Addis Ababa University

Addis Ababa Institute of Technology (AAiT)

School of Electrical and Computer Engineering

Energy Audit and Conservation improvement for Textile industries Case Study at Yirgalem Addis Textile Factory

A thesis submitted to Addis Ababa Institute of Technology, In partial Fulfillment of the Requirement for the Degree of Master of Science in Electrical Engineering (Electrical Power Engineering)

By: Azeb Yosef, GSE/1918/04

Advisor: Getachew Bekele - (PhD)

April, 2018

Addis Ababa

Addis Ababa University

Addis Ababa Institute of Technology (AAiT)

School of Electrical and Computer Engineering

Energy Audit and Conservation improvement for Textile industries

Case Study at Yirgalem Addis Textile Factory

By

Azeb Yosef, GSE/1918/04

APPROVAL BY BOARD OF EXAMINERS

___________________________ ______________________________

CHAIRMAN DEPARTMENT OF GRADUATE COMMITTEE SIGNATURE

___________________________ ______________________________

ADVISOR SIGNATURE

___________________________ ______________________________

INTERNAL EXAMINER SIGNATURE

___________________________ ______________________________

EXTERNAL EXAMINER SIGNATURE

Declaration

I, the undersigned, declare that this MSc thesis is my original work, has not been presented for fulfillment of a degree or otherwise in this or any other university, and all sources and materials used for the thesis have been acknowledged.

Name: Azeb Yosef

Signature: _____________

Place: Addis Ababa, Ethiopia

Date of submission: _____________

This thesis work has been submitted for examination with my approval as a university advisor.

Dr. Getachew Bekele _________________

Advisor's Name Signature

Table of Contents

ACKNOWLEDGMENT

First and for most, I am grateful to Almighty God for giving me grace, wisdom and strength in all my endeavours.

The successful completion of any survey study of this kind is only possible through the invaluable support of a number of people. My special thanks and gratitude is extended to my advisor, Dr. Getachew Bekele for his unreserved professional guidance, constructive corrections and insightful comments, feedback and support.

I also like to express my deepest gratitude to YTAF technical staff Ato Grima, Ato Tamirat and Ato Teame for their deep concern and support during the course of this thesis work.

My sincere thanks goes to my family, specially my husband, Daniel for his unlimited support and encouragement.

Finally, I wish to express my deep gratitude to all my friends, individuals and organization who support me one way or the other.

ABSTRACT

Energy conservation is an essential step towards overcoming the problem of energy crisis and environmental degradation. Textile industry comprises a large number of plants which all together consume a significant amount of energy. Improving energy efficiency should be a primary concern for textile plants. Even the available cost-effective options for energy- efficiency often are not implemented in textile plants mostly because of limited information on how to implement energy-efficiency measures.

Yirgalem Addis Textile Factory PLC (former Adei Ababa Yarn factory) is one of the oldest textile factories in Ethiopia, which has more than 50 years experience in spinning, knitting, weaving, dyeing, garments and blanket activities. The long time service given by the different electrical units within the factory would entail wear-out and therefore would be good area for energy conservation opportunities. Thus, the main purpose of this study is to assess the energy conservation and or efficiency and to suggest energy efficient technologies for yirgalem Addis textile industry as case study. The study can be applicable for other similar industries in the country and elsewhere.

The major objective of the study is to provide a comprehensive overview of the present energy management strategies in the industry, and identifying energy conservation opportunities so as to come up with solutions to improve the efficiency of the current energy utilization of the plant. In this thesis work both primary and secondary data has been used for energy loss review and to identify the areas for possible improvements in energy utilization. The collected data has been analyzed and feasible energy conservation improvement opportunities both for electrical energy as well as fuel energy which can be applied in this sector are identified and recommendations to minimize energy consumption without affecting quality and productivity are formulated.

The findings reveal that a bulk of the energy in the industry is wasted due to utilization of low efficiency equipments. Based on the motor analysis it was found that by replacing 38 very old, rewound more than two times and standard motors with energy efficient motors the factory can save 405,028kWh, with average payback period of 2.93yrs. By improving of the installation of lighting system and by replacing existing lighting fixtures with energy efficient lighting technologies the factory can save 107,328.82kWh of electric energy per year, resulting into total saving in electricity bill of USD 2583.94$/yr. It was found that by increasing the boiler efficiency to the acceptable range through establishing regular maintenance and insulation of boiler surface and insulation of steam pipes the factory can save 20% of its fuel cost.

Implementation of efficient energy management programs, replacing rewound, old and standard efficiency motors with energy efficient ones; use of power factor correction, use of energy efficient lighting technologies and removing unnecessary lighting fixtures; establishing adequate maintenance program, proper insulation of boiler surface and steam pipes, replacing of failed valves and steam traps are the major strategies recommended in this thesis to achieve improved energy efficiency levels.

Key Words: *Energy audit, Energy conservation improvement strategies, Motor Master+, efficient improvement technologies, efficient improvement of lighting, Boiler and steam system*

List of Figure

List of Tables

Acronyms

YATF	Yirgalem Addis Textile Factory
ECOs	Energy Conservation Opportunities
MM+	MOTER MASTER Plus
CFL	Compact Florescent Lamp
MV	Mercury Vapor
ER	Energy Required
ALR	Actual Lamp Required
ED	Energy Difference
AS	Actual Saving
IL	Lamp Illumination
OH	Operating Hour
KWh	Kilo Watt Hour
KJ	Kilo Joule
Kg	Kilogram
EEM	Energy-Efficient Motors
KW	Kilo Watt
TP	Total Power
LR	Lamp Rating
NL	Number of Lamps
HPMV	High Pressure Mercury Vapor
APFC	Automatic Power Factor Correction
ES	Energy Saving
BS	Birr Saving
ETB	Ethiopian Birr
SME	Small and Medium Enterprise
PF	Power Factor
EEU	Ethiopian Electric Utility

CHAPTER ONE

1. Introduction

1.1Background

Energy is important for economic development in any nation and it is key for ensuring a sustainable industrial development. It should be considered as any other valuable raw material resource required for running a business in industries. Energy has costs and environmental impacts, and it needs to be managed well in order to increase the profitability and competitiveness and to mitigate the seriousness of these impacts.

Many manufacturers are facing an increasingly competitive global business environment. Rise in energy price is leading to rise in cost of products. Hence an opportunity to reduce cost without reducing the quantity and quality of the product is necessary to compute in the global business. Cost effective investment into energy-efficiency technologies meet the challenges of maintaining the output of high quality product despite reduced production cost. In general, reducing energy costs, without any reduction in productivity, results in a direct increase of profit.

Textile manufacturing industries consume vast amount of energy due to prolonged use of the equipments in inefficient way. A well planned and efficient energy utilization scheme for such industries would help to reduce their energy bills and also it enables them to save unnecessary investments to cover up for their energy deficits.

Many manufacturing industries of the country do not have new ways to reduce their costs of energy and optimize the operation of their facilities. As a result energy management and energy conservation have been given low priority and low attention has given to the concept of improving energy efficiency through energy auditing as required.

An energy audit is key to developing an energy management system in industries and it has various degrees of complexity and can vary widely from one organization to another. Energy audits can be carried out by external consultants or using internal resources.

Energy audit is designed to determine where, when, why and how energy is being used. This information can then be used to identify opportunities to improve efficiency, decrease energy costs and reduce greenhouse gas emissions that contribute to climate change. Energy audits can also verify the effectiveness of energy management opportunities (EMOs) after they have been implemented [2].

Energy efficiency improvements particularly focus on available technology to make such improvements, with some technology options being well-known and proven over many years of application, and some of which may be relatively new and less well-known. Indeed, lack of information is a key barrier to energy efficiency improvements in many situations. However, experience in many countries of supply and demand-side activities shows that plants, buildings and equipment can often be improved substantially through simple low-cost actions.

For nations, energy efficiency offers a number of benefits; including improved use of national resources, reduced energy imports, improved balance of trade, conservation of foreign exchange, reduced capital requirements for new energy production facilities, and reduced environmental pollution from energy use and production. Improper energy investment may even slow the rate of national economic growth.

In this thesis, an all rounded assessment of the energy utilization has been conducted for Yirgalem Addis Textile Factory PLC as a case study. A comprehensive study of energy utilization efficiencies of the different utilities of the plant and efficient use of energy and energy conservation in the textile industry through conducting energy audits and energy analysis has been carried out by assessing the energy losses at the selected plant. The thesis provides information on energy-efficient technologies and production measures applicable to textile industries based on international industries experience. And finally, based on measurements and collected data, energy saving and efficiency improvement opportunities has been identified and recommended which would greatly apply to all similar industries in the country and elsewhere.

1.2 Statement of the Problem and Motivation

As a result of fast economic development in Ethiopia the electric energy demand is growing very fast since the past few years. Ethiopian Government is currently expanding the electric power generation plants to provide good supply of electric power to the nation, but less attention is given to energy management in using the energy efficiently.

Therefore, energy conservation has to be considered at the demand side to achieve a sustainable power supply system in the country and to minimize the gap between the continuously energy increasing demand and the limited generation capacity.

Industrial energy efficiency is one of the most important means of energy conservation as industries are the most energy consuming sectors. Energy waste is often common and impacts both the environmental sustainability and the production costs. If Investment to improve industrial energy efficiency is implemented properly it can deliver large energy savings, improved productivity, and reduced environmental pollute.

Energy in the textile industry is mostly used in the forms of electricity, as a common power source for machinery, cooling and temperature control systems, lighting, office equipment.

Textile industries use huge amount of energy for their various processes. But there are problems in the industry sector in using the energy efficiently. As a result, they are forced to pay big amount of money on their energy bills and causes problems on the competitive market.

Most factories in our country do not have proper way of utilization of energy and less attention is being given for energy auditing.

Some of the reasons for this are lack of awareness, lack of skilled human resource in energy management etc.

Hence this thesis addresses the energy utilization efficiency problems encountered by the textile industries of Ethiopia by identifying possible solutions which would significantly improve their energy consumption with little or no extra investment.

1.3 Objective

1.3.1 General Objective

The general objectives of this study is to provide a comprehensive overview of the present energy management and utilization strategies in Yirgalem Addis Textile Factory (YATF), and identifying energy conservation opportunities so that to come up with solutions to improve the efficiency of the current energy utilization of the plant.

1.3.2 Specific Objective

The specific objectives include:

- Study the on-going energy efficiency and management strategies/measures undertaken by selected plant.
- Identifying the types and cost of energy used by the factory
- Analyzing the possible causes of energy losses at the plant
- Identifying possible ways of efficiency improvement
- Computing the investment required to improve the efficiency of energy utilization
- Study cost effectiveness of the improvements, etc.

