total Cost	Birr	156,580,202.46	182,822,062.22	149,154,913.73	175,394,053.31

3.1.2 Lighting System

Lighting system of Messebo cement factory not specifically designed for the specific applications. The existing illumination in some department is higher and in some other smaller than that of the required lux. i.e. if the lighting provided is higher than the standard required lux for any part of the production as shown in the table.

Lighting system data of the factory distributed throughout the entire of the factory is summarized in table 3.3. There are around 767 florescent lamps currently installed in Messebo cement factory with power rating of 40 W of each. The fluorescent tubes are type T-12 tubes (T-12 lighting tubes are 12/8 inches in diameter and the “T-“designation refers to a tube’s diameter in terms of 1/8 inch increments).

Table 3--3: Summary of collected lighting system data of Messebo cement factory

No.	Department	NL (each)	TP(w)	RA(m2)	OH (hours)	UE (wh/day)
1	Raw materials stores	24	960	178	24	23040
2	Production control Room	23	920	88	24	22080
3	Admi.Buil.	92	3680	624	8	29440
4	Raw Mill control Room	33	1320	172	24	31680
5	Clinic	16	640	112	24	15360
6	Cooler control Room	33	1320	165	24	31680
7	Eng. Dep.	212	8480	672	24	203520
8	Cement Mill control Room	32	1280	144	24	30720
9	Packing & transport	48	1920	372	16	30720
10	Water treatment room	8	320	51.6	24	7680
11	Workshops	33	1320	198	8	10560
12	Coal Pre.Control Room	32	1280	216	24	30720
13	Garage	26	1040	203	8	8320
14	Kibebs	30	1200	206	8	9600
15	Maintenance	25	1000	168	8	8000
16	Crushing cotol Room	32	1280	208	24	30720
17	Cement Stores	24	960	152	24	23040
18	Oil Pump Room	5	200	36	16	3200
19	Substation control room	22	880	203	24	21120
20	Time Keeper	4	160	35	24	3840
21	Guard	5	200	35	8	1600
22	Crushing	8	320	97.2	24	7680
		767	30680			584320

3.1.3. Electric Motor Systems

Motors and drives are used throughout the cement plant to move fans (preheater, cooler, alkali bypass), to rotate the kiln, to transport materials and grinding cements. There are around 700 electric motors installed at Messebo cement factory. If the replacement does not influence the process operation, motors may be replaced at any time. However, motors are often rewired rather than being replaced by new motors. Many motors of different power ratings are currently in operation in the factory (See some of them in Appendix A). Most of these motors are old, rewound, not regularly maintained and efficiency loss is common to the motors that are rewound.

Energy efficient motors reduce energy losses through improved design, better materials, tighter tolerances, and improved manufacturing techniques. With proper installation, energy-efficient motors can also run cooler (which may help reduce facility heating loads) and have higher service factors, longer bearing life, longer insulation life, and less vibration. Efficient motors also tend to have a better relative performance at part load, which is of increased benefit for applications with variable load requirements. In this regard there is a high opportunity to save energy in the factory.

Basic electric motors of data were collected from main cement production processes with different name plate of operating parameters and measured value of the existing electric motors of the factory. The collected electric motors data of Messebo cement factory is summarized in Table 3.4.

Table 3--4: Collected Electric Motors Data of Messebo Cement Factory

No.	Description of motor	Type of motor	Name Plate			Actual measurement				Department
			Rated power(kw)	Rated efficiency	Speed (rpm)	output power (kw)	Power factor	Voltage (v)	Current drawn(A)	
1	Mill Main drive	YKK710-6	2500	85%	993	2111.1	92%	5.18k	258.3	Raw Mill
2	Kiln inlet fan	2315S ,SG	1600	83%	1000	956.6	91%	6.11k	97.6	Rotary kiln
3	Main Drive motor	412BL2M1	2900	80%	996	2149.3	90%	5.9k	263.5	Raw Mill
4	Kiln outlet fan	M472INF/M	1400	86%	740	918.9	92%	6.09k	101.6	Rotary kiln
5	Lime stone Crusher	432MD1M1	630	81%	1000	407.6	93%	5.89k	39.3	Crusher
6	Single Stage Hammer Crusher	M212HC1M1	710	86%	1500	529.8	91%	6.27k	44.6	Crusher
7	Cement Mill Main Drive	562BE3MD1	900	82%	744	614.2	92%	6.09k	66.6	Cement Mill
8	Exhaust gas fan	M472CH/M1	1000	84%	740	618.4	90%	6.11k	62.2	Cooler
9	Coal Mill main drive	L92BL1	500	81%	990	262.2	93%	6.59k	26.4	Coal Mill
10	Cement Mill Fan motor	YRKK900-8	1600	73%	744	1086.3	92%	6.38k	94.5	Cement Mill
11	ID Fan HV Cabinet	442FN1M1	1800	80%	994	1212.52	88%	6.39k	174.7	Raw Mill

12	Coal Mill Fan Motor	YRKK450-4	710	81%	1500	520.1	95%	5.88k	57.7	Coal Mill
13	Chain Conveyor	392CV5M1	30	75%	1460	21.3	87%	378	31.6	Raw Mill
14	Clinker crusher	Y280M-4	90	85%	1450	53.8	94%	388	53.4	Cooler
15	Circulating gas fan	M472OUF/M	250	79%	1470	121.7	93%	392	206.3	Cooler
16	Hot gas fan	M472FND M1	45	75%	1470	31.2	90%	390	44.8	Cooler
17	Deep pan conveyor	M472FN3M 1	30	80%	1470	16.8	89%	387	34.4	Cooler
18	Bucket Elevator	M492DP/M 1	185	75%	980	125.5	92%	386	197.2	Raw Mill
19	Roots fan (primary)	442MD/M1	300	85%	1470	96.7	88%	377	201	Raw Mill
20	Belt Conveyor	YRKK560-6	160	82%	1500	103.9	89%	367	172.7	Raw Mill
21	Belt Conveyor	Y200L2-6	22	75%	980	15.9	88%	386	27.2	Crusher
22	Fan for filter	M212BC/M 1	75	80%	1112	49.4	90%	385	86.2	Crusher
23	Belt Conveyor Frequency control	M212FN/M 1	200	85%	1500	129.3	93%	395	165.7	Crusher
24	Fan for filter	M212BC3M 1	18.5	78%	2240	12.8	91%	400	13.9	Crusher
25	Bucker Elevator	M212FN3M 1	160	76%	1500	79.2	87%	387	116.3	Cement Mill
26	Bucker Elevator	Y315S-	110	86%	1500	36.7	86%	388	53.5	Cement

		2(VVVF)								Mill
27	Fan for bag filter	592BE/MD1	55	80%	1480	25.5	89%	394	38.9	Cement Mill
28	Belt conveyer drive	592FN4M	5.5	83%	1450	3.5	91%	390	5.8	Cement Mill
29	Belt conveyer drive	Y200L2-6	11	75%	1460	6.3	93%	377	7.7	Cement Mill
30	Reversible belt conveyer	Y2-132M-4	5.5	80%	1440	3.6	95%	378	5.3	Cement Mill
31	Reversible belt conveyer	Y132M_4	7.5	75%	1460	7.8	90%	381	11.7	Cement Mill
32	Roots Fan	L42FNM1	132	82%	1470	69.9	88%	366	147.8	Coal Mill
33	Belt Conveyor	Y200L2_6	22	75%	150	14.2	96%	384	15.9	Coal Mill
34	Bucket Elevator	L22BC/M1	55	80%	1480	37.3	90%	387	35.1	Coal Mill
35	Fan for filter	L42BE/M1	37	75%	1000	25.3	86%	360	29.8	Coal Mill
36	Bag filter Screw conveyer Drive	L42FN3M1	5.5	80%	1450	2.8	88%	390	4.5	Coal Mill
37	Water injection Pump	Y132S2-2	7.5	75%	2900	4.6	87%	396	6.3	Coal Mill
38	Classifier Motor	Y2-132S2-2	22	80%	1460	15.9	86%	388	17.6	Coal Mill
39	Motor for oil pump	Y132S-B5	3	75%	1430	1.8	91%	380	2.8	Cooler
40	Centrifugal Fan	Y180L-4	22	80%	1450	13.7	87%	387	31.9	Cooler

3.2 Data Analysis

3.2.1 Energy Loss Assessment

In industry energy assessments determine where and how much energy is consumed and identify steps to improve the facility's energy efficiency. The energy loss assessment of the factory can be determined depend on the average specific energy consumption or energy intensity (energy consumed per unit of output) of the factory. In this study benchmark is uses to compare a defined energy characteristic of Messebo cement factory to other selected cement plants.

Standard benchmark cement plants focuses on comparing the average level of energy consumption (both for electricity and fuel) of the cement plant with the selected cement plants to produce cement. These selected benchmarks uses similar technology configurations, uses the same raw materials and produces the same types of cement production with Messebo cement factory. These selected plants have also higher energy efficiency performance of their clinker production than other cement plants abroad (the selected cement plants of china are efficient as compared with plants above in figure 3.1). Since energy intensity is a measure (indicator) of the energy efficiency of plants in this paper also the comparison their energy is done based on their energy intensity consumption used to produce a unit product. Table 3.5 shows the energy consumption of different cement production plants in four cement plants in China. [13]

Table 3-5: Energy consumption of different cement production plants in selected cement plants in China [13]

No.	Items	Unit	Energy efficient selected cement plants in China			
			1	2	3	4
1	Specific Ele. Consumption (cement)	KWh/ton	86.69	82.75	78.56	87.20
2	Specific Fuel (coal & oil) Consumption(clinker)	Lits/ton	59.06	78.25	56.07	54.08
3	Energy Intensity (elec)	KJ/Kg	312.08	297.90	282.82	313.92
4	Energy Intensity fuel	KJ/Kg	2,370.00	3,140.00	2,250.00	2,170.00

During 2009- 2012 year, the annual average thermal (fuel) energy intensity of the factory varies from 3347.78- 3886.13 KJ/Kg of clinker production with average intensity of 3587.22 KJ/Kg of clinker production. However, there is a gap between these efficient plants (taken as benchmark with an average of 2482.5 KJ/Kg of clinker production). Hence a difference of 1,104.72 KJ/Kg of clinker exists between the average best practice and what exists at Messebo factory. There is 18% difference fuel energy between these efficient plants and the factory average energy. Figure 3.2, shows the comparing of the energy intensity and specific energy of Messebofactorywithstandardbenchmarkplants

Similarly, the annual average electrical energy intensity varies from 102.38 -125.98 kWh/ton of cement with annual average electrical energy intensity of 115.72 kWh/ ton of cement, but the electrical energy intensity across these efficient plants (taken as benchmark) with an average of 83.8 kWh/ ton of cement. Hence a difference of 31.92kwh/ton of cement exists between the average energy as compared to benchmark plants and what exists at the factory.