1.4 Methodology

1.4.1 Data Collection

The necessary data to conduct the thesis has been collected from the respective factory, Yirgalem Addis Textile factory. The data that has been collected includes:

- Name plate and motor and other equipments ratings.
- Energy consumption of the factory for the last three years
- The current energy requirement to produce a unit product
- working conditions and maintenance procedures of the different equipment currently being used for production in the plant
- Energy cost of the factory for the last four years, energy bill
- Production cost of the factory
- Energy management profile of the factory

- Necessary measurements were taken from energy intensive equipments (motors) for Voltage, Current, active reactive power

In addition to the data collected from the factory, observations were made during the site visit and information was obtained from visual inspection of the equipments, Plant surveys and from interviews made with the technical managers to identifying energy conservation opportunities and the areas where improvements in energy utilization are possible.

1.4.2 Literature Review

A review of literatures has been conducted on the area of industrial energy utilization, auditing and efficiency in related to Textile industries. Different books, journals, case studies, research works, profile and reports of the YATF, websites, magazines, & guidelines for energy audit and efficiency in connection to Textile industry have been reviewed in order to achieve the objective of the thesis.

1.4.3 Data Analysis

The collected data has been analyzed both quantitatively and qualitatively. By considering the objective of the study appropriate software, MOTOR MASTER Plus (MM+) is used for analysis of the collected data in order to Identify Energy Conservation Opportunities, Evaluate Cost-effectiveness of Capital Improvements, Prepare a Motor and Motor-Driven Systems Improvement Plan and predict the payback period.

Motor Master+ supports motor and motor systems for improvement planning through identifying the most efficient action for a given repair or motor purchase decision. MotorMaster+ can be used to identify inefficient or oversized inventory motors and compute the energy and demand savings associated with selection of a replacement energy-efficient model.

Data gathered regarding fuel consumption of the factory has been analyzed using appropriate formulas and online calculations to estimate the loss, saving and payback period.

After detailed analysis of the collected data and running the appropriate software for simulation purposes, conclusion and recommendation are forwarded.

1.5 Literature Review

There are a lot of researches done and documented in many publications on energy conservation improvement to provide solution for the problem on energy consumption and conservation.

In this work literature review of different studies on the areas of industrial energy audit and energy conservation improvement related to textile industry has been done in order to achieve broad knowledge of the subject matter.

This section includes the topics related to the study reviewed from several sources such as websites, journals, books, magazines, handout and others. It also provides energy conservation technologies that are being applied for industries sector especially on textile industries.

Energy audits may be considered as the first step towards understanding how energy is being used in a given facility. Energy audit is usually one of the first step in an energy management program. It shows how efficiently energy is being used and highlights opportunities for energy cost saving. It can also be ways to improve productivity. Energy audits take a through look at particular facility, processes, or technologies [7].

Energy audit is a process of checking the way energy is used and identify areas where wastage can be minimize if not totally eradicate. Energy audit consists of several tasks which can be carried out depending on the type of audit and the function of audited facility. It started with review the historical data of energy consumption which can be compiled from the electricity bills [2].

Energy audit Manual and Tool [2] Demonstrated that energy audit is one of the first tasks to be performed in accomplishing an effective energy management program designed to improve the energy efficiency and reduce the energy operating costs of a facility without negatively affecting the output. The study revealed basic component, types, benefits, key steps Energy Management Opportunities of Energy auditing and methodology that should be followed during audit.

In response to the wave of challenges related to energy use, some industries around the world have reduced energy intensities by adopting 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. By doing so, industries have not only gained improvement in environmental protection, but also gained economic and social dividends [8].

Motors are fairly efficient at rated loads. In general three- phase motors are more efficient than single-phase motors and larger motors are more efficient than the smaller ones. Motor voltage unbalance will increase motor losses due to the negative sequence voltage that the causes a rotating magnetic field in the opposite direction of the motor rotation. A 2% voltage unbalance will increase losses by 8%; a 3% unbalance will increase losses by 25% and a 5% unbalance will increase losses by 50%. The power factor of three-phase motors is between 80% & 90% at full load & decreases as load is reduced. The installation of capacitors for power factor correction up to 0.95 or so) will decrease current requirements, thereby reducing I^2R losses in supply lines [6].

The Textile guide by Japan Energy Conservation Center [6], incorporated energy conservation technologies to promote energy conservation in the textile industry applicable to the developing countries which could be achieved through conducting surveys of energy usage and efficiency at the plant level and Preparing manuals on energy management and energy conservation/saving technologies, based on the findings of the survey which would be applicable for all similar industries. The paper includes type and source of energy used in each field and analyzes in detail the actual conditions of energy consumption in each field of the textile industry and compiled for the practical application of the energy saving techniques. A step-by-step description also included to help for implementation of the energy conservation measures, specifically in the area of the dyeing and finishing process.

The rational use of energy calls for a broad application of energy conservation technologies in the various industrial sectors where energy is wasted. One of these energy intensive industrial sectors to be considered to improve efficiency through the introduction of modern energy conservation technologies is the textile industry. The textile industry is one of the major energy consuming industries and retains a record of the lowest efficiency in energy utilization. About 23% energy is consumed in weaving, 34% in spinning, 38% in chemical processing and another 5% for miscellaneous purposes [1].

Jatin Gupta [13] describes type; breakdown and amount of energy textile industry can use and identified the key areas where electrical energy can possibly saved. The study focuses on induction motor being the major energy consumer of the plant and indentified opportunities for energy saving. The thesis provides information on energy-efficient improvement technologies and measures which can be applicable to all textile industry. The work includes energy audit conducted on major areas with energy saving potential, analysis is done on different motors in a textile plant and includes energy saving and cost information available. The thesis reports the analysis done on rewound induction motors for its efficiency and detail comparisons between rewound induction motors and new motors has been done. For some measures this report also provides range of savings and payback periods found in under varying conditions. The thesis report analysis is done only on rewound induction motors for its efficiency improvement The thesis concluded that is rewound motors replaced by new ones, have a payback period in the range of 2 years to as less as 6 months.

CleverBooks, [34] describes different type of boilers and their fuel consumption and provides boiler efficiency improvement technologies which can be applicable to all types of boiler. It indicates the steps that should be followed to improve boiler efficiency and provide tools necessary to accurately compare fuel usage and evaluate efficiency of boiler. The book overview the main energy saving opportunities for steam and high temperature hot water boilers and demonstrates how simple actions save energy, cut costs and increase profit margins. And it shows the saving which can be achieved through implementation of the ECOs.

Amare Matebu [16] provides information on overview of textile industries and presents quality management system of textile industries. The work focuses on textile industry in Ethiopia and shows the quality management system exist in all textile industries. The thesis shows that almost all textile industries in Ethiopia are suffering from quality related problems such as poor performance of products in the export market, low quality and insufficient raw material supply, incompetence in the world market, customer dissatisfaction, low productivity, and poor utilization of the resources. The thesis also identifies the major components of QMS for textile industries and propose the appropriate implementation model of quality management system to avoid the existing problem and which can help the industry to compete in the world market..

1.6 Significance of the Study

In this century energy is one of the main concerns of the world. This thesis contribute to ensure the power demand in the public grid by energy saving.

Textile manufacturing industries consume vast amount of energy due to prolonged use of the equipments in inefficient way. This study identifies areas for energy loss and mechanism for improvement in the textile industry. It also enable industries to increase efficiency, save energy consumption and money by minimize the energy loss which leads the reduction of environmental pollution.

1.7 Organization of the Thesis

The thesis is organized into five chapters which are briefly summarized below.

Chapter one presents the introduction part of the thesis which includes, background of the study, statement of the problem, objectives of the study, methodology followed in the thesis work and literature review of related studies.

Chapter two presents overview of textile industries, main production process of textile industries, energy management and opportunities for energy saving in the industry. This chapter gives theoretical background for the thesis work. It also describes the energy consumption of the industries, overview of the selected factory including production capacity and energy consumption.

Chapter three incorporates data collection overall energy intensity of the factory, energy loss assessments and data analysis, energy consumption comparison with benchmarking plants.

Chapter four discusses cause of energy losses and opportunities for efficiency improvements of the main energy consuming area of the factory, simulation result of MotorMaster + software.

Chapter five presents the conclusion and recommendation that shows the summery of the study.

CHAPTER TWO

2. Overview of Textile Industry and Energy Conservation Improvement

2.1. Over View of Textile industries

Textile industry has come a long way to be an organized industry from being a mere domestic industry. Starting with the Industrial Revolution, it has gained a state of supremacy with time. High production of wool, cotton and silk all over the world has given a boost to the textile industry in past years. Though the industry originated in UK, the art of textile production passed to Europe and North America after mechanization of textile manufacturing process in those areas. Asian countries also industrialized their economies and took steps for the growth of this sector. Japan, India, Hong Kong and China have become leading producers of textile because of the availability of cheap labour which is a very important factor for this industry. Now the industry has matured enough for growth outside the traditional western markets [14].

Textile industries fulfill one of the three basic needs of the human being i.e housing, food and clothing by providing cloths for them. The industrial revolution was based up on the principle materials like Coal, iron, steel and cotton. Technological developments from the second part of the eighteenth century awards led to an exponential growth of cotton output, first starting in the UK and later spreading to other to other European countries. The production of synthetic fibers that started at the beginning of the twentieth century also grew exponentially [13].

Textile is any kind of woven, knitted, knotted or tufted cloth, or a non-woven fabric. Non-woven fabric is a fabric which is made of fibers / yarn that have been bonded into a sheet like structure by means of mechanical actions or chemical bonding. Textile also refers to the yarns, threads and wools that can be spun, woven, tufted, tied and otherwise used to manufacture cloth. The production of textiles is an ancient art, whose speed and scale of production has been increased almost beyond recognition by mass-production with the introduction of modern manufacturing techniques. The textile industry comprises of establishments that produce yarn, thread, and fabric and a wide variety of other textile products for use by individuals and businesses, but not including apparel or garment. Some of the items made in this industry include household items, such as carpets and rugs; towels, curtains, and sheets; cord and twine; furniture and automotive upholstery [16].

Jitan Gupta[13] explained in his research China is the largest cloth producer in the world and has the largest production capacity for textile products consisting of Cotton, manmade fibers and silk and it is the world's top textile exporter with 40% of world textile and cloth exports.

As mentioned in different researches Textile industry has played an important role in the development of human civilization and the industry is considered as labor-intensive industry developed on the basis of an abundant labor supply. As **Ali Hasanbeigi** mentioned in his researched on Energy-Efficiency Improvement Opportunities for the Textile Industry the number of persons employed in the textile and clothing industry in China in 2005 was around **8 Million.**

The textile industry uses a wide variety of machines to sew fabrics and make clothes, carpets and other textile goods. These machines range greatly in size, from massive heavy-duty industrial machines used almost solely in major textile factories, to small consumer-sized sewing machines, which are useful in both factories and in homes use.

2.1.1. Textile production processes

The textile industry is one of the most complex industrial chains in the manufacturing industry because of the wide variety of textile products, substrates, processes, machinery and components used, and finishing steps undertaken. Different types of fibers, methods of yarn and fabric production, and finishing processes combinations (preparation, printing, dyeing, chemical/mechanical finishing, etc), all interrelate in producing a finished fabric. The combination of processes and process parameters is almost infinite and has a considerable influence on energy efficiency [12].

Textile mills take natural and synthetic fibers, such as cotton and polyester and transform them into yarn, thread, or webbing. Yarns are strands of fibers in a form ready for weaving, knitting, or otherwise intertwining to form a textile fabric. They form the basis for most textile production and commonly are made of cotton, wool, or a synthetic fiber such as polyester. Yarns also can be made of thin strips of plastic, paper, or metal. To produce spun yarn, natural fibers such as cotton and wool must first be processed to remove impurities and give products the desired texture and durability, as well as other characteristics. After this initial cleaning stage, the fibers are spun into yarn [16].

Textile manufacturing or production is a very complex long process a lot of steps involved to be performed to get the final product. The textile manufacturing process starts from fiber to finished products.

A number of processing operations are available in the textile manufacturing, the sequence of which depends on the requirements of the final product.

The major textile processes:

- Yarn production1
- Fabric Production
- Finishing

These main processes consists a lot of sub process.

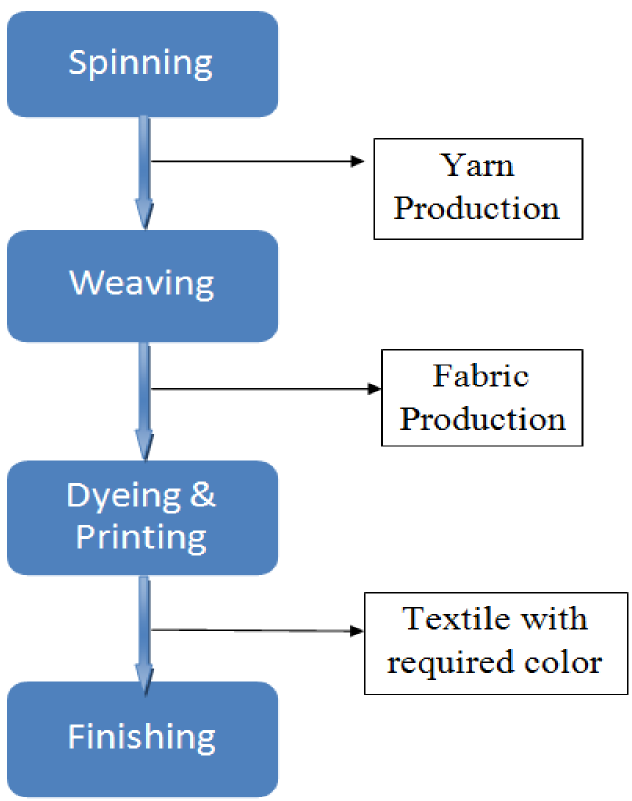


Figure 1 Flow chart of major Textile Manufacturing Processes

I. Spinning

All textiles are made up of fibres that are arranged in different ways to create the desired strength, durability, appearance and texture.

During spinning process fibres are subjected to various mechanical processes that comb, align and spin them to produce a yarn. In some cases two or more yarns are twisted together to form a twine. Chemical auxiliaries are used to provide lubrication, allowing high speed processing.

The process involves in the ring spinning yarn formation are the removal of unwanted non-lint or trash from a fiber mix to get Straightens, parallels, and cleans cotton fiber. Other sub processes are involved in this process to reduce the thickness, remove short length Fiber, to make the parallel fiber, reduce thickness, twist, transfer yarn from multi ring bobbin to one cone of Standardized weight.

In order to increase the strength of the fibre, increase fibre uniformity and reduce friction during the spinning process, spinning oils are added.

II. Weaving

Weaving is the process of interlacing two or more yarns at right angles to form a fabric. On a loom weft yarn is woven between taught, parallel warp yarns. To prevent the yarn from breaking during the weaving and knitting processes, a chemical treatment (Sizing chemicals and lubricants) are added to strengthen the yarn and reduce friction.

Pre-treatment processes, like Washing, De-sizing, Bleaching can be carried out with fibers, yarns or fabrics in order to enables the material to accept dyes and functional chemicals.

III. Dyeing and Printing

Textiles are usually coloured to make them attractive and beautiful. The two ways of adding colour to a textile Substrate are printing and dyeing.

Printing is a process in which a multicolour effect is produced on the textile at discrete places where as dyeing completely covers the substrate with colour.

IV. Finishing

This stage includes final operations necessary for making the textile suitable and attractive. It gives the final properties to the fabric as per the end use requirement of appearance, texture or quality.

The finishing process includes drying to remove moisture from the fabric, providing dimensional stability to get the required dimensions of width and length, Calendering to make the fabric a kind of glossy skin by pressing the fabric against a hot metal surface, softening to breakdown the stiffness of the fabric after calendaring.

2.1.2. Energy use in Textile Industry

Different researches and case studies declared that Energy in the textile industry is used in the forms of electricity, for machinery, cooling and temperature control systems, lighting, office equipment, etc. and oil as a fuel for boilers which generate steam. Thermal energy in textile mill is largely consumed in heating of water and drying of water, this shows that fuel consumption in textile mills is almost directly proportional to amount of water consumed. Hence, if consumption of water can be reduced, it will also save energy [2].

The textile industry is one of the high energy consuming industries with lowest efficiency in energy utilization.

The share of total manufacturing energy consumed by the textile industry in a particular country depends upon the structure of the manufacturing sector in the country.

The textile industry uses large quantities of both electricity and fuels. The share of electricity and fuels within the total final energy use of any one country's textile sector depends on the structure of the textile industry in that country. For instance, in spun yarn spinning, electricity is the dominant energy source, whereas in wet-processing the major energy source is fuels. Manufacturing census data from 2002 in the U.S. shows that 61% of the final energy used in the U.S. textile industry was fuel energy and 39% was electricity. The U.S. textile industry is also ranked the 5th largest steam consumer amongst 16 major industrial sectors studied in the U.S. The same study showed that around 36% of the energy input to the textile industry is lost onsite (e.g. in boilers, motor system, distribution, etc.) [9].

Yarn and Fabric production mostly use electricity as power source of the machines motors whereas energy use in the finishing processes is mostly thermal. Finishing processes have higher energy consumption than the yarn and fabric production.

Each manufacturing process has its own energy consumption characteristics; the amount of energy consumption depends on type of process. Also the type of energy sources consumed in each different processing stage is different, some processes require more electricity while others requires more heat energy, energy use in the main textile processes is discussed below.

- **Spinning process**

Electricity is the major energy used in spinning process to operate machines for yarn production, and Fuel is used to provide steam for humidification system for preheating the fibers before spinning them together. The humidification system is used during the cold season; thus the fuel used by a cotton spinning plant highly depends on the geographical location and climate in the area where the plant is located.

Amount of energy consumption in this process is varies depending on type of spinning system, type of machines (winding and doubling), desired yarn properties and raw material characteristics.

- **Weaving**

The major energy consumption in the weaving sector is electricity. The amount of energy consumption changes depending on fabric structure and technical parameters of weaving machine. The amount of energy consumed by each loom during its weaving operation can be estimated from the motor capacity and weaving speed. Weft insertion systems and lighting consumes large amount of electrical energy. Sizing which is an important process between spinning and weaving processes, for possible preparatory operations for weaving, uses thermal energy.

- **Dyeing and Printing**

In this processing stages of pretreatment, bleaching, dyeing, printing finishing, post treatments and drying-fixation processes consume large amount of thermal energy. Fiber requires cleaning before entering the fabric production to remove impurities through an energy intensive process requiring large amounts of hot water loaded with non-ionic detergents and builders (inorganic salts) to emulsify the wool grease.

The wet processing of textiles consumes only a small portion of electrical energy mainly for running the various processing machinery's.

The energy used in wet processing depends on various factors such as the form of the product being processed (fiber, yarn fabric, cloth), the type of machine, the state of final products etc.

- **Finishing**

This stage (cloth manufacturing process) mostly consumes electric energy for inspection, spreading, marking, cutting, sewing, laying up, cutting, sewing, cleaning with air suction, ironing, etc. Only heating and ironing processes may require steam or hot air.

The energy used in this process depends on various factors such as the form of the product being processed (fiber, yarn, fabric), the machine type, the specific process type, the state of the final product, etc.

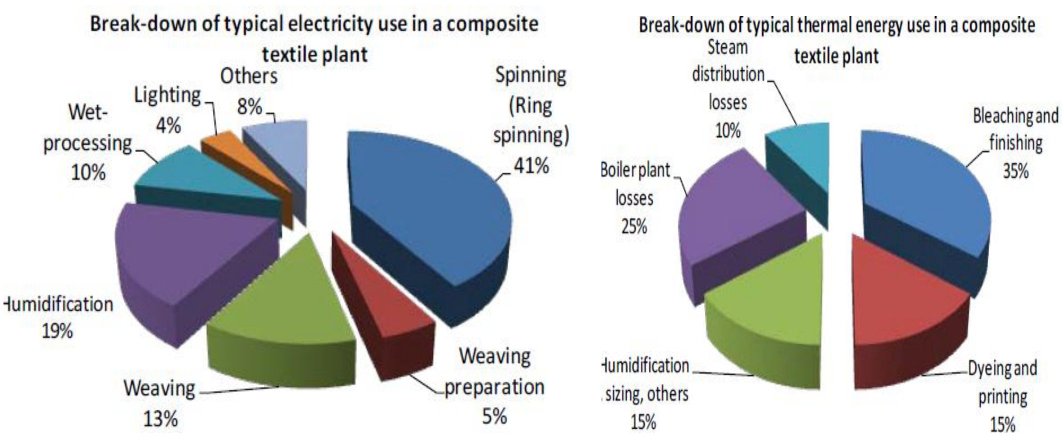


Figure 2 Breakdowns of Typical Electricity and Thermal Energy Used in a Composite Textile Plant [9]

2.2. Over view of Yirgalem Addis Textile factory plc and its Energy Profile

2.2.1. Over view of Yirgalem Addis Textile factory plc

Yirgalem Addis Textile Factory PLC is a former Adei Ababa Yarn factory which is privatized from government since Nov, 2010. The Textile factory has more than 50 years experience in spinning, Knitting, Weaving, Dyeing and Garment and Blanket activities. Currently the factory has more than 800 employees. The factory is located in the southern part of capital city of Ethiopia Addis Ababa at Debrezite road, Nifas Silk Lafto Sub city.