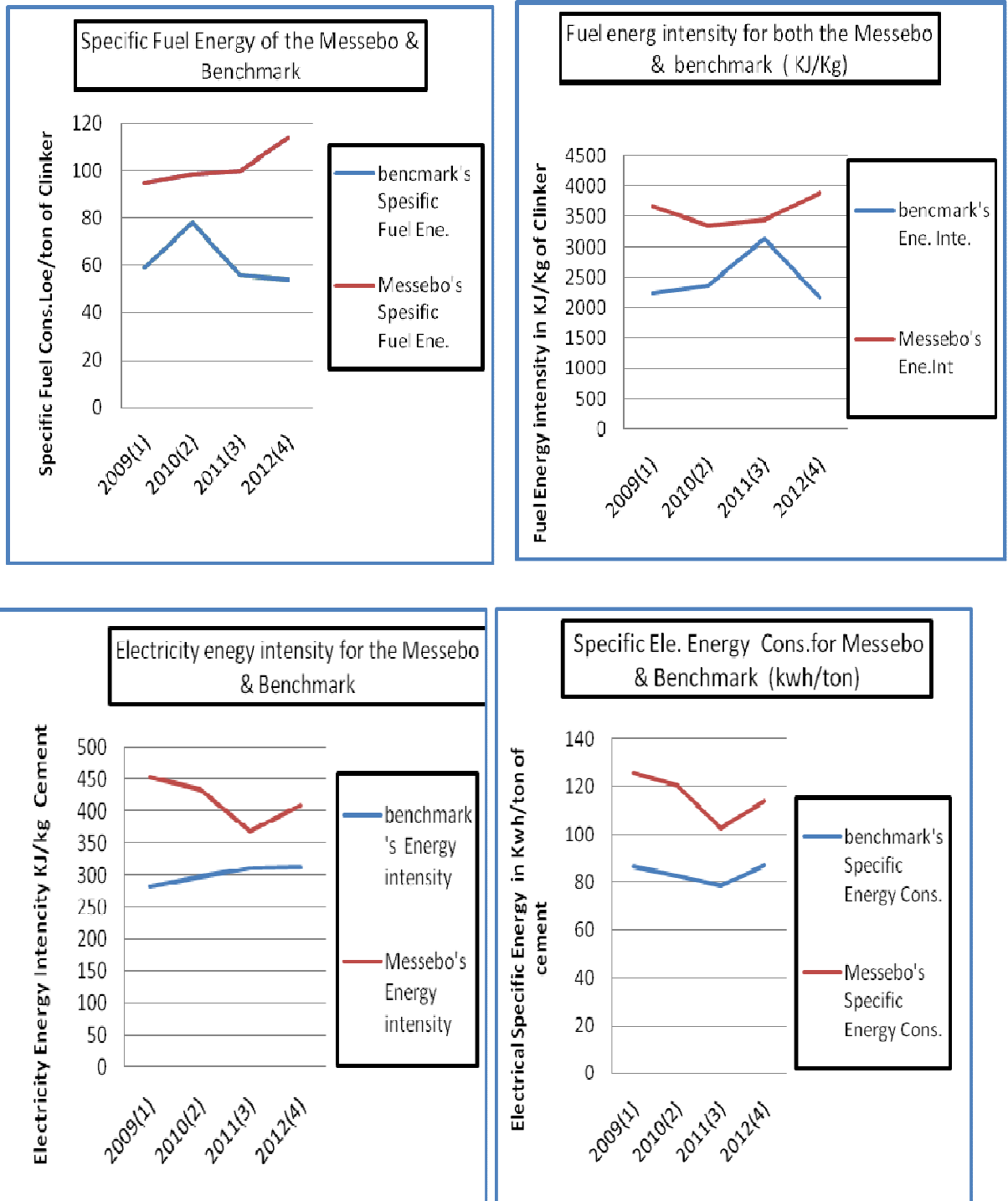


Figure 3--2: Comparing of the energy intensity and specific energy of Messebo factory with standard benchmark

There is 16% difference of specific electrical energy between these efficient plants and the factory of average energy. The energy intensity of the factory for both in the electricity and fuel had a significant difference as compared to the benchmark cement plant experience. This shows that Messebo cement factory has not operated efficiently. As the result this study suggests on possibility of energy consumption reduction through energy efficiency improvements of their energy intensive equipments.

The following calculation also shows clearly how much the company is actually spending on energy due to uses of inefficient energy systems.

The average annual cement and clinker production of Messebo cement factory in the years from 2009- 2012 ranges given as follow:

Cement production = 789,298.52 ton of cement per year and

Clinker production = 614,103.75 ton of clinker/year.

Average cost of fuel oil for the given year of interval [8] = 4.725 birr/Lit.

Average cost of electricity [8] = 0.5birr per kWh.

Average cost of coal [8] =1345.52birr/ton

Coal (Gross calorific value) [19] =4000 kCal/kg (28 GJ/ton)

Difference in fuel oil energy intensity = 1,104.72 KJ/Kg of clinker.

Difference in electricity energy intensity = 31.92kwh/ ton of cement

Specific heat of heavy fuel oil [34] = 0.0411 GJ/litre)

Annual cost due to inefficient use of fuel energy intensity

$$= \text{fuel energy per output} * \text{cost of fuel}$$

$$= \frac{[[\text{fuel energy intensity (kJ/kg)} * \text{clinker prod. (ton/year)}]]}{[\text{specific heat fuel (kJ/tons)}]} * \text{cost fuel (birr/ton)}$$

$$= 32,600,637.46 \text{ birr/year}$$

Annual cost due to inefficient use of electricity energy intensity

$$= \text{electricity consumption in kWh} * \text{cost of electricity.}$$

$$= \text{energy inte (kwh/ton)} * \text{production (ton/year)} * \text{cost ele (birr/kwh)}$$

$$= 12,597,204.38 \text{ birr/year}$$

Therefore, the total annual cost of energy intensity due to inefficient use of their energy becomes the sum of both energy intensity cost of electricity and fuel i.e:

$$= \text{cost of fuel} + \text{cost of electricity}$$

$$= 32,600,637.46 \text{ birr/per year} + 12,597,204.38 \text{ birr/per year}$$

$$= 45,197,841.70 \text{ birr/per year}$$

From this result, Messebo cement factory pays additional such amount of payment which actually was not necessary.

In addition cement industry, by its nature, leads to CO₂ emissions. Because CO₂ is released in the process of turning limestone into clinker, combustion of fuels and inefficiency use of electrical systems. Cement industry is responsible for 5% of total global emissions of CO₂ gas. [35]

Since environment and efficiency are closely interlinked with each other, it is known that CO₂ also released from inefficiency use of electrical systems. By improving the energy efficiency system of the industry considerable amount of energy can be saved and it also leads to have

clean environment. The CO₂ emissions from cement industry could be calculated based on the type of energy input used and their related CO₂ emission factor.

Adopt an emission factor of 0.52 t CO₂ per ton of clinker and 0.425 t CO₂ per ton of cement to roughly estimate the CO₂ emissions from clinker and cement production respectively. And also an emission factor of 94.6 t CO₂ per TJ of fuel and 0.813 KgCO₂ per kwh to roughly estimate the CO₂ emissions from fuel and electricity consumption respectively [24]. According to these estimation factors of the main energy input of the factory, CO₂ emission of Messebo cement factory is estimated as follow. Since Messebo cement industry uses fuels (coal) and electricity (emits CO₂ indirectly) for manufacturing cement, peoples who lives around the cement factory get gradually impact on their health problem. Estimated total CO₂ emission of Messebo cement factory based on the input energy and their corresponding CO₂ emission factor is summarized in table 3.6.

Table 3--6: Shows Average CO₂ Emissions resulting from the process production and energy consumption of Messebo cement factory

	Production		Energy Consumption	
	Cement production	Clinker production	Electricity	Fuel
	789,298.52 (ton)	614,103.75 (ton)	90,640,790.68 (kWh)	678.41 (TJ)
Emission factor	0.425 tCO ₂ /ton	0.52 tCO ₂ /ton	0.813 kgCO ₂ /kWh	94.6 tCO ₂ /TJ
Emission (tCO ₂)	335,451.87	319,333.95	73,690.96	64,177.84
TotalEmission(tCO ₂)	792,654.62			

This estimation is made for the average production & energy consumption data of four consecutive years, which is already considered above. As shown in the table 3.6, the factory emits around 0.79 million of tCO₂ in four consecutive cement production years. This result can be reduced with improving the efficient of energy intensive equipments of the factory. As the result, this factory consumes large amount of energy and they pay a lot of cost due to inefficient use of energy as compared with the selected benchmark cement plants. Analyzing of the energy intensive equipment of the major electrical energy consumer such as electric motors and lighting systems of the factory.

3.2.2 Analysis of Lighting Systems

Analyzing of the lighting system of the factory will do through comparing the existing lighting system with appropriate illumination (lux standards) level for various departments of the factory, which may reduce the energy use cost throughout the entire factory.

For the purpose of analyzing the illumination of the existing lighting systems of the factory, it is necessary to consider & determine the following main things.

- The existing total number of lamps and total power rating of them installed in each department
- Area of the room of each department measured in square meter.
- Operating hours of each lamps
- required standard illumination (RSE) of specific working stations/departments and
- total lumen output and illumination produced by the existing lamp installed in the department

These things uses to determine the actual number of lamps needed to post in each department due to use of proper illumination level with the same florescent lamp rating of the existing lamp in the factory. Luminous intensity of each florescent lamp installed in each department of the factory is with 85(lumens per watts) see table 3.7. [5] These data also analyzed based on the following calculation and according to the considered things above.

$$TP = \text{rating power of lamp (w)} * ENL$$

TP the total power rating of lamps installed in each department

ENL The existing number of lamps installed in each department

Table 3--7 : Provides an overview of the luminous intensity of various lamps [5]

No.	Lamp Type	Luminous Intensity (Lumens/watt)
1	Tungsten Incandescent	15
2	Fluorescent	60--85
3	High Pressure Hg vapor lamps—80W	2880
4	High Pressure Hg vapor lamps—400W	14400
5	High Pressure Na --70W	5740
6	High Pressure Na --400W	46,800
7	Low pressure Na—10W	1,000
8	Low pressure Na –18W	3,150
9	CFL up to & including 7W	45
10	CFL 8---10W	50
11	CFL 11---15W	55
12	CFL 16---24W	60

The term luminous flux is used to measure the visible light output of lamps, being emitted from a light in all directions. The relationship between the watt and lumen (lumen/watt) is important as it is possible to calculate the luminous flux (lumens) a particular lamp will produce by considering the radiated power at each wavelength and the corresponding eye sensitivity at that wavelength.

$$TLu(\text{lumens}) = ENL(\text{watt}) * \text{intensity}(\text{lumens/watt})$$

TLu ----- total lumen output of the lamp installed in the department

The illuminance E at a point on a surface is defined as the luminous flux F (lumens) incident upon a small element of the surface divided by the area A (m²) of the element i.e. 1 lux is equivalent to 1lumens/m².

$$E = TLu(\text{lumens}) / RA(\text{m}^2) \text{ or lux}$$

E -----The illumination produced by the installed lamps

RA ----Room area of each department measured in square meter.