Currently, the factory has more than 800 employees and 90% of the employees are women.

The factory is designed to produced different products, like cotton yarn, Bleached yarn, knitted fabric, Dyed knit fabric, different sport & under wears and is supplying its products to different international and local customers.

The factory operates throughout the year and the working hrs and shifts of the factory depends on the market condition.

Figure 3 some part of YATF

2.2.2. Production Facilities and Capacity of YATF

The company is an integrated textile factory consisting of Spinning, Knitting, Knit dyeing, Garment stone washing, Blanket weaving, blanket stitch bond (non-woven) and garment production.

The Knitting plant produces various types of knit constructions such as jersey, rib, pique, popcorn and interlock.

The dyeing plant is equipped with stone wash and garment wash facility for Jeans and knit products. The blanket unit is also equipped with weaving, direct warping and sectional warping, raising, stitch bonding and carding facilities to produce quality woven and non woven blankets.

The company has undertaken expansion and rehabilitation Projects, expansion in its blanket and garment plants and rehabilitation project in its knitting and dyeing plants that enables the company be more competitive in the international market.

Table 1 plant's production capacity

No.	Plant/Section	Product type	Unit	Production capacity/day
1	Spinning	Yarn	Kg	6,000
2	Knitting	Grieg knit fabric	Kg	10,500
3	Dyeing & Finishing	Finished knit fabric	Kg	10,000
4	Garment	Finished knit garment	Pcs	15,000
5	Blanket	Woven & non woven blanket	pcs	1500 up to 1800

Table 2 Annual production capacity of Blanket plant

No.	Production unit	unit	Annual production
1	Non woven Blanket	pcs	540,000
2	Woven Blanket	pcs	435,000
3	Raising Finishing	pcs	1,200,000

The company has two lines for production but the operation of these production lines depends on the market condition. Most of the time the factory is not producing with its full capacity due to unavailability of Market.

Annual production for four years has been collected as show in Table3 below

Table 3 Annual production of the factory

Description	Unit	2008	2007	2006	2005	Average annual production
Garment	Pcs	708,000	570,000	210,000	464,000	488,000
Knitting	Kg	299,000	209,000	413,000	508,000	357,250
Dyeing	Kg	412,000	333,000	398,000	454,000	399,250
Blanket	Pcs	55,000	130,000	131,000	218,000	133,500

As indicated in Table 4, below which shows annual cost of the factory for four years has been collected and the average annual cost is ETB is 68,413,000.00.

Table 4 Annual Company cost four years

Description	Unit	2008	2007	2006	2005	Average annual cost (ETB)
Total Company Cost	Birr	92,122,000.00	73,850,000.00	58,888,000.00	48,792,000.00	68,413,000.00
Heavy Oil	Birr	2,981,207.00	3,155,699.00	2,208,300.00	1,829,700.00	2,543,726.50
Water	Birr	296,944.00	266,889.00	200,219.00	165,892.00	232,486.00
Electric	Birr	796,756.00	756,725.00	553,547.00	458,644.00	641,418.00

Figure 4 Picture of Knitting & garment sections

2.2.3. Energy use profile of YATF

The factory uses both electric and fuel energy to operate different motors, machines and equipments in order to achieve final production. The factory uses electricity as energy source for machines, lighting, funs and different office equipments, Furnace oil for boiler to generate steam and Diesel oil to run stand by generators.

The factory power distribution system consists of three distribution transformers of capacity 630KVA each, Six (6) transformers with capacity of 315kva each and two backup Diesel generators of capacity 180KVA and 300KVA used as emergency power supply for some critical loads.

Electric and fuel consumption of the factor for three years has been collected. The annual average fuel consumption of the factory is Furnace oil 419,318.285lit and diesel 147,192.295 lit.

Annual average Electric energy consumption of the selected plants of the factory is:-

- Knitting /Dyeing - 499,334.005 KW/hr
- Spinning - 102,461.105KW/hr
- Blanket & Garment- 494,009.905KWh

2.3. Energy Conservation Improvement in Textile Industry

In general, energy in the textile industry is used in the forms of Electricity and fuel. Electricity used as power source for machinery, cooling and temperature control systems, lighting, office equipment, etc.; and fuel is used for boilers to generate steam.

Energy conservation improvement in Textile industry can be achieved through implementing an organization-wide energy management program by improving the awareness and knowledge to obtain the participation and cooperation of employees involved in the production process, retrofit/process optimization which includes scheduling of timely maintenance plan and complete replacement of the current machinery with new energy saving technology. Energy management program is key factor to energy conservation improvement.

A successful energy management program begins with a strong organizational commitment to the continuous improvement of energy-efficiency. This involves assigning oversight and management duties to an energy director, establishing an energy policy, and creating a cross-functional energy team. Steps and procedures are then put in place to assess performance through regular reviews of energy data, technical assessments, and benchmarking. From this assessment, an organization is able to develop a baseline of energy use and set goals for improvement. Such performance goals help to shape the development and implementation of an action plan[9].

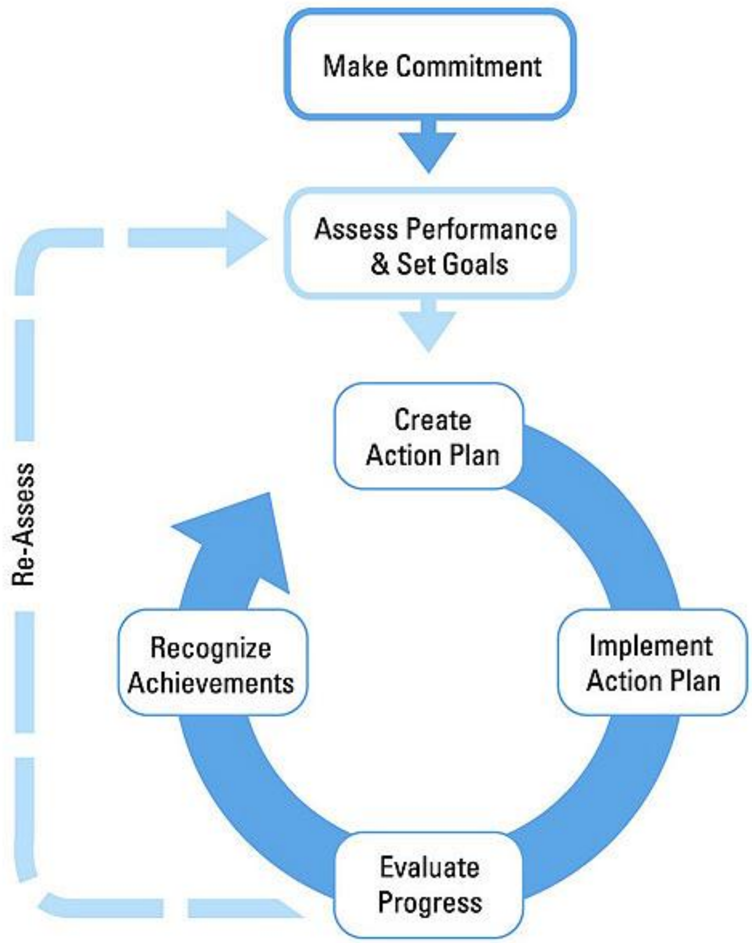


Figure 5 Main Elements of a Strategic Energy Management Program[9]

The textile industry is one of the most complicated manufacturing industries because it is a fragmented and heterogeneous sector dominated by small and medium enterprises (SMEs). Energy is one of the main cost factors in the textile industry. Especially in times of high energy price volatility, improving energy efficiency should be a primary concern for textile plants. There are various energy-efficiency opportunities that exist in every textile plant, many of which are cost-effective. However, even cost-effective options often are not implemented in textile plants mostly because of limited information on how to implement energy-efficiency measures, especially given the fact that a majority of textile plants are categorized as SMEs and hence they have limited resources to acquire this information. Know-how on energy-efficiency technologies and practices should, therefore, be prepared and disseminated to textile plants [9].

SARITA SHARMA [1] shows the importance of energy management program in textile industry and provides information on energy management measures which are applicable to textile industry in order to promote energy saving opportunities efficiently. He also indicated the effectiveness of applying Energy Management in Textile Industry separately considers general management techniques for "rational use of energy" and process-specific techniques to be developed in each specialized technical field.

The study identified some applicable energy saving opportunities on different equipments and processes of textile factory.

2.3.1. Saving of electricity use

- **Lighting**

Lighting is very essential requirement in textile industries and accounts considerable electric use in the industries. Inadequate lighting at place of work can create problem in human health and affect in production and product quality.

The Textile Industry use vast number of lighting lumps especially in the garment area for sewing machines. Considerable energy can be saved in the textile industries by changing lamps with energy efficient once and by using the lighting efficiently. Many researches recommend illumination of the area with natural light to save energy.

The lighting system provides many opportunities for cost-effective energy savings with minimum changes. Lighting energy use represents only 5-25% of the total energy in industrial facilities, but it is usually cost-effective to address because lighting improvements are often easier to make than many process upgrades [18].

It is important to check whether the light source is utilized in the most efficient way and take electricity saving measures, if necessary, such as reducing the number of lamps in use, replacing the existing lamps with efficient once, by using light control switches.

- **Electric motors**

Energy-efficient motors reduce energy losses through improved design, better materials, tighter tolerances, and improved manufacturing techniques. With proper installation, energy-efficient motors may help reduce facility heating loads, and have higher service factors, longer bearing life, longer insulation life, and less vibration.

It is known that oversized motors, especially motors operating below 50% of rated load, are not efficient and should be immediately replaced with appropriately sized energy-efficient units. In actuality, several pieces of information such as the load on the motor, the operating efficiency of the motor at that load point, the full-load speed (in revolutions per minute [rpm]) of the motor to be replaced, and the full-load speed of the downsized replacement motor are required, to complete an accurate assessment of energy savings.

The efficiency of both standard and energy-efficient motors typically peaks near 75% of full load and is relatively flat down to the 50% load point. Motors in the larger size ranges can operate with reasonably high efficiency at loads down to 25% of rated load. There are two additional trends: larger motors exhibit both higher full- and partial-load efficiency values, and the efficiency decline below the 50% load point occurs more rapidly for the smaller size motors. Software packages such as Motor Master+ can aid in proper motor selection [9].

Jatin Gupta [13] Provides information on energy saving opportunities for electric motor. The work declared that energy can be saved by taking care of the motor with good ventilation so that the motor can breathe normally and increase its efficiency. The work also identified the key areas where energy can possibly be saved and practical comparisons between rewound induction motors and new motors are shown and the work declared that rewound motors, if replaced by new ones, have a payback period depending on the HP of the motor will be in the range of one up to two years.

2.3.2. Efficient use of steam

Steam is widely used in processes of textile industry, in Spinning, Weaving, and Garments for drying, heating and maintaining the required temperature of system.

Steam can be used efficiently by using proper piping, steam accumulator; proper type and size of steams trap to avoid leaks, insulating the steam pipes and flanges to avoid steam leaks, incorporating regular boiler and steam pipe maintenance, improving squeezing of fabrics through the mangles to reduce the thermal energy consumption for dryers.

- **Boiler**

Maintaining the optimum ratio of fuel to air is important to efficient operation of these systems. A lack of air leads to incomplete combustion, resulting in losses of combustibles in the flue gases. Excess air needlessly increases the dry flue gas losses, as does the temperature of the flue gas. The temperature of the flue gas depends on the effectiveness of heat transfer in the boiler, and is a good indicator of the condition of internal heat transfer surfaces. The portable combustion analyzer is a useful tool for gauging the combustion efficiency of boiler plant systems [2].

Also applying a simple maintenance program helps to ensure that all components of the boiler are operating at peak performance and results in substantial savings. In the absence of a good maintenance system, the burners and condensate return systems can wear or get out of adjustment. Improved maintenance may also reduce the emission of air pollutants.

The heat boiler is a large energy user in industry; hence Small changes or improvement in this area can save a lot of energy and money.

- **Stem Pipe**

The noted feature of steam use in the textile industry is that the amount of steam involved is not so large but the locations where steam is required are widespread so that steam losses due to heat radiation from steam transportation pipes and pressure drops are considerable. Therefore for steam transportation over long distances, high pressure and small diameter rather than low pressure and large-diameter piping is desired, with pressure reducing valves placed as necessary to regulate the steam pressure at the point of use, thereby curbing heat losses. Also, as pressure losses around bends are great, it is desirable to make their radii large. In order to prevent steam leaks from joints due to the thermal expansion of the pipe, expansion joints should be placed where required. Furthermore, in order to maintain the temperature inside the valve, tank and treatment tank as well as the piping, it is necessary to install them heat-insulated, using appropriate heat insulating materials, so as to efficiently use steam while preventing heat losses [6].

- **Steam accumulators**

Since live steam is often used in dyeing factories, fluctuations in steam use during working hours are large. On the other hand, since high performance water tube boilers and once-through boilers are designed such that water retained inside the boiler is very little, the boiler cannot react to momentary and sudden load changes, while responding to automatically controlled slow load changes is not a problem. In such a case, a steam accumulator can be installed midway through the heat transporting pipe, between the boiler and the heat consuming load, in order to store excess steam when the load is light by transforming it to heated water. This then transforms the heated water back to steam when the load is heavy in order to reinforce supply to the load. This allows the boiler to continuously operate with the average load and is quite advantageous in view of energy saving [6].

One solution to these problems is the installation of a steam accumulator, which stores excess steam the boiler produces at times of low load. When more steam is needed, the accumulator discharges this excess steam to the plant. The amount of stored steam is proportional to the water volume and changes in pressure. Installation of steam accumulator increases fuel consumption efficiency.

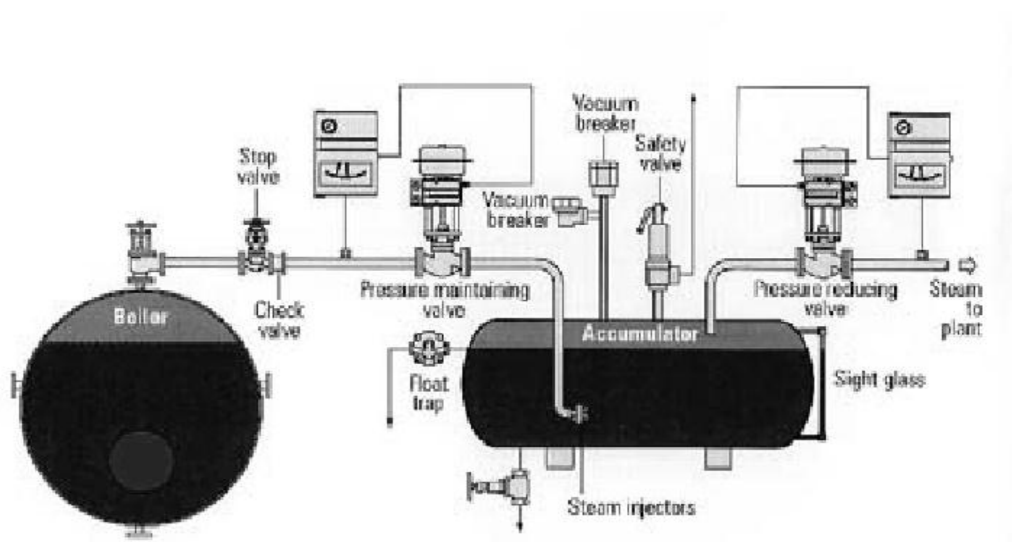


Figure 6 Boiler & Steam distribution system [34]

CHAPER THREE

3. Data Collections and Energy Loss Assessments

3.1. Data collection

The necessary data have been collected from different sources in order to have more understanding on energy conservation of the selected plant and for undergoing the thesis work on Energy Audit and Energy Conservation improvement at YATF. Generally primary and secondary data have been collected. Primary data includes the collection of information through direct observation, personal interviews, company documentation and conducting measurements. The secondary data have been collected from other related problem areas; it includes the study of other researches with related problems, web-sites and other documentary records relevant for the study.

The data collected from file documentation of different departments of the factory and direct observation includes:

- Annual fuel and electric consumption of the factory for the past 3 consecutive years from the utility department file
- Annual production cost of the factory for the last 4 years
- Annual energy cost of the factory for the past 4 years
- Annual production of the factory for the past 4 years
- Installed power capacity of the main processes of the factory
- Measured value of each motors and boiler
- Lighting data of the factory

The collected data during the energy audit conducted in YATF are presented in the following tables and charts.

Installed power capacity gathered from all equipments in the main processes of the factory is plotted in Table 5, department wise.

Table 5 Installed Power Capacity

No.	Plant/Section	Installed power (KW)
1	Spinning	399.39
2	Dyeing	494.45
3	Knitting	257.44
4	Garment	376.78
5	Blanket	566.73
Total		**2,094.79**

3.2. Energy Consumption and losses Assessment at YATF

3.2.1. Energy consumption of the plant

The factory consumes both electric and thermal energy to run different machines and equipments for processing of different textile products. Electricity used for operating of different machinery, cooling and temperature control systems, lighting, office equipment, etc. and fuel is consumed for boilers to generate steam for dyeing and finishing processes. The most fuel consuming plant of the factory is Dyeing, which consumes more than 85% of the total steam produced for its process, and most of the electrical energy of the factory is consumed by spinning, Knitting, Garment and blanket plants and, Blanket plant consume around 33% of the electrical energy. Annual energy consumption of the factory has been collected as shown in Tables 6 & 7.

The power supply of the factory consists:-

- ✓ Three (3) distribution transformers with capacity of 630kVA each and Six (6) transformers with capacity of 315kVA each
- ✓ Two Diesel generators with capacity of 300kVA & 180kVA used as emergency power supply for critical loads.

Based on the given data the annual electric consumption of the factory is **1,356,187.36KWH** and the annual fuel consumption is **422, 652.29 lit** of Furnace oil and **150,527.63lit** of diesel oil.

Table 6 Fuel Consumption factory

Type of Fuel	Unit	2014	2015	2016	Average
Furnace oil	Lit	429,320.29	358,972.00	479,664.57	**422, 652.29**
Diesel	Lit	157,198.30	293,085.00	1,299.59	**150,527.63**

Table 7 Annual electric energy consumption of selected plants of YATF

Section/ Process	Unit	2014	2015	2016	Average
Knitting & dyeing	kWh	499,430.99	519,003.41	479,664.57	499,366.32
Spinning	kWh	102,550.11	121,983.11	82,939.10	102,490.77
Blanket & garment	kWh	754,996.94	592,066.75	915,927.12	754,330.27
Total		**1,356,978.04**	**1,233,053.27**	**1,478,530.79**	**1,356,187.36**

Electrical energy consumptions of the factory were classified in three categories, electric motor, lighting and other equipments as shown on Fig 8. The energy consumption of electric motors and lighting was evaluated using the KW rating of the device and its operating hour. Whereas the energy consumption of the other equipments was found by subtracting the energy consumption of the electric motors and lightings from the total energy consumption of the factory.