Since lighting system needs to install based on the required standards illumination (RSE) of the specific working stations, the factory should be install the lighting system according to the standard. Table 3.8: shows required standard illumination values for the working stations of the factory. The luminous intensity of various lamps and required standard illumination (RSE) used to evaluate whether the current installation system is appropriate or not.

Table 3--8: Required standard illumination values for the working stations of the factory [5]

No.	items	Illumination Required(lux)
1	Offices	500
2	workshop	750

Depend on the existing of specific work stations of Messebo cement factory, the actual number of lamps required to post (ALP) for the specific area of application was required. To determine ALP, the existing number of lamp (ENL), required standard illumination (RSE) of specific work stations and the illumination produced by the installed lamps of each department (E) will be used.

The analyzed lighting data of each department of Messebo cement factory are florescent lamps with rating of 40W and summarized in table 3.9.

Table 3--9: Summary of analyzed lighting system data of Messebo cement factory

No.	Department	NL (each)	TP(w)	TLU (lumens)	RA(m 2)	E(lux)	ALR (each)	OH (h)	UE (^{wh} /day)	RE (^{wh} /da)	ES (^{wh} /day)
1	Raw materials stores	24	960	81600	178	457.40	16	24	23040	15360	7680
2	Production control Room	23	920	78200	88	888.64	13	24	22080	12480	9600
3	Admi.Buil.	92	3680	312800	624	501.28	92	8	29440	29440	0
4	Raw Mill control Room	33	1320	112200	172	652.33	25	24	31680	24000	7680
5	Clinic	16	640	54400	112	485.71	16	24	15360	15360	0
6	Cooler control Room	33	1320	112200	165	680.83	24	24	31680	23040	8640
7	Eng. Dep.	212	8480	720800	672	1072.62	99	24	203520	95040	108480
8	Cement Mill control Room	32	1280	108800	144	755.56	21	24	30720	20160	10560
9	Packing & transport	48	1920	163200	372	438.71	55	16	30720	35200	-4480
10	Water treatment room	8	320	27200	51.6	527.13	8	24	7680	7680	0
11	Workshops	33	1320	112200	198	566.67	29	8	10560	9280	1280
12	Coal Pre.Control Room	32	1280	108800	216	503.70	32	24	30720	30720	0
13	Garage	26	1040	88400	203	435.47	30	8	8320	9600	-1280
14	Kibebs	30	1200	102000	206	495.63	30	8	9600	9600	0
15	Maintenance	25	1000	85000	168	505.95	25	8	8000	8000	0
16	Crushing cotol Room	32	1280	108800	208	523.08	31	24	30720	29760	960
17	Cement Stores	24	960	81600	152	536.49	22	24	23040	21120	1920
18	Oil Pump Room	5	200	17000	36	472.22	5	16	3200	3200	0
19	Substation control room	22	880	74800	203	367.75	30	24	21120	28800	-7680
20	Time Keeper	4	160	13600	35	388.57	5	24	3840	4800	-960
21	Guard	5	200	17000	35	485.71	5	8	1600	1600	0
22	Crushing	8	320	27200	97.2	279.84	14	24	7680	13440	-5760
		767	30680				627		584320	447680	136,640

$$ALP = \left[\frac{RSE \text{ (lux)}}{E \text{ (lux)}} \right] * ENL \text{ (each)}$$

ALP – The actual number of lamps needed to post in each department due to use of proper illumination level with the same florescent lamp rating of the existing lamp in the factory.

RSE -----Required standard illumination level of each department

$$EU = ENL * \text{rating power lamp}$$

EU---the energy spend by the lighting system along the entire of the industry

$$RE = ALR * \text{rating power lamp}$$

RE----the required energy after improving the utilization illumination level of the factory

$$ES = EU - RE$$

Energy saved (ES) is the difference of energy from the utilized energy and the actual required energy, after improving the illumination level of the lighting system of the factory.

According to the analysis, the factory have been installed with 767 existing lamps with total power demand of 30.68kw and 0.21GWh annually energy consumption. But after improved/optimized the illumination of the system the actual florescent lamps required in the factory could minimize to 627 lamps. Therefore there are around 140 unnecessary lamps installed, which cause to pay additional birr. This analysis of lighting lamps have done through comprising of the existing illumination level at the specific area of the factory with the standards of illumination (see table 3.9), the saving potential of lighting systems from illumination level improvement.

3.2.3 Analysis of Electric Motors

3.2.3.1 Motor efficiency

The efficiency of a motor can be defined as “the ratio of a motor’s useful power output to its total power output.”

$$\eta = \left[\frac{\text{output power at the existing load}}{0.7457 * \text{Name plate rated power}} \right] * 100\%$$

A motor's function is to convert electrical energy to mechanical energy to perform useful work. In the process of convert electrical energy to mechanical energy to serve a certain load, motors losses their energy as shown in the figure 3.3. Losses can vary from approximately 2 % to 20%. [16]

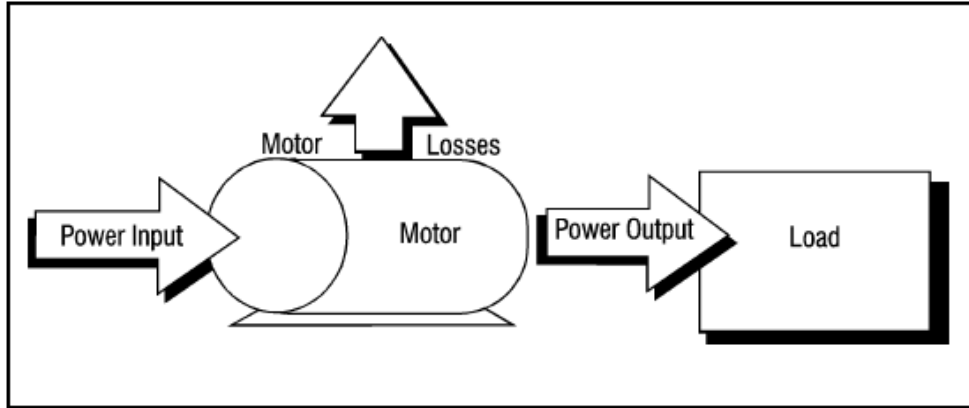


Figure 3--3: Illustration of motor energy losses [17]

The efficiency of a motor is determined by intrinsic losses that can be reduced only by changes in motor design. Intrinsic losses are of two types: fixed losses - independent of motor load, and variable losses - dependent on load. Fixed losses consist of magnetic core losses and friction and winding losses. Magnetic core losses (sometimes called iron losses) consist of eddy current and hysteresis losses in the stator. They vary with the core material, geometry and with input voltage. Friction and winding losses are caused by friction in the bearings of the motor and aerodynamic losses associated with the ventilation fan and other rotating parts. Variable losses consist of resistance losses in the stator and in the rotor and miscellaneous stray losses. Measures adopt for energy efficiency concentrate on each loss specifically discussed as follows:

Stator and Rotor I^2R Losses

These losses are major losses and typically account for 55% to 60% of the total losses. I^2R losses are heating losses resulting from current passing through stator and rotor conductors.

I^2R losses are the function of a conductor resistance, the square of current. Resistance of conductor is a function of conductor material, length and cross sectional area. The suitable selection of copper conductor size will reduce the resistance. Reducing the motor current is most readily accomplished by decreasing the magnetizing component of current. This involves lowering the operating flux density and possible shortening of air gap. Rotor I^2R losses are a function of the rotor conductors (usually aluminum) and the rotor slip. Utilization of copper conductors will reduce the winding resistance. Motor operation closer to synchronous speed will also reduce rotor I^2R losses.

Core Losses

Core losses are those found in the stator-rotor magnetic steel. These losses could happen due to hysteresis and eddy current effect during 50 Hz magnetization of the core material. These losses are also independent of load and account for 20– 25 % of the total losses. The hysteresis losses which are a function of flux density, are reduced by utilizing low-loss grade of silicon steel laminations. The reduction of flux density is achieved by suitable increase in the core length of stator and rotor. Eddy current losses are generated by circulating current within the core steel laminations. These are reduced by using thinner laminations.

Friction and Winding Losses

Friction and winding losses result from bearing friction, winding and circulating air through the motor and account for 8 – 12 % of total losses. These losses are independent of load. The reduction in heat generated by stator and rotor losses permits the use of smaller fan. The winding losses also reduce with the diameter of fan leading to reduction in winding losses.

Stray Load-Losses

These losses vary according to square of the load current and are caused by leakage flux induced by load currents in the laminations and account for 4 to 5 % of total losses. These losses are reduced by careful selection of slot numbers, tooth/slot geometry and air gap.

In addition, distribution conductors are used to supply currents to motors and these cables produce I^2R 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. The only way to improve motor efficiency is to reduce motor losses. Even though standard motors operate efficiently with typical efficiencies ranging between 83 and 92% energy-efficient motors perform significantly better. An efficiency gain from only 92 to 94 % results in a 25% reduction in losses. [17]

The primary factors affecting motor efficiency are:

- ✓ Speed (high-speed motors tend to be more efficient)
- ✓ The size of the motor (larger motor rate capacity tend to be more efficient).
- ✓ Type of enclosure (open enclosures tend to be more efficient)
- ✓ Design classification (lower slip motors tend to be more efficient).
- ✓ Size of the air gap between the rotor and the stator. Large air gaps tend to maximize efficiency at the expense of power factor, while small air gaps slightly compromise efficiency while significantly improving power factor.
- ✓ Rewinding of motor may reduce its efficiency
- ✓ Temperature Totally-enclosed fan-cooled (TEFC) motors are more efficient than screen protected drip-proof (SPDP) motors.
- ✓ Motor load: generally motors operating below 75% of full load relatively reduces their efficiency and with operating below 50% totally inefficient.
- ✓ Age. New motors are more efficient.

3.2.3.2 Motor Load

There is a clear link between the motor's efficiency and the load. Manufacturers design motors to operate at a 50-100% load. But once the load drops below 50% the efficiency decreases rapidly as shown in Figure 3.4. Operating motors below 50% of rated loads has a similar, but less significant, impact on the power factor. [17] High motor efficiencies and power factor close to 1 are desirable for an efficient operation and for keeping costs down of the entire plant and not just the motor. For this reason, it is useful to determine both the load

and efficiency when assessing a motor's performance. In most countries it is a requirement for manufacturers to display the full-load efficiency on the motor's nameplate.

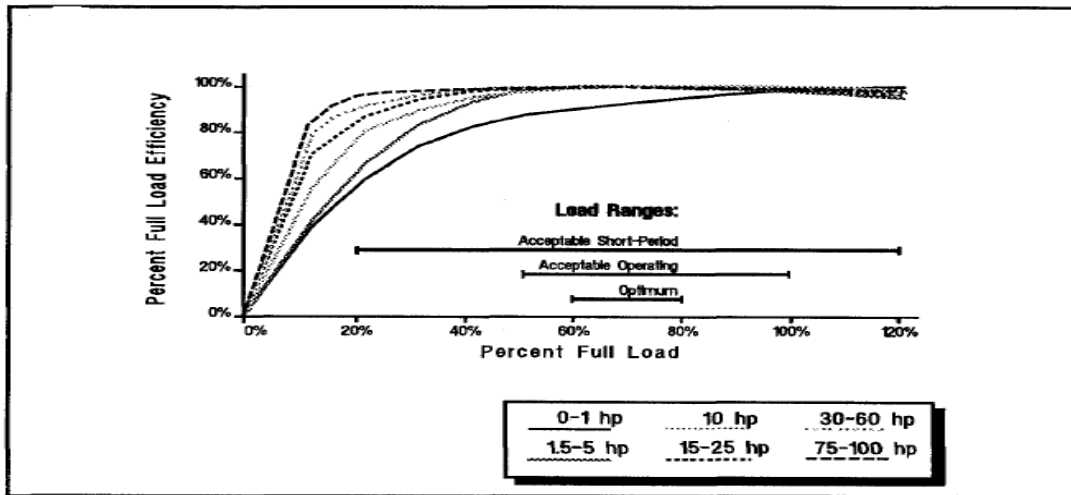


Figure 3--4: Motor part load efficiency as a function of % full Load.[17]

However, when a motor has been in operation for a long time, it is often not possible to determine its efficiency because nameplates of motors are often lost or painted over. In this case the motor's efficiency value can be obtained from tables with typical motor efficiency values. The US DOE fact sheet provides tables with typical motor efficiency values. [17] [37]

Motor Load Estimation Techniques

Rated motor load describes the capacity of the motor to do work. Power and energy measurements are used to determine loads on equipment, energy consumption, running costs, and to verify proper system sizing and operation. To compare operating costs of an existing motor and a more efficient replacement unit needs to determine operating parameters of the motor, efficiency improvement values, and load. Part-load is a term used to describe the actual load served by the motor as compared to the rated full-load capability of the motor.

A motor load survey is carried out to measure the operating load of different motors across the plant. The results are used to identify motors that are undersized (causing motor burn out) or oversized (resulting in inefficiency). To calculate the motor load it should be compare the

power draw (obtained through watt meter or voltage, amperage, and power factor measurements) with the nameplate rating of the motor.

$$P_i = [1.73 * V * I * PF] / 1000$$

Where:

P_i = Three-phase power in kW

V = RMS voltage, mean line-to-line of 3 phases

I = RMS current, mean of 3 phases

PF = Power factor as a decimal

Rated power can be determine by taking the nameplate value using the following equation:

$$P_r = [hp * 0.7457] / \eta_r$$

Where,

P_r = Input power at full-rated load in kW

HP = Nameplate rated horse power

η_r = Efficiency at full-rated load (motor nameplate value)

Motor load can be determined when field data measurements are available through different load estimation techniques discussed below [17].

a. Kilowatt Ratio Motor Load Estimation Technique

The motor load can be derived using the kilowatt ratio technique if nameplate full-load efficiency values are available and when either direct power (kW) or voltage; amperage and power factor readings are available.

$$\text{Motor load} = [P_i/p_r] * 100\%$$

Where,

Load = Output power as a % of rated power

P_i = Measured three phase power in kW

P_r = Input power at full-rated load in kW

b. Voltage Compensated Slip Technique

The voltage compensated slip technique may be used when nameplate data plus supply voltage and measured speed are known.

$$\text{Motor Load} = \frac{RPM_{synch} - RPM_{measured}}{[RPM_{synch} - RPM_{fullnameplate}] * \left[\frac{Rated\ voltage}{Measured\ voltage} \right]^2} * 100\%$$

Where:

RPM_{synch} – synchronous speed in revolution per minute

Rpm_{measured} - measured speed in revolution per minute

Rpm_{nameplate}-- nameplate speed in revolution per minute

Measured voltage– measure three phase voltage

Rated Voltage – nameplate three phase voltage

c. Voltage Compensated Amperage Ratio Technique or Line Current Measurements

Finally, the voltage compensated amperage ratio technique may be used when only supply voltage and current measurements are available.

$$\text{Motor load} = \left[\frac{\text{Amps measured}}{\text{Amps full load nameplate}} \right] * \left[\frac{\text{Volts measured}}{\text{Volts nameplate}} \right] * 100\%$$

Where:

Amps measured – measured three phase current

Amps nameplate – nameplate three phase current

To determine motor loading Kilowatt Ratio motor load estimation technique is preferred over amperage readings because kw readings take into account the change in power factor and amperage that occur as the motor loading changes. [34] Table: 3.10 contain parameters of all the three parameters of the analyzed existing electric motors of the factory.

Table 3--10: Analyzed of Electric Motors Data of Messebo Cement Factory

No.	Description of motor	Type of motor	Name Plate			Calculated		Actual measurement				Department
			Rated power(kw)	Rated efficiency	Speed (rpm)	Loading	Input power (kw)	output power (kw)	Power factor	Voltage (v)	Current drawn(A)	
1	Mill Main drive	YKK710-6	2500	85%	993	72%	2483.65	2111.1	92%	5.18k	258.3	Raw Mill
2	Kiln inlet fan	2315S ,SG	1600	83%	1000	50%	1152.53	956.6	91%	6.11k	97.6	Rotary kiln
3	Main Drive motor	412BL2M1	2900	80%	996	59%	2686.63	2149.3	90%	5.9k	263.5	Raw Mill
4	Kiln outlet fan	M472INF/M	1400	86%	740	56%	1068.49	918.9	92%	6.09k	101.6	Rotary kiln
5	Lime stone Crusher	432MD1M1	630	81%	1000	52%	503.21	407.6	93%	5.89k	39.3	Crusher
6	Single Stage Hammer Crusher	M212HC1M1	710	86%	1500	64%	616.05	529.8	91%	6.27k	44.6	Crusher
7	Cement Mill Main Drive	562BE3MD1	900	82%	744	56%	749.02	614.2	92%	6.09k	66.6	Cement Mill
8	Exhaust gas fan	M472CH/M1	1000	84%	740	52%	736.19	618.4	90%	6.11k	62.2	Cooler
9	Coal Mill main drive	L92BL1	500	81%	990	42%	323.70	262.2	93%	6.59k	26.4	Coal Mill
10	Cement Mill Fan motor	YRKK900-8	1600	73%	744	50%	1488.08	1086.3	92%	6.38k	94.5	Cement Mill
11	ID Fan HV Cabinet	442FN1M1	1800	80%	994	54%	1515.65	1212.5	88%	6.39k	174.7	Raw Mill
12	Coal Mill Fan Motor	YRKK450-4	710	81%	1500	59%	642.10	520.1	95%	5.88k	57.7	Coal Mill
13	Chain Conveyor	392CV5M1	30	75%	1460	53%	22.67	21.3	87%	378	31.6	Raw Mill
14	Clinker crusher	Y280M-4	90	85%	1450	51%	63.29	53.8	94%	388	53.4	Cooler
15	Circulating gas fan	M472OUF/M	250	79%	1470	38%	154.05	121.7	93%	392	206.3	Cooler
16	Hot gas fan	M472FNDM1	45	75%	1470	52%	41.60	31.2	90%	390	44.8	Cooler
17	Deep pan conveyor	M472FN3M1	30	80%	1470	45%	21.00	16.8	89%	387	34.4	Cooler
18	Bucket Elevator	M492DP/M1	185	75%	980	51%	167.33	125.5	92%	386	197.2	Raw Mill
19	Roots fan (primary)	442MD/M1	300	85%	1470	37%	155.65	132.3	0.88	377	225	Raw Mill
20	Belt Conveyor	YRKK560-6	160	82%	1500	53%	126.71	103.9	89%	367	172.7	Raw Mill
21	Belt Conveyor	Y200L2-6	22	75%	980	54%	21.20	15.9	88%	386	27.2	Crusher
22	Fan for filter	M212BC/M1	75	80%	1112	53%	61.75	49.4	90%	385	86.2	Crusher

23	Belt Conveyor Frequency control	M212FN/M1	200	85%	1500	55%	152.12	129.3	93%	395	165.7	Crusher
24	Fan for filter	M212BC3M1	18.5	78%	2240	54%	16.41	12.8	91%	400	13.9	Crusher
25	Bucker Elevator	M212FN3M1	160	76%	1500	38%	104.21	79.2	87%	387	116.3	Cement Mill
26	Bucker Elevator	Y315S-2(VVVF)	110	86%	1500	29%	42.67	36.7	86%	388	53.5	Cement Mill
27	Fan for bag filter	592BE/MD1	55	80%	1480	37%	31.88	25.5	89%	394	38.9	Cement Mill
28	Belt conveyer drive	592FN4M	5.5	83%	1450	53%	4.22	3.5	91%	390	5.8	Cement Mill
29	Belt conveyer drive	Y200L2-6	11	75%	1460	43%	8.40	6.3	93%	377	7.7	Cement Mill
30	Reversible belt conveyer	Y2-132M-4	5.5	80%	1440	52%	4.50	3.6	95%	378	5.3	Cement Mill
31	Reversible belt conveyer	Y132M_4	7.5	75%	1460	78%	10.40	7.8	90%	381	11.7	Cement Mill
32	Roots Fan	L42FNM1	132	82%	1470	43%	85.24	69.9	88%	366	147.8	Coal Mill
33	Belt Conveyor	Y200L2_6	22	75%	150	48%	18.93	14.2	96%	384	15.9	Coal Mill
34	Bucket Elevator	L22BC/M1	55	80%	1480	54%	46.63	37.3	90%	387	35.1	Coal Mill
35	Fan for filter	L42BE/M1	37	75%	1000	51%	33.73	25.3	86%	360	29.8	Coal Mill
36	Bag filter Screwconveyor Drive	L42FN3M1	5.5	80%	1450	41%	3.50	2.8	88%	390	4.5	Coal Mill
37	Water injection Pump	Y132S2-2	7.5	75%	2900	46%	6.13	4.6	87%	396	6.3	Coal Mill
38	Classifier Motor	Y2-132S2-2	22	80%	1460	58%	19.88	15.9	86%	388	17.6	Coal Mill
39	Motor for oil pump	Y132S-B5	3	75%	1430	45%	2.40	1.8	91%	380	2.8	Cooler
40	Centrifugal Fan	Y180L-4	22	80%	1450	50%	17.13	13.7	87%	387	31.9	Cooler

CHAPTER FOUR

Energy Efficiency Improvement of Messebo Cement Factory

4.1 Energy Efficiency Improvement of Electric Motors

4.1.1 Replace Standard Motors with Energy Efficient Motors

High efficiency motors use improved design and better quality materials to decrease electrical (resistance), magnetic (core), mechanical (winding and friction), and stray losses. Electrical losses, caused by electrical resistance in wires, can be reduced by using lower-resistance materials (e.g., copper instead of aluminum) for stators and rotors. Magnetic losses can be reduced by using larger cross-sections of iron in the stators and rotors, thinner laminations, and improved magnetic materials. Mechanical losses can be decreased by using improved bearings and fan design. Stray losses can be reduced by optimal design and careful manufacturing.