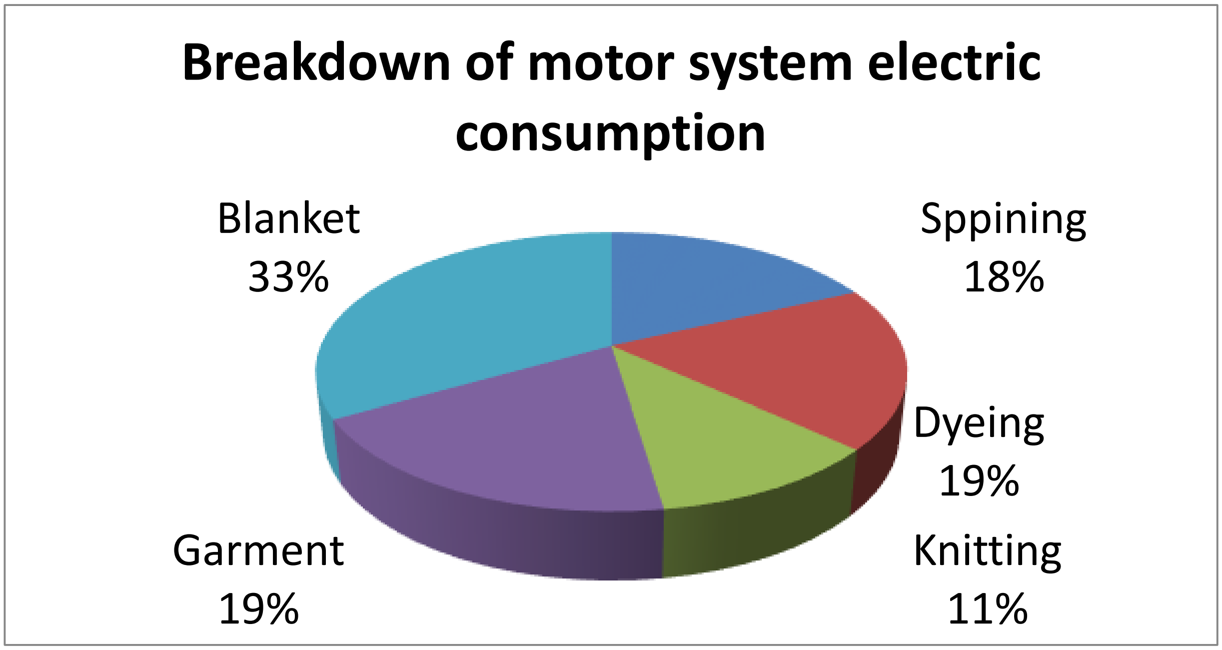


Figure 7 Breakdown of motor system electric consumption

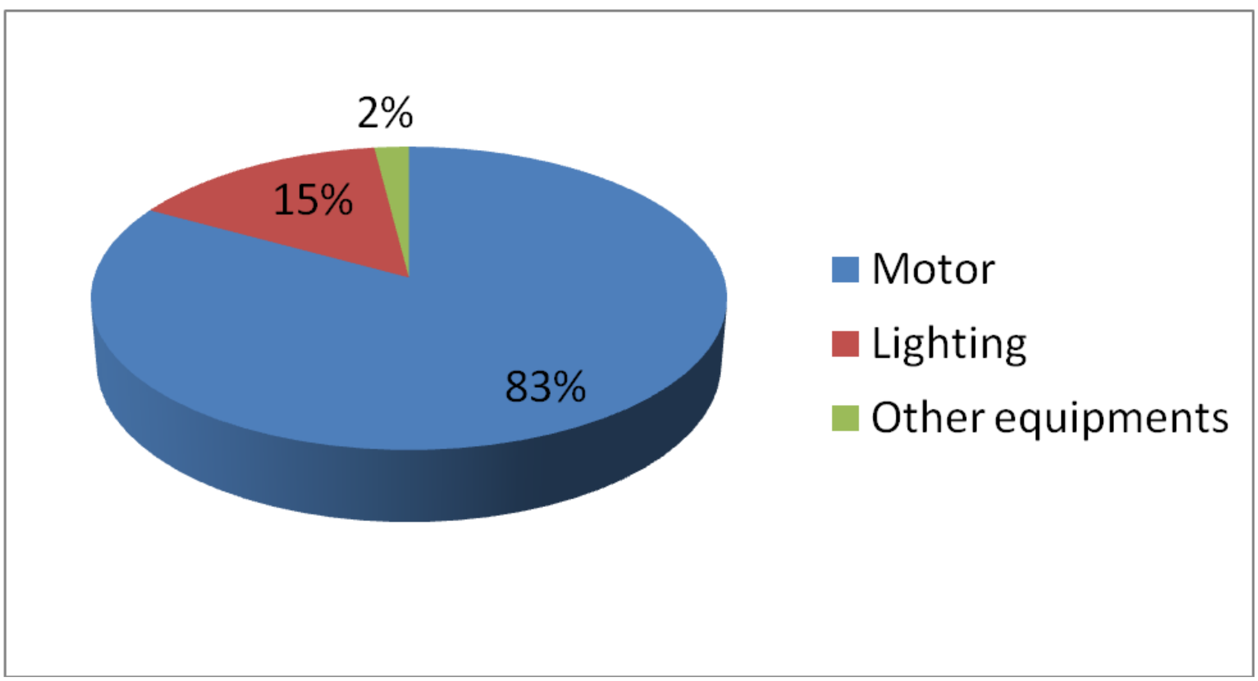


Figure 8 Electrical Load Classification

Fuel and Electric cost of the factory for past four years has been collected as shown in table 8. This shows that the factory's fuel cost is high as compared to the Electric cost. And the average total annual energy cost of the factory is **($162,462.98)**

Table 8 Average annual Fuel and Electricity cost of the plant

Description	Unit	2013	2014	2015	2016	Average
Fuel	Birr	2,981,207.00	3,155,699.00	2,208,300.00	1,829,700.00	**2,943,726.50**
Electricity	Birr	796,756.00	756,725.00	553,547.00	458,644.00	**685,418.00**
Total		**3,777,963.00**	**3,912,424.00**	**2,761,847.00**	**2,288,344.00**	**3,759,393.50**

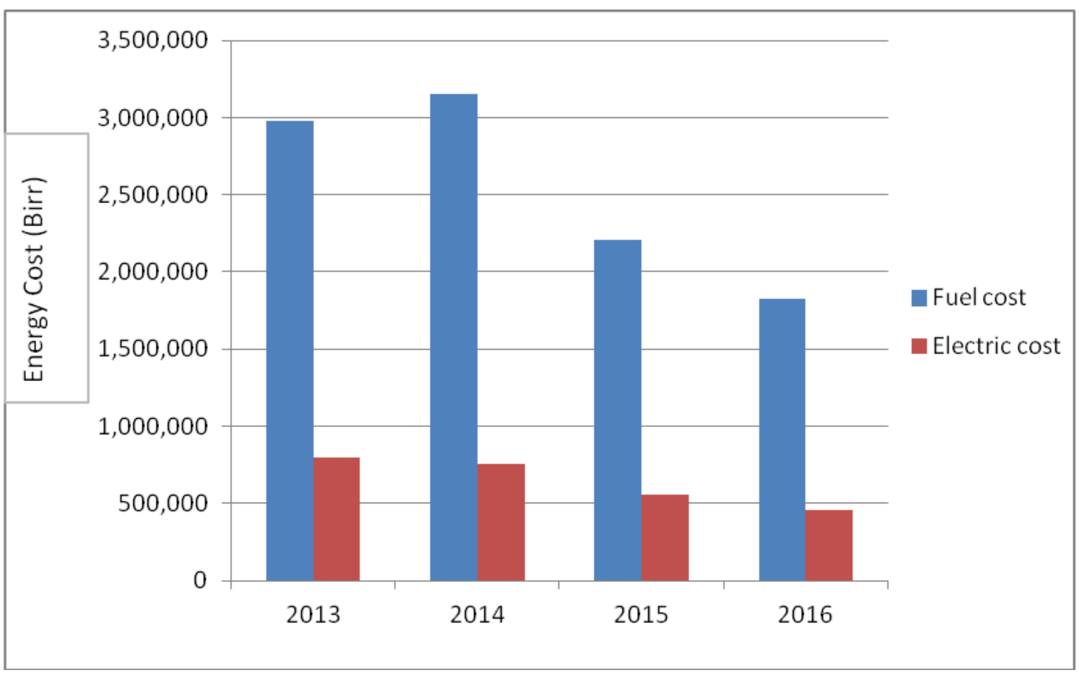


Figure 9 Fuel and Electricity Cost Profile

- **Lighting Load Data**

Number of lamps and their capacity and the room area in m^2 has been collected from each department as shown in table below.

Table 9 Lighting data

Department	NL	TP(w)	RA(m2)	OH(hr)	EU(wh)
Store	163	6520	660	12	78240
Spinning	300	12000	1320	12	144000
Knitting	200	12000	870	12	144000
Air compressor	20	1200	123	12	14400
Admensrator	56	3360	234	8	26880
Canteen	22	880	98	8	7040
Garment	420	16800	3500	12	201600
Dyeing	130	5200	590	12	62400
Blanket	370	22200	3036	16	355200
Guard	7	280	25	24	6720
Workshop	18	720	67	8	5760
Time keeper	4	160	16	12	1920
Show room	8	320	30	8	2560
Total	**1,672**	**81,540.0**			**1,080,680.0**

- **Motor data**

Basic electric motors data such as name plate of operating parameters and measured value of the existing electric motors were collected from main production processes of the factory. The collected electric motors data of YATF factory is summarized in Table 10.

Table 10. Motors data of YATF

No.	Motor Description	Qty	Nameplate data						Measured data		Loading %
			power	V	I	RPM	eff	PF	V	I	
1	Blower comparting	3	37	380	36	1480	80	81	370	28	77.8
2	Exhust fun	2	7.5	380	15.4	1440	82	90	365	9.24	60.0
3	spreader row	1	0.37	220	2.16	1390	86	68	213	1.08	50.0
4	Cooling fan spreed	1	0.08	220	0.34	1680	83	80	220	0.204	60.0
5	Feeder motor	1	0.75	220	3.55	1400	98	85	219	2.485	70.0
6	Conveyer motor	1	2.2	230	8	1390	89	76	217	6	75.0
7	Folder Motor	2	1.1	230	5	1380	75	80	215	3.25	65.0
8	Upper conveyer	1	4	230	14.9	1420	76	82	213	8.344	56.0
9	Lower conveyer	1	4	230	14.9	1420	79	82	215	6.854	46.0
10	compressor	1	15	380	21	1470	89	85	364	12.6	60.0
11	softner	1	5.5	380	10.4	1440	76	85	368	5.928	57.0

12	Washing M/c	6	18.5	380	37	1460	80	87	370	26.64	72.0
13	squeesing	1	10.25	380	13.2	1340	89	86	370	7.92	60.0
14	Sizing	1	10.25	380	13.2	1340	89	86	370	7.92	60.0
15	proceser	9	2.2	230	8	1365	88	85	220	5.68	67.91
16	folder	9	2.2	230	8	1365	75	85	220	4.16	49.74
17	swing machin	105	0.4	220	1	1430	84	82	217	0.6	59.18
18	Bioler	1	48	380	81	1480	90	86	378	63.4	77.86
19	Atlas Capo camp	1	15.74	380	21	1470	91	89	378	12.6	59.68
20	Cutter	5	2.2	230	9.7	1400	78	77	221	6.111	60.53
21	Age cutting	3	0.16	220	3.46	2750	76	66	220	1.6954	49.00
22	Heat transfer	4	1	230	3.55	2130	80	0.75	217	2.3075	61.33
23	Pulling befama	1	20	380	37	1460	81	87	380	22.57	61.00
24	pressing	1	11	380	14.2	1480	78	75	373	8.52	58.89
25	Rolling	1	41.5	380	63	1490	80	90	379	41	64.91
26	Cotton Blend	1	43	380	75	1470	81	86	376	54	71.24
27	Woolen Blend	1	13.5	380	15.2	1470	87	82	367	9.12	57.95
28	Carding	2	25.5	380	32	1480	80	83	365	19.2	57.63

3.2.2. Energy losses Assessment at YATF

As per the collected data for annual energy consumption and annual production of YATF and the energy intensity (the amount of energy consumed to produce a unit of product) of the factory has been calculated as shown on Table 10. Also energy intensity of similar factories from different country with best energy efficiency performance has been selected as benchmark.