Energy efficient motors are the ones in which, design improvements are incorporated specifically to increase operating efficiency over motors of standard design. Design improvements focus on reducing intrinsic motor losses.

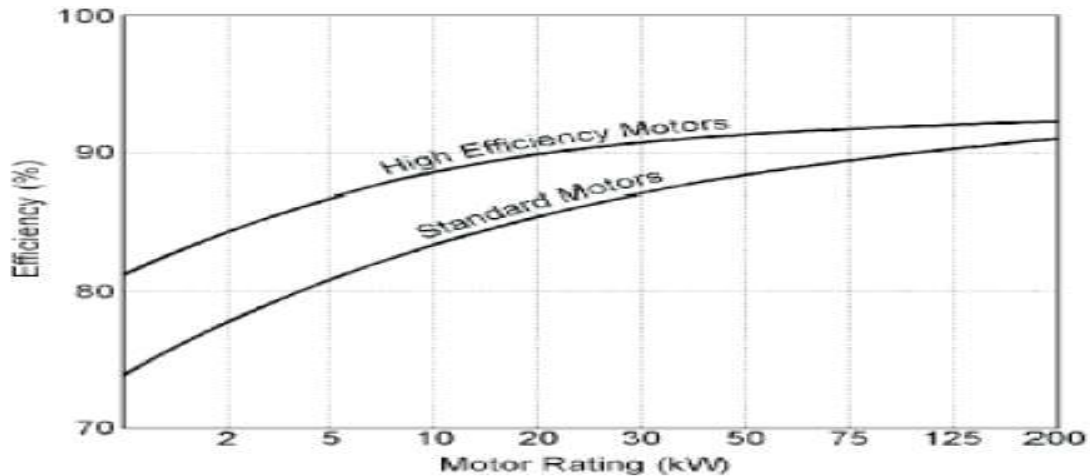


Figure 4--1: Standard vs. high efficiency motors (for typical 3- phase Induction Motors)

Improvements include the use of lower-loss silicon steel, a longer core (to increase active material), thicker wires (to reduce resistance), thinner laminations, smaller air gap between stator and rotor, copper instead of aluminum bars in the rotor, superior bearings and a smaller fan, etc. They cover a wide range of ratings and the full load efficiencies. Energy efficient motors are higher from 3 to 7 % of standard efficiency motors (see figure 4.1.)

Though high efficiency motors typically cost 30% more than standard motors, the decreased electricity usage can offset the higher capital costs in a short time. An industrial motor can use electricity worth about four times its capital cost annually. Changing to high efficiency models yields larger efficiency improvements and percentage cost savings in the small motor sizes, but greater absolute cost savings in the large sizes. Larger motors are often rewound, not replaced, when they malfunction. Rewinding is initially less expensive than purchasing a new motor, but ultimately costs more because of degraded efficiency. The efficiency of a rewind motor is typically about 2 percentage points below that of a new standard motor [20][38]

An energy efficient replacement motor can always be found in the same frame size and with comparable starting torque and locked rotor current as the existing motor. High motor efficiencies and power factor close to one are desirable for an efficient operation and for keeping costs down of the entire plant. However, as a result of the modifications to improve

performance, the costs of energy efficient motors are higher than those of standard motors. The higher cost will often be paid back rapidly in saved operating costs, particularly in new applications or end-of-life motor replacements. But replacing existing motors that have not reached the end of their useful life with energy efficient motors may not always be financially feasible, and therefore it is recommended to only replace these with energy efficiency motors when they fail. [38]

4.1.2 Replacing Under Load Motors with Proper Sized Motors

Probably the most common practice contributing to less motor efficiency is that of under-loading. Under loading results in lower efficiency, power factor and higher than necessary first cost for the motor and related control equipment.

Under loading increases motor losses and reduces motor efficiency and the power factor. Under-loading is the most common cause of inefficiencies for several reasons:

- Equipment manufacturers tend to use a large safety factor when selecting the motor.
- Equipment is often under-utilized. For example, machine tool equipment manufacturers provide for a motor rated for the full capacity load of the equipment. In practice, the user may rarely need this full capacity, resulting in under-loaded operation most of the time.
- Large motors are selected to enable the output to be maintained at the desired level even when input voltages are abnormally low.
- Large motor are selected for applications requiring a high starting torque but where a smaller motor that is designed for high torque would have been more suitable.

Motor size should be selected based on a careful evaluation of the load. But when replacing an oversized motor with a smaller motor, it is also important to consider the potential efficiency gain. Larger motors namely have inherently higher rated efficiencies than smaller motors. Therefore, the replacement of motors operating at 60 – 70% of capacity or higher is generally not recommended. If the plant's motor operates under 50% of full rated load, it consider to replace large, partially loaded motors with smaller, full loaded motors either from

company catalog / new energy efficient motor. Table 4.1: shows under load operating electric motor of Messebo cement factory.

Table 4--1: Under load operating electric motor of Messebo cement factory

No.	Description of motor	Type of motor	Name Plate			Calculated		Actual measurement				Department
			Rated power(kw)	Rated efficiency	Speed (rpm)	Loading	Input power (kw)	output power (kw)	Power factor	Voltage (v)	Current drawn(A)	
1	Circulating gas fan	M472OUF/M	250	79%	1470	38%	154.05	121.7	93%	392	206.3	Cooler
2	Deep pan conveyor	M472FN3M1	30	80%	1470	45%	21.00	16.8	89%	387	34.4	Cooler
3	Roots fan (primary)	442MD/M1	300	85%	1470	37%	113.76	96.7	88%	377	201	Raw Mill
4	Bucker Elevator	M212FN3M1	160	76%	1500	38%	104.21	79.2	87%	387	116.3	Cement Mill
5	Bucker Elevator	Y315S-2(VVVF)	110	86%	1500	29%	42.67	36.7	86%	388	53.5	Cement Mill
6	Fan for bag filter	592BE/MD1	55	80%	1480	37%	31.88	25.5	89%	394	38.9	Cement Mill
7	Belt conveyer drive	Y200L2-6	11	75%	1460	43%	8.40	6.3	93%	377	7.7	Cement Mill
8	Roots Fan	L42FNM1	132	82%	1470	43%	85.24	69.9	88%	366	147.8	Coal Mill
9	Belt Conveyor	Y200L2_6	22	75%	150	48%	18.93	14.2	96%	384	15.9	Coal Mill
10	Water injection Pump	Y132S2-2	7.5	75%	2900	46%	6.13	4.6	87%	396	6.3	Coal Mill

On the other hand there are no rigid rules governing motor selection and the savings potential needs to be evaluated on a case-by-case basis.[2] [38] As the result of the analysis, this factory uses electric motor operated inefficient due to under load operation and low efficiency of rating, thus needs to improve their energy efficiency.

4.2 MotorMaster+ international Software

MotorMaster+ international can aid in proper motor selection and supports for motor systems improvement planning, through identifying the cost effectiveness, operating cost due to the continued operation of an existing standard efficiency motor to make decision on purchasing new premium efficiency, rewinding or replacing of the existing motor. This software helps on motor selection and analysis of the saving potential as the result of comparison of the existing motor with efficient motor.

This is one of the software that provides by U.S. department of energy's best practices program for the purpose of [27]:

- evaluates the performance of the existing motor with the proper energy efficient motors
- In decisions regarding replacement of oversized and under loaded motors
- call attention to a life-cycle cost approach to motor replacement decisions
- Assist motor users in selecting the proper motor for an application
- Increase awareness of electric motor system efficiencies

In this study, Motormaster+ international software uses field data measurements of the motor as input parameters for the existing motor in the factory taken from table. And also field data measurements and the purchase price for the energy efficient motors column taken from the Motormaster + international software catalogue. Table 4.2: Shows the input and output field data measurements for analysis saving potential of electric motor using MotorMaster + international software. These values are selected in such a way to improve the loadings of the existing operation. The output parameters that can get from the software are: Energy, demand savings and a simple back period. In this part the saving potential of electrical energy and cost of energy are found by evaluating of the electric motors and looking for alternative options to increase the efficiency of the existing motors. In this study, Motormaster + international software was used to evaluate or determine properly sized to its load requirement and more efficient motors than the existing inefficient motor. From figure 4.2 to figure 4.3 shows, how Motormaster + international software selects the required motor to specific application and evaluates the energy saving potential and effectiveness of the efficient motors of the factory.

Table 4--2: Input and output field data measurements for analysis saving potential of electric motor

Input for existing motors (Existing data)	Input for energy efficient motors (software catalogue)	output parameters
<ul style="list-style-type: none"> • Power rating (kW) • Loading • efficiency • nameplate speed (rpm) and • voltage rating (v) 	<ul style="list-style-type: none"> • Power rating(kW) • loading • efficiency • Voltage rating(v) • Nameplate speed(rpm) and • the purchase price 	<ul style="list-style-type: none"> • Energy • demand savings and • a simple back period

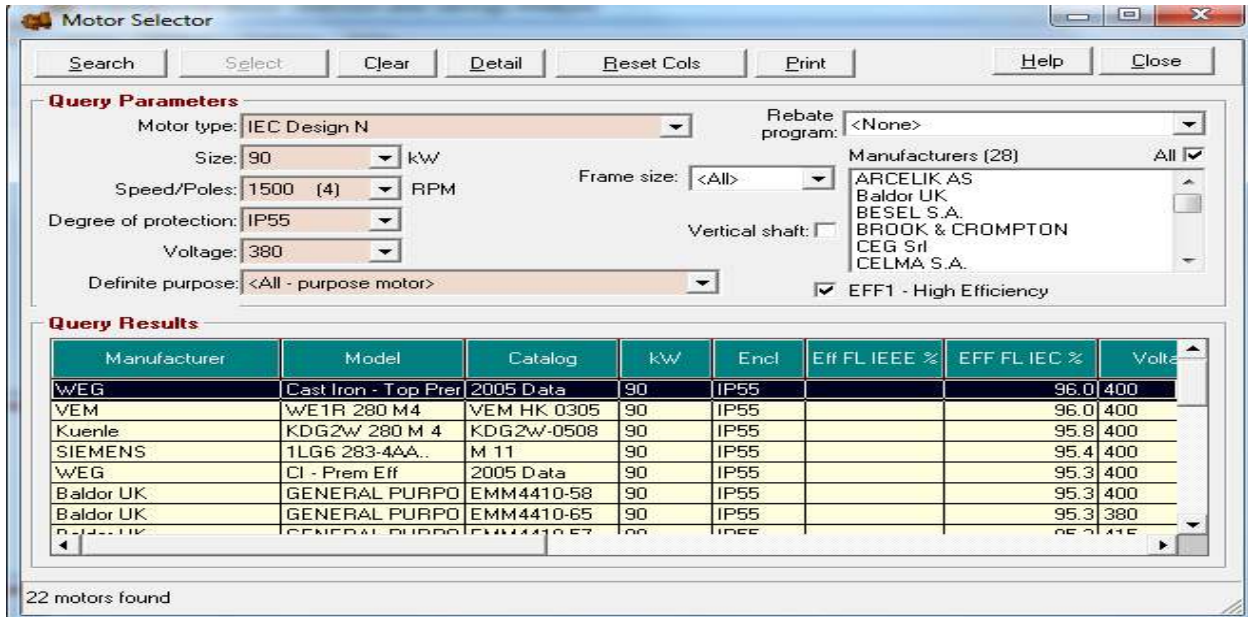


Figure 4--2: Motor selections from MotorMaster Catalog

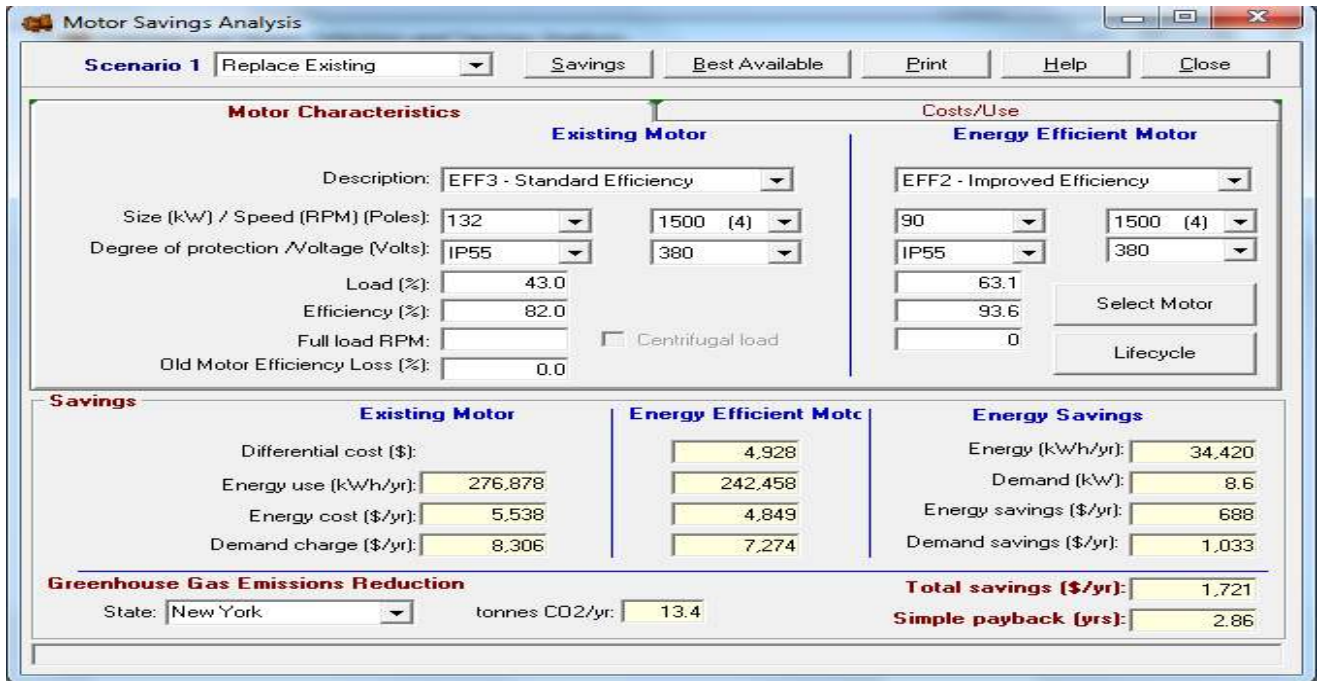


Figure 4--3: shows the energy saving potential of high efficient motor as compared to standard

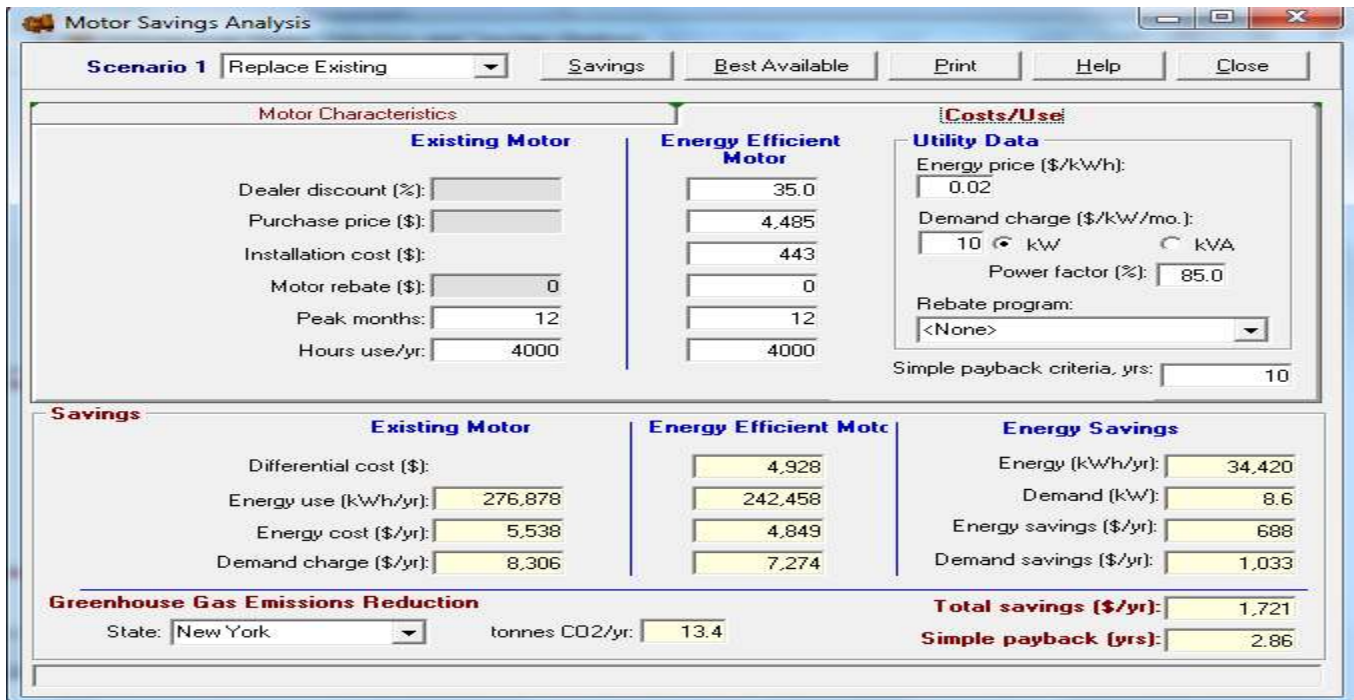


Figure 4-4: Saving energy potential and cost effectiveness of energy efficient motor as compared to standard one

The investment cost (which paid in short payback period) needed to buy that energy efficient motors was effective. From the energy analysis summarized in figure 4.4 i.e. to buy an energy efficient motor for rootsfan which air blower at coal mill department on line one plant, it should have 4485 dollar to purchase the motor, 443 dollar for the installation. But these costs will be back after 2.86 years with an energy savings of 34,420 Kwh per year and 1,721 \$/year of cost saving with reduction of 13.4tonnes/year CO₂. This is due to replacement of under load motors with proper sized motors and standard electric motors with energy efficient electric motors. Table 4.3: shows summarized potential of energy and cost saving of proper sized motors and energy efficient motors as compare with the existing inefficient electric motors of the factory.

4.3 Energy Efficiency Improvement of Lighting Systems

Although lighting is often a small component of industries energy uses, efficiency improvements to lighting systems leads a significant energy saving. As the result of the analysis energy efficiency improvement of lighting system of Messebo cement factory discussed here.

4.3.1 Optimization of Illumination of Lighting System of the Factory

As discussed in the above section, there are 767 lighting lamps installed in the factory all fitted with 40w fluorescent lamps. In certain office segments the illumination is not significant and additional lamps needs to be installed to bring the appropriate brightness. On the other hand, there is more than sufficient illumination in the other offices indicating possibility of reducing the number of lamps installed in these offices.

After the appropriate illumination has been checked, only 627 lamps of the same ratings would be requiring. This results in reduction of 140 lamps which is equivalent to 5.6 kW of power demand. It also results in energy saving of 49.87MWh per year (see in table 3.9 above) and in money savings of 24,936.80 Birr annually.

4.3.2 Replacement of T-12 Tubes with T-8 Tubes

In many industrial facilities, it is common to find T-12 lighting tubes in use. T-12 lighting tubes are 12/8 inches in diameter (the “T-“ designation refers to a tube’s diameter in terms of 1/8 inch increments). T-12 tubes consume significant amounts of electricity, and also have extremely poor efficacy, lamp life, lumen depreciation, and color rendering index. Because of this, the maintenance and energy costs of T-12 tubes are high. T-8 lighting tubes have around twice the efficacy of T-12 tubes, and can last up to 60% longer, which leads to savings in maintenance costs. Typical energy savings from the replacement of a T-12 lamp by a T-8 lamp are around 30% [28].

After implementing the actual number of lamp (ALPs) that will be posted for the factory i.e 627 out of currently total installed 767 lamps, further save energy by replacing T-12 tubes lamp with T-8 tubes lamps. Thus, the energy savings, due to replacement actual number of lamp (ALPs) of T-12 tubes lamp, by T-8 tubes lamp, with the same power rating 40w lamp, and this can be determined as the follows:

Demand Saving (DS):

$$\begin{aligned} DS &= [0.30 * ALP * \text{rating power of lamp}] / 1000 \\ &= 7.524 \text{kw} \end{aligned}$$

Thus, Energy Saving (ES):

$$\begin{aligned} ES &= [0.30 * RE * 365] / 1000 \\ ES &= 49.021 \text{Mwh/year} \end{aligned}$$

Unit cost of electric energy = 0.5 Birr/kWh

$$\begin{aligned} &= 49.021 \text{Mwh/year} * 0.5 \text{birr/Kwh} \\ &= 24,510.50 \text{birr/year} \end{aligned}$$

It results from the total energy consumption can save energy of 49.02MWh per year and money of 24,510.5 Birr annually.