Table 11 Energy intensity of the main plant of the factory

Description	Unit	2014	2015	2016
Yarn production	kg	413,000	209,000	299,000
Fabric production	kg	298,000	312,000	402,000
Total	kg	711,000	521,000	701,000
electric consumption	kwh	1,012,701.60	1,153,775.70	1,083,565.98
Fuel Consumption	lt	566,004.19	423,586.96	494,795.58
Specific Electric Consumption	kwh/kg	1.42	2.21	1.55
Specific fuel Consumption	lt/kg	0.59	0.66	0.59
Energy intensity(electric)	KJ/kg	5127.60	7972.35	5564.68
Energy intensity(fuel)	KJ/kg	21292.14	23843.16	21231.31

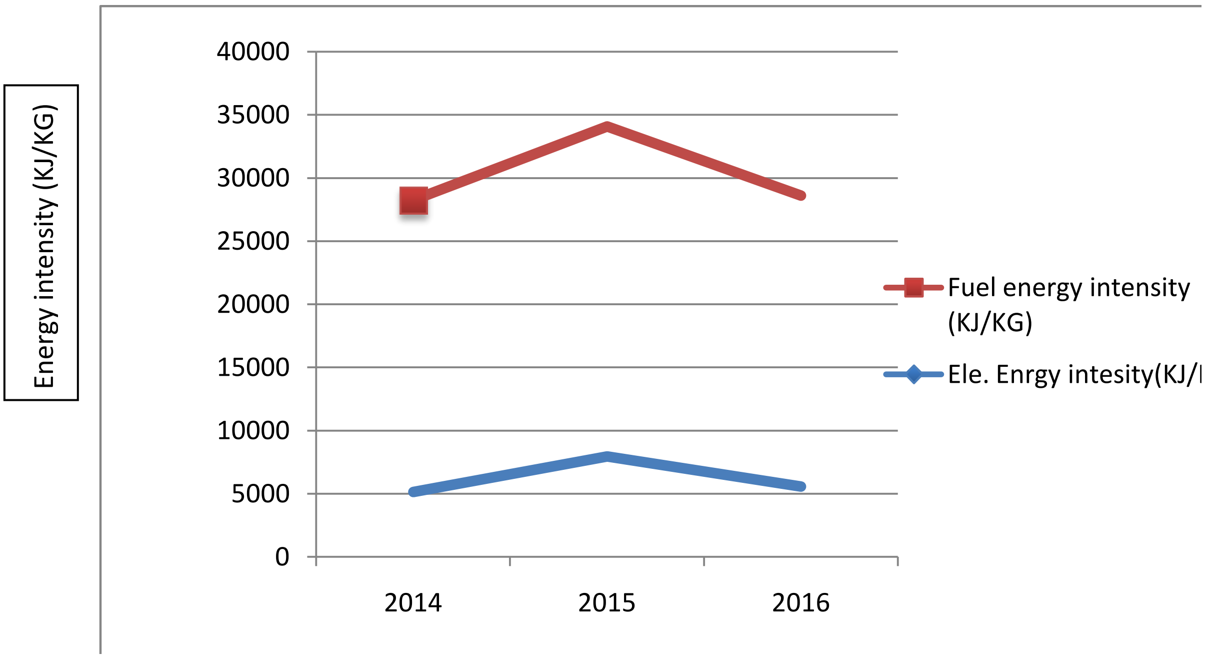


Figure 10 Energy intensity of YATF

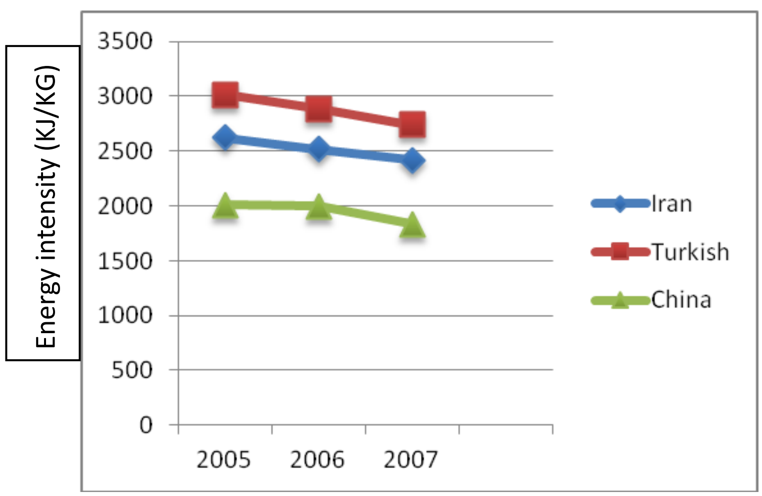


Figure 11 Electric Energy intensity of the bench mark plants

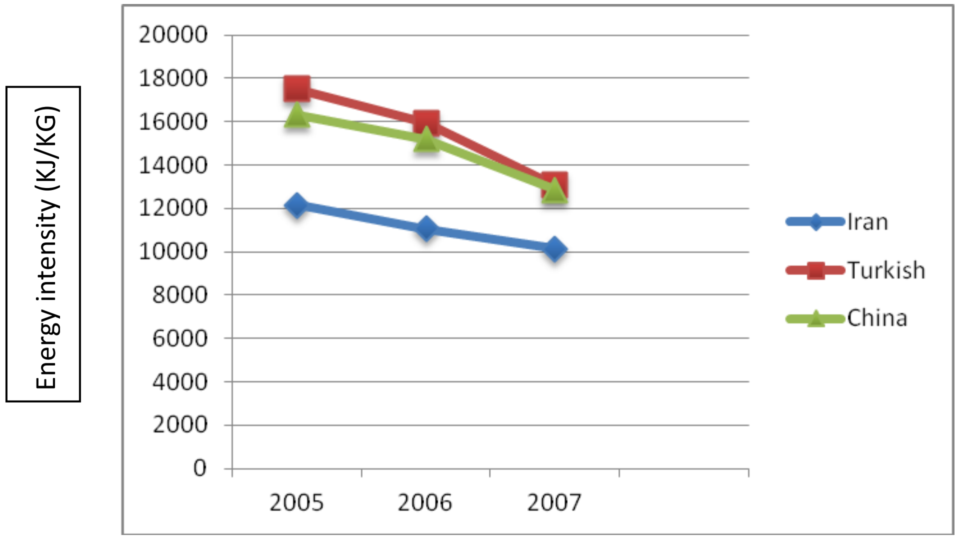


Figure 12 Fuel Energy intensity of the bench mark plants

- **Energy comparison**

The average annual fuel energy intensity of YATF is **26,104kJ/Kg.** Similarly the average energy Intensity of various textile plants taken as bench mark shown in above Fig 10 is **13,806.67 kJ/Kg** of textile product. Hence a difference of **12,297.33 kJ/Kg** Fuel Energy intensity exists between the average practice and what exists at YATF.

With regards to electricity energy intensity of YATF the average electric energy intensity is **6,216kJ/kg**. Similarly the average electric energy Intensity of various textile plants taken as bench mark shown in above Fig 11 is **2,460kJ/kg** of product. Hence a difference of **3,756kJ/kg(1.04kwh/kg)** of electric energy intensity exists between the average practice and what exists at YATF.

From the analysis of the energy intensity of YATF, it can be seen that there is a significant difference between the energy intensity of the plant as compared to the selected benchmarks textile plant experience. This shows that there is actually a room for improving the energy efficiency of the plant. The following calculation shows clearly the unnecessary cost which the company is actually spending due to inefficient use of energy. The annual cost due to inefficient use of fuel and electricity of the factory can be calculated using the current price of fuel and electricity as follow:-

- Average annual production of Yarn is 756,500kg
- Cost of fuel oil = 10.5 birr/lit.
- Cost of electricity = 0.5778birr per/kWh.
- Specific heat of heavy fuel oil is 41,100kJ/lt
- Difference in fuel energy intensity = 12,023.33 kJ/kg of product.
- Difference in electricity energy intensity = 3,756kJ/kg(1.04kWh/kg) of Yarn

- Annual cost due to inefficient use of fuel oil energy intensity

  = [fuel Energy int. (kJ/Kg) * Annual production (kg/yr)*cost of fuel (Birr/lt)]
  Specific heat of heavy fuel (kJ/li)

  = 1,991,747.98 Birr/year ($ 86,222.86)

- Annual cost due to inefficient use of electric energy

  = Elect. Energy consumption (kWh/kg) * Annual production (kg/yr) * Electricity cost (Birr/kWh)

  = 354,589.93Birr/year ($15,350.21)

- Therefore, the total annual cost of energy intensity due to inefficient use of energy

  = cost of fuel + cost of electricity

  = **2,346,337.91 Birr/year**

CHAPTER FOUR

4. Causes of Major Energy Losses and Opportunities to Improve Energy Efficiency

4.1. Causes of Major Energy losses

The textile industry uses large quantities of both electricity and fuels. The share of electricity and fuels within the total final energy use of any one country's textile sector depends on the structure of the textile industry in that country. For instance, in spun yarn spinning, electricity is the dominant energy source, whereas in wet-processing the major energy source is fuels. Manufacturing census data from 2002 in the U.S. shows that 61% of the final energy used in the U.S. textile industry was fuel energy and 39% was electricity. The U.S. textile industry is also ranked the 5th largest steam consumer amongst 16 major industrial sectors studied in the U.S. The same study showed that around 36% of the energy input to the textile industry is lost onsite (e.g. in boilers, motor system, distribution, etc.)[9]

Based on energy audit conducted in YATF and the collected data, the major power consuming areas in the textile plant which have high energy saving opportunities are rewound motors, compressors, Boiler, steam pipe, lighting etc

In order to assess the causes of major energy losses in YATF, three years energy consumption data were collected as shown in Table 7 & 8. The data indicated that the fuel consumption of the plant is higher as compared to the electrical energy consumption. Also it has been observed that Motors consume most of the electrical energy of the plant, which is around 93%.

In the energy comparison in the previous chapter, it can be seen that there is a significant difference between the energy consumption of the plant as compared to the selected benchmarks textile plant experience, especially in the fuel consumption.

Accordingly Boilers, steam pipes, motors and lighting are the major causes of energy losses and were considered the focus areas for further improvements.

During the plant audit visit, areas with visible abnormal symptoms of inefficient transfer of energy in the system has been observed, like abnormal heating of motors and steam pipes, heavy noise, visible steam leakage, etc.

Smooth energy transfer from one form to other does not produce abnormal heating, heavy noise, spark, etc.