CHAPTER FIVE

Simulation Result Discussions, Conclusion and Recommendations

5.1. Simulation Result Discussions

Based on the collected cement production and energy consumption of four consecutive production year, Messebo cement factory consumes 62,164,245.81 liters of fuel (coal & oil) and 90,640.79068 of MWh electrical energy annually. The factory also spends 165,987,807.93 amounts of birr annually on these energies. This is to produce an average cement of 789,298.52 ton per year and clinker production of 614,103.75 ton per year. Table-5.1 shows the cost of energy consumption of Messebo cement factory due to inefficiently use of energy as compare with selected cement plants

Table 5--1: Shows energy consumption cost of Messebo cement factory due to inefficiently use of energy as compare with selected cement plants.

	Production		Messebo's energy consumption		Selected cement plant average energy consumption		Energy consumption difference	
	Cement (ton of ce./year)	Clinker (ton of cli./year)	kWh/ton of cement	KJ/Kg of clinker	kWh/ton of cement	KJ/Kg of clinker	kWh/ton of cement.	KJ/Kg of clinker
	789,298.52	614,103.75	115.72	3587.22	83.8	2482.5	31.92	1104.72
Cost (birr/year)	12,597,204.38	32,600,637.46						
Total cost	45,197,841.84 birr/year							

The electrical energy and fuel consumption of Messebo cement factory has a significant difference with the selected efficient cement plants. The annual average thermal (fuel) energy intensity consumption of the factory is 3587.22 KJ/Kg of clinker production but the average energy intensity consumption of the selected four energy efficient cement plants (benchmark) of 2482.5 KJ/Kg of clinker production. Similarly, the annual average electrical energy consumption of Mecebo cement factory is 115.72 kWh/ ton of cement, but the average electrical energy consumption of these selected efficient cement plants (as benchmark) of 83.8 kWh/ ton of cement. Hence Messebo cement factory consumes an extra of fuel and electrical energy of 1,104.72 KJ/Kg of clinker and 31.92 kwh/ton of cement respectively as compared to benchmark plants. Due to this they pay 45,197,841.84birr/year.

To reduce the energy consumption and energy cost of Messebo cement factory this paper analyzes two different cases. These cases are energy improvement of existing lighting system and electric motor of the factory. Table 5.2 and table 5.3 discuss detail methods performed to improve energy consumption & cost of Messebo cement factory.

5.1.1 Energy Improvement of Existing Lighting System

There are 767 lighting lamps installed in the factory all fitted with 40w fluorescent lamps. Due to illumination optimization of the existing lighting system minimized to 627 lamps of the same ratings. As the result of reduce the number of lamp by 140 lamps can be save 49.87MWh energy and 24,936.80 birr cost annually. Table 5.2 shows energy improvement of existing lighting system of Messebo cement factory.

Table 5--2: Energy improvement of existing lighting system

Existing Lamps	Existing lamps				
	Number of lamps	Total Rating (kw)	EU (kwh/day)		
	767	30.68	584.32		
Way of Improvement					
Replacing T-12 tubes with T-8 tubes lamps	Replaced No. of lamps	ER(kwh/day)	ES(MWh/year) (30%RE)	Cost Saving birr/year	
	627	447.68	49.02	24,510.50	
Illumination optimization	Reduced No. lamps	Total rating (kw)	ER (kwh/day)	ES (MWh/year)	Cost Saving birr/year
	140	5.6	447.68	49.87	24,936.80

After implementing the required number of lamps i.e 627 out of currently total installed 767 lamps, by replacing T-12 tubes lamp with T-8 tubes lamps further can be save 49.02MWh energy& 24,510.5 birr annually.

5.1.2 Energy Efficiency improvement by replacing under loaded electric motors of Messebo cement factory

Messebo cement factory motors frequently operate under varying load conditions due to process requirements. A common practice in this situation is to select a motor based on the highest anticipated load. But this makes the motor more expensive as the motor would operate at full capacity for short periods only, and it carries the risk of motor under-loading. An alternative is to select the motor rating based on the load duration curve of a particular application i.e the selected motor rating is slightly lower than the highest anticipated load and would occasionally overload for a short period of time. But the biggest risk is overheating of

the motor, which adversely affects the motor life, efficiency and increases operating costs more than the effect that happen with under load operation.

Table 5.3 shows the cost saving, energy savings per year and the number of years required to recover the investment in energy efficient motors respectively.

Table 5--3: Improvement of electric motors with replacement of under load operating motors with proper sized motors.

No.	Type of existing Motor	Existing Motor			Replaced efficient motor			Type of Replaced motor	Investment cost \$/year	Energy saving Kwh/year	Money saving \$/year	back pay period	CO2 reduction (tonne /year)
		kw	Load (%)	η(%)	kw	Load (%)	η(%)						
1	standard	132	43	82	90	63.1	93.6	Improved	4928	34,420	1721	2.86	13.4
2	Standard	250	38	79	160	59.4	94.9	Standard	9181	80,425	2413	2.29	31.4
3	Standard	300	37	85	160	69.4	95.2	Standard	9181	56,107	2805	3.27	21.9
4	Standard	160	38	76	90	67.6	92.3	High	3932	56,595	2830	1.38	22.1
5	Standard	110	29	86	45	70.9	92	High	1781	9676	484	3.68	3.8
6	standard	55	37	80	30	67.8	91.8	Improved	1921	13,077	654	2.93	5.1
7	standard	30	45	80	15	90	90.4	Improved	880	7,748	387	2.27	3
8	standard	22	48	75	15	70.4	92	High	1583	10,421	521	3.03	4.1
9	standard	11	43	75	5.5	86	89.8	High	822	4,159	208	3.95	1.6
10	standard	7.5	46	75	4	86.3	88.7	High	657	2,837	142	4.63	1.1
Total									34,866	275,465	12,165		106.5

As discussed in section two, motors operating below 75% of full load relatively reduces their efficiency and operating below 50% totally inefficient, electric motors operates under load should be replaced. When replacing standard motors with energy efficient motors are more

effective, but it needs investment cost to buy those energy efficient motors which pay back in small periods.

Replacement of large, partially loaded motors with smaller, full loaded motors either from company stock / new energy efficient motor is relevant. As the result, replacement of standard motors with energy efficient motors i.e under load motors with proper sized motor can save 275.5MWh of energy, 218,970 birr of money annum and small payback period.

5.2. Conclusions

Messebo cement factory gives good attention on how they are profitable by producing a lot of products. But they give low attention on follow up their energy utilization and energy efficiency. This implies a lot of unnecessary expenditure on energy due to inefficient use of their energy. This study may help them for analyzing the progress of their energy utilization and energy efficiency, especially on their electric motor using MotorMaster +software. And also helps them on how they can get the energy efficiency improvement opportunities (technologies and measures) to improve the system.

This study suggests energy efficiency improvement opportunities such as optimizing the illumination of the existing lighting system, replacement of existing lamps with energy efficient lamps, replacement of energy efficient motors with the standard motors, selecting of proper sized motors and others that achieve significant energy saving with small payback period. By improvement the energy efficiency of the factory, the energy consumption loss due to inefficient use of their energy can reduce by 374.39 MWh and the respective energy cost can reduce by 268,417.30 birr annum.

5.3. Recommendations

The following recommendations are made based on the study that has been conducted.

If this factory uses MotorMaster + software properly, to selecting the energy efficient electric motor, they can have best understanding on the electric motor of their energy efficiency

trends, energy saving potentials and on having proper documentation about electric motor operating specifications before the motor disturb the system like fail or name plate paint out.

This factory's managers & their staffs' also gives low attention on how their energy uses efficiently, which is a means of most successful and cost-effective way of bringing optimum energy consumption. Thus, upgrading the efficiency of new technologies alone cannot achieve optimal savings, but when combined with a strong energy management program such as good operational and maintenance practices, day to day follow-up on their energy utilization and efficiency as well as understanding on systems perspective can lead to significant savings. Ethiopian government also gives low attention to check the amount of energy presently being generated is efficiently used and give awareness of energy conservation especially for the industry sectors of the country. Thus, the government should involve on the technical and financial expenditure of improving energy efficiency of industries. Especially on:

- creating awareness on general management of the industry on use of their energy efficiently without investing
- Implement the cost effective measures with investing such as to optimization system, recover waste heat and install power generation on-site.

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.

5.4. Suggestions for Future Work

In Messebo cement factory a large amount of energy consumption for cement production occurs in the clinker production process. This involves passing raw materials through a preheater stack containing cyclone heaters to a long rotating kiln to create clinker and then cooling clinker in the clinker cooler. In this process, a significant amount of waste heat discharged from the:

- Kiln exit gases
- Clinker cooler system and
- Kiln pre-heater system.

This waste heat is typically escaped to the atmosphere without being used. Thus, it is better to recover the waste heat due to cogeneration system to generate power on site for various applications such as drying of raw materials and coal. Cogeneration systems can either be direct gas turbines that utilize the waste heat or the installation of a waste heat boiler system that runs a steam turbine system. This may be accomplished through detail farther study on heat energy loss (energy loss balance) around the kiln areas of the factory.

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Appendix A: Descriptions of Electric Motors and Drives of Messebo Cement Factory

Eqpt. No	Description	Type	Qnt	Eqpt No	Description	Type	Qnt
2	Lime stone Crusher	3-ph slip-ring motor Type: YRKK560-6-630 Power:630kW, 6kV, 50Hz, Ip54 IM N: 992 r/min	2	3	Single Stage Hammer Crusher	3-phase squirrel-cage motor, Type : YRKK560 Power : 710 kW, 6kv,50HZ, IP54 N: 990r/min	2
28	Fan for filter	3-phase squirrel-cage motor, Type : Y280S-4 1 Power:75kW, 380V , 50Hz N: 1120 r/min	1	7	Belt Conveyor	3-phase squirrel-cage motor, Type : Y250M-4 Power : 55kW, 380V, 50Hz, IP54 N: 1450r/min	2
6	Fan for filter	3-phase squirrel-cage motor, Type : Y160M-2 1 Power:18.5kW,380V, 50Hz, Ip54 IM N: 2240 r/min	1	10	Roots fan (primary)	3-phase squirrel-cage motor, Type : Y355M1-4 power: 185kw, 380, 50Hz, IP54 n: 1483r/min	1
5	Fan for filter	3-phase squirrel-cage motor, Type:Y225S-4 1 Power:37Kw, 380V, 50Hz n=1000rpm	1	9	Bridge Scraper Recamier	3-phase squirrel-cage motor, Type : Y315M-6 Power: 90kW,380V	2