Also area for cause of major energy losses has been observed like, unnecessarily working lamps, very old and rewound motors, dust accumulated on motors, Boiler and steam pipes, etc

4.1.1. Lighting

Lighting is an essential requirement in textile industries as well as all other industries. Light is a radiant energy from a hot body which produces the visual sensation upon the human eye. It is required for practical purposes as well as aesthetic purposes. Illumination differ from light very much, through generally, these terms are used more or less synonymously. Light is the cause and illumination is the result of that light on surfaces on which it falls. The power consumption by the industrial lighting varies between 2 to 10% of the total power depending on the type of industry. Proper and adequate lighting in the textile industry improves the visibility of an object, enhances work performance, improve the job satisfaction and reduce loss and compensation payment due to accidents in the industry.[23].

Table 12 Average standard Luminance required [23]

No.	Working Station	Average Illuminance required(LUX)
1	Office	500
2	canteens	150
3	Boilers and pump houses	20-100
4	Spinning	150-450
5	Knitting	300-750
6	Weaving	200-700
7	Grey close inspection	700-1000
8	Final inspection	700-1000
9	Work shops	200-750
10	Clock rooms, Entrances, Corridors, Stairs	100

Two types of lamps are used in YATF: fluorescent and high pressure mercury vapor (HPMV) lamps (CFL). Fluorescent lamps were used in most of the areas, representing around 90% of the total lighting used in the plant. HPMV are mainly used in garment and utilities areas; they represent 10% of the total lighting used in the facility.

Most of the fluorescent lamps in the factory are not energy efficient lamps and it has observed that excess lamps are installed in some areas and some lamps are remaining ON during non working hours (in unoccupied areas), which leads to unnecessary energy consumption.

4.1.2. Electric motors

Industrial motors frequently operate under varying load conditions due to process requirements. A common practice in cases where such variable-loads are found is to select a motor based on the highest anticipated load. In many instances, an alternative approach is typically less costly, more efficient, and provides equally satisfactory operation. With this approach, the optimum rating for the motor is selected on the basis of the load duration curve for the particular application. Thus, rather than selecting a motor of high rating that would operate at full capacity for only a short period, a motor would be selected with a rating slightly lower than the peak anticipated load and would operate at overload for a short period of time. Since operating within the thermal capacity of the motor insulation is of greatest concern in a motor operating at higher than its rated load, the motor rating is selected as that which would result in the same temperature rise under continuous full-load operation as the weighted average temperature rise over the actual operating cycle. Under extreme load changes, e.g. frequent starts / stops, or high inertial loads, this method of calculating the motor rating is unsuitable since it would underestimate the heating that would occur [26].

In YATF there are around 315 motors installed in different department of the factory with different rating power ranging from 0.2kW to 57kW. Most of the motors are very old which have been in service many years, rewound and not regularly maintained. It is known that the efficiency of rewound is less. During the audit in the factory it has been observed the main causes for motor inefficiency are inadequate maintenance, many times rewinding practices, lack of power factor correction & motor loading problems etc.

4.1.3. Boiler and steam pipe

The cost of boiler fuel is typically the largest energy cost of the factory. poor maintenance and leak on pipes can be a significant source of wasted energy, Basel Tahseen in his study declared that a typical plant that has not been well maintained could have a leak rate between 20 to 50% of total compressed air production capacity and this can be a huge cause for high energy costs. Leak repair and proper maintenance can reduce this loss. In YATF it has been observed that there is no regular boiler maintenance schedule in the factory and leaks on the steam pipe, which can be significant cause for energy loss.

4.2. Data Analysis and Opportunities to Iimprove Energy Efficiency

During the auditing it has been observed that there are different opportunities to improve energy efficiency at YATF for efficiently utilization of energy by avoiding unnecessary consumption, taking energy efficient measures and choosing the most appropriate equipment to reduce the cost of the energy.
The power rating of each equipment in the factory was readout and recorded from name plates and average operation hours have been obtained from the operation department of the factory through interview.
Based on the audit conducted and collected data, the major power consuming areas in the textile plant which have high energy saving opportunities are rewound motors, compressors, Boiler, steam pipe, lighting etc.

4.2.1. Lighting Data Analysis and Efficiency Improvement

4.2.1.1. Lighting Data Analysis

The lighting system provides many opportunities for cost-effective energy savings with minimum changes. Lighting energy use represents only 5-25% of the total energy in industrial facilities, but it is usually cost-effective to address because lighting improvements are often easier to make than many process upgrades [25].
The number and rating of lamps in each department and section of the factory has been collected and presented in table 9.

Based on the collected lighting data and **Average standard Luminance required(LUX**) for different type of room, luminous intensity of lamps and the standard illumination required in various working stations has been calculated in order to evaluate the current lighting installation system of the factory as shown on Table 12.

The total power rating of the lamps installed in each department has been calculated as follow

TP = LR×NL

Where LR- lamp rating

NL- number of lamps installed in each department

TL-total Total lumens output of lamps installed in the department

TL = TP× Lo

Lo – is the luminous output of each fluorescent lamp, which is 70lumens/watt[23]

IL – The illumination produced by the installed lamps expressed in lux is calculated as follow

IL = TL/RA

RA – Room area of each department in square meter

ALR – The actual lamps required for proper illumination

ALR = (illumination required in each room,/Lumen per Fixture)*Room Area

Energy utilization (EU) for the lighting systems can be calculated using equation **TP*OH**, and compared with the energy required (ER) after a proper illumination. Energy difference(ED) is the energy difference between the currently utilized with the installed lamps and the actual required lamp, ED is the energy which can be saved by using lighting system efficiency improvement method.

EU = NL×LR

ER = ALR×LR

ED = EU-ER

Table 13 Lighting Data Summary

Department	NL	TP(w)	TL (lux)	RA (m2)	IL (lux/m2)	ALR	OH (hr)	EU (wh)	ER (wh)	ED
Store	163	6520	521600	660	790.3	118	24	78240	50914.3	27325.7
Spinning	300	12000	960000	1320	727.27	236	12	144000	101828.6	42171.4
weaving	200	8000	640000	870	735.6	155	12	96000	74571.4	21428.6
Air compressor	16	1280	102400	123	832.52	10	12	15360	4612.5	10747.5
Administration	56	2240	179200	234	765.8	37	8	17920	11700	6220
Garment	420	16800	1344000	3500	384	547	12	201600	262500	-60900
Dyeing	130	5200	416000	590	705.1	105	12	62400	50571.4	11828.6
Blanket	350	28000	2240000	3036	737.8	257	16	448000	164600	283400
Guard	7	280	22400	25	896	4	24	6720	3750	2970
Workshop	18	720	57600	67	859.7	10	8	5760	3350	2410
Time keeper	4	160	12800	16	800	3	12	1920	1200	720
Show room	8	320	25600	30	853	5	8	2560	1500	1060
Total	**1,672**	**81,520**				**1,406**		**1,080,480**	**731,098.21**	**349,381.79**

Lighting data for each department of the factory has collected and analyzed as shown in the table 12.

Currently there are around **1,672** florescent lamps installed in the factory with power rating of 40W. The total installed capacity of the lighting system is about **81.5kW** with daily energy consumption of the factory **1,080.5kWh**. As per the lighting data analysis the actual florescent lamps required in the factory should be around **1,406** lamps with difference of **266** lamps. However **8o** lamps in the garment and factory compound were not considered in the deduction considering illumination requirement of the garment area and security of the compound. This shows that there are around **186** unnecessary lamps installed in the factory. And there is significant energy differences between the energy utilization (EU) due to currently install florescent lamps and the actual energy required (ER). This shows that there is energy loss due to current lighting systems in the factory.

4.2.1.2. Energy efficient improvement for lighting

Identifying energy savings opportunities in lighting systems involves critically assessing the existing energy use and reducing energy in the lighting systems is not prohibitively expensive. Due to its nature of operations, the share of lighting in textile industry electricity use is relatively high when compared to other industries. And it is important to re-examine whether the light source is utilized in the most efficient way and take electricity saving measures without affecting Lighting quality and visual comfort levels for all departments.

As shown in the analysis result above there is opportunity for energy conservation with the lighting system. Based on the result of lighting data analysis and the survey done at the factory, some of the energy saving opportunities of the lighting system of the factory that should be implemented will be discussed in the next sub-sections.

❖ **Improving Installation System**

Taking into account the number of luminaires, the power of each lighting bulb, and the normal working behavior of the illumination systems, it is calculated that the installation of this system would allow a reduction of **186** lamps and in the consumption of electricity of around **11.22kw,** this results in energy saving of **44,161.92kWh/yr**, and a saving of **1063.2 $/yr** with very small investment for implementation.

- **Replacing existing lamps with energy efficient lamps**

The types of florescent lamps available in YATF are T-12 tube lamps. T-8 florescent lamps are more efficient than T-12 lamps which is smaller diameter and do not reduce in lighting levels after prolonged use, which leads in saving of around 30% as mentioned in different researches.

T-12 lamps have poor efficiency, less lamp life, lumen depreciation, and color rendering index, high maintenance and energy costs.

Retrofit in lighting systems by upgrading of the conventional T12 fluorescent lamps to more energy efficient T8 lamps would be applicable for the selected factory.

In addition to energy savings and better lighting qualities, high-intensity fluorescents can help improve productivity and have reduced maintenance costs.

As per the lighting data analysis the required numbers of lamps are **1,406,** the saving that can be abstained by replacing of these **1406 T-12** lamps with **T-8** tube lamps considering the 30% saving can be calculated as follow**:**

Power demand saving (PDS) = (**0.3×ALR×LR)/1000)**

= 16.87kW

Energy saving= (0.3*ER*working days/yr)/1000

= 63,166.9kwh

Birr saving= ES*R= 1520.8 $/yr

- **Lighting controls**

In addition to saving energy by using more energy-efficient lamps, energy can also be saved by leaving the lights on for a shorter period of time using available lighting controls to shut off during non-working hours, to ensure lighting is only used when needed.

Lights can be shut off during non-working hours by automatic controls, such as occupancy sensors which turn off lights when a space becomes unoccupied. It is important to properly specify and install the occupancy sensors to provide reliable lighting during periods of occupancy. Manual controls can also be used in addition to automatic controls to save additional energy in smaller areas.

Lighting controls can contribute significantly to saving energy in new and installed lighting systems. The payback period for lighting control systems is generally less than 2 years, as shown by many studies.

4.2.2. Assessments of Electric Motors

According to the analysis by the International Energy Agency (IEA), Electric motors are the biggest consumer of electricity. The analysis describes that electric motors account for about two thirds of industrial power consumption