						,n=1480rpm	
13	Belt Conveyor	3-phase Frequency control Type : YJTG315L2-4 1 Power:200Kw,380V, 50Hz, n=1450rpm	2	8	Belt Conveyor reversible	3-phase squirrel-cage motor, Type: Y132M-4 Power: 7.5kW, 380V,50Hz n=1480rpm	2
4	Belt Conveyor	3-phase squirrel-cage motor, Type : Y200L2-6 Power: 22kw, 380V, 50Hz, IP54 N: 980r/min	2	19	Deep pan conveyor	3-phase squirrel-cage motor, Type : Y200L-4 Power : 30kW, 380V, 50Hz, IP54 N:1480r/min	2
26	Raw Mill Main Motor	3-ph slip-ring motor Type : YRKK800-6 Power : 2900 kW, 6kv, 50Hz, Ip54 n : 996r/min	1	5	Motor of oil pump	3-phase squirrel-cage motor, Type: Y160L-4 Power: 15kW, 380v , 50Hz, Ip44 N: 1500r/min	2

7	Bucket elevator	<p>3-phase squirrel-cage motor, Type : Y250M-6 Power : 37kW n=1000rpm</p>	1	24	Belt Conveyor	<p>3-phase squirrel-cage motor, Type: YRKK560-6 Power :160kW 380v 50HZ N: 1500r/min</p>	2
25	ID FAN Heater exchanger for Coupling	<p>3-phase squirrel-cage motor, Type : YKK710-6 Power : 2500kW n=993rpm</p>	1	22	Bag filter Screw conveyor Drive	<p>3-phase squirrel-cage motor, Type: SEW DV132S4IEC Power :5.5kW 380v 50HZ, IP 55 N: 1450rpm</p>	1
29	Clinker crusher	<p>3-phase squirrel-cage motor, Type: Y280M-4 Power :90kW 380v 50HZ n=1450 rpm</p>	2	20	Belt conveyer drive	<p>3-phase squirrel-cage motor, Type: Y200L2-6 Power :11kW 380v 50HZ n=1460rpm</p>	1

21	Hot gas fan	<p>3-phase squirrel-cage motor, Type: M492DP/M1 Power :45kW 380v 50HZ n=1470rpm</p>	1	23	Kiln outlet fan	<p>3-phase squirrel-cage motor, Type: M472INF/M Power :1400kW 6kv 50HZ n=740rpm</p>	1
35	Motor for oil pump	<p>3-phase squirrel-cage motor, Type: Y132S-B5 Power :3kW 380v 50HZ n=1430rpm</p>	1	5	Kiln Cooling Fan	<p>3-phase squirrel-cage motor, type:YVF315M-4 Power: 132kw, 380V, 50HZ, IP54 n= 1470rpm</p>	2

22	Exhaust gas fan	3-phase squirrel-cage motor, Type:YRKK630-8 power: 1000kw, 6kV,50Hz, IP54,IN:F n: 740r/min	1	4	Motor(Reversible)	3-phase squirrel-cage motor, Type : Y2-132M-4 Power : 5.5kW, 380v, 50Hz, IP54 N= 1440r/min	2
40	Centrifugal Fan	3-phase squirrel-cage motor, Type : Y180L-4 1 Power : 22 kW Speed : 1450 r/min	1	6	Cement Mill Main Drive	3-phase squirrel-cage motor, Type:YRKK500-4 Power: 900kW 6.0kV n:1482r/m	1
38	Circulating gas fan	Type : Slip ring motor YRKK900-8 Type: M472ouf/M Power: 250kw, 380V 50HZ Speed: 1470rpm	1	36	Water injection Pump	3-Phase Squirrel cage motor Type: SEW DV132ML4 Power:7.5kW, 380V, IP55 Speed:2900r/min	2

13	Main Drive Motor for ball mill	Type : Slip ring motor YRKK900-8 Power : 1600kW Rated Voltage : 6.0kV Rated, 50Hz Main motor Speed : 744r/min	2	1	Motor for bucket elevator	3-phase squirrel-cage motor, Type : Y315S-4 Power : 110 kW Speed: 1500r/min	1
39	Classifier Motor	3-phase squirrel-cage motor, Type: Y2-13252-2 Power: 22kW 380V,50Hz, IP54 Speed:1482r/min	1	18	Auxiliary Drive Motor	3-phase squirrel-cage motor, Type : Y250M-4 Power : 380V,55kW, 50Hz Speed : 1480 r/min	1
30	Belt conveyer motor	3-phase squirrel-cage motor, Type : Y315M1-4 1 Power: 132 kW 380V 50Hz	1	29	Main Drive Motor	Variable speed DC motor Type : ZSN4-400-22 1 Voltage : 660V	1

31	Motor for fun	<p>3-phase squirrel-cage motor, Type : Y225M-4 1 Power : 45 kW n: 1450 r/min</p>	2	32	motor for fan	<p>3-phase squirrel-cage motor, Type : Y315L1-4 2 Power : 160 kW 380v 50Hz n : 1450 r/min</p>	1
33	Main Drive	<p>3-phase frequency control motor Type: YPT315L2-4 2 Power : 200kW,380V,N=145 0rpm</p>	1				

APPENDIX B: Basic Energy Efficiency Actions for Plant Personnel

Staff can be trained in both skills and the general approach to energy efficiency in day-to-day practices. Personnel at all levels should be aware of energy use and objectives for efficiency. By passing information to everyone, each employee can save energy. In addition, performance results should be regularly evaluated and communicated to all personnel, recognizing high performers. Examples of some simple tasks employees can do include the following [19]:

- ❖ Switch off motors, fans and machines when they are not being used, especially at the end of the working day or shift, and during breaks, when it does not affect production, quality or safety. Similarly, turn on equipment no earlier than needed to reach the correct settings (temperature, pressure) at the start time.
- ❖ Switch off unnecessary lights; rely on day lighting whenever possible.
- ❖ Use weekend and night setbacks on HVAC in offices or conditioned buildings.
- ❖ Report leaks of water (both process water and dripping taps), steam and compressed air. Ensure they are repaired quickly. The best time to check for leaks is a quiet time like the weekend.
- ❖ Check to make sure the pressure and temperature of equipment is not set too high.
- ❖ Prevent drafts from badly fitting seals and doors, and hence, leakage of cool or warm air.
- ❖ Carry out regular maintenance of energy-consuming equipment.
- ❖ Ensure that the insulation on process heating equipment is effective.

APPENDIX C: Support Programs for Industrial Energy Efficiency Improvement

This appendix provides a list of energy efficiency support available to industry. A brief description of the program or tool is given, as well as information on its target audience and the URL for the program. Included are federal and state programs. Use the URL (Universal Resources Locator) to obtain more information from each of these sources. An attempt was made to provide as complete a list as possible; however, information in this listing may change with the passage of time.

Tools for Self-Assessment

MotorMaster+

Description: Energy-efficient motor selection and management tool, including a catalog of over 20,000 AC motors. It contains motor inventory management tools, maintenance log tracking, efficiency analysis, savings evaluation, energy accounting, and environmental reporting capabilities.

Target Group: Any industry

Format: Downloadable software (can also be ordered on CD)

Contact: U.S. Department of Energy

URL: <http://www1.eere.energy.gov/industry/bestpractices/software.html>

Steam System Assessment Tool

Description: Software package to evaluate energy efficiency improvement projects for steam systems. It includes an economic analysis capability.

Target Group: Any industry operating a steam system

Format: Downloadable software package (13.6 MB)

Contact: U.S. Department of Energy

URL: <http://www1.eere.energy.gov/industry/bestpractices/software.html>

Steam System Scoping Tool

Description: Spreadsheet tool for plant managers to identify energy efficiency opportunities in industrial steam systems.

Target Group: Any industrial steam system operator

Format: Downloadable software (Excel)

Contact: U.S. Department of Energy

URL: <http://www1.eere.energy.gov/industry/bestpractices/software.html>

Optimization of Insulation of Boiler Steam Lines

Description: Downloadable software to determine whether boiler systems can be optimized through the insulation of boiler steam lines. The program calculates the most economical thickness of industrial insulation for a variety of operating conditions. It makes calculations using thermal performance relationships of generic insulation materials included in the software.

Target Group: Energy and plant managers

Format: Downloadable software

Contact: U.S. Department of Energy

URL: <http://www1.eere.energy.gov/industry/bestpractices/software.html>

ASDMaster: Adjustable Speed Drive Evaluation Methodology and Application

Description: Software program helps to determine the economic feasibility of an adjustable speed drive application, predict how much electrical energy may be saved by using an ASD, and search a database of standard drives.

Target Group: Any industry

Format: Software package (not free)

Contact: Electric Power Research Institute (EPRI), (800) 832-7322

URL: <http://www.epri-peac.com/products/asdmaster/asdmaster.html>

Approach to Motor Management

Description: A step-by-step motor management guide and spreadsheet tool that can help motor service centers, vendors, utilities, energy-efficiency organizations, and others convey the financial benefits of sound motor management.

Target Group: Any industry

Format: Downloadable Microsoft Excel spreadsheet

Contact: Consortium for Energy Efficiency (CEE), (617) 589-3949

URL: <http://www.motorsmatter.org/tools/123approach.html>

AirMaster+: Compressed Air System Assessment and Analysis Software

Description: Modeling tool that maximizes the efficiency and performance of compressed air systems through improved operations and maintenance practices

Target Group: Any industry operating a compressed air system

Format: Downloadable software

Contact: U.S. Department of Energy

URL: <http://www1.eere.energy.gov/industry/bestpractices/software.html>

Fan System Assessment Tool (FSAT)

Description: The Fan System Assessment Tool (FSAT) helps to quantify the potential benefits of optimizing a fan system. FSAT calculates the amount of energy used by a fan system, determines system efficiency, and quantifies the savings potential of an upgraded system.

Target Group: Any user of fans

Format: Downloadable software

Contact: U.S. Department of Energy

URL: <http://www1.eere.energy.gov/industry/bestpractices/software.html>

Pump System Assessment Tool 2004 (PSAT)

Description: The tool helps industrial users assess the efficiency of pumping system operations. PSAT uses achievable pump performance data from Hydraulic Institute standards and motor performance data from the MotorMaster+ database to calculate potential energy and associated cost savings.

Target Group: Any industrial pump user

Format: Downloadable software

Contact: U.S. Department of Energy

URL: <http://www1.eere.energy.gov/industry/bestpractices/software.html>

Best Practices Program

Description: The U.S. DOE Best Practices Program provides training and training materials to support the efforts of the program in efficiency improvement of utilities (compressed air, steam) and motor systems (including pumps). Training is provided regularly in different regions. One-day or multi-day trainings are provided for specific elements of the above systems. The Best Practices program also provides training on other industrial energy equipment, often in coordination with conferences.

Target Group: Technical support staff, energy and plant managers

Format: Various training workshops (one day and multi-day workshops)

Contact: Office of Industrial Technologies, U.S. Department of Energy

URL: <http://www1.eere.energy.gov/industry/bestpractices/training.html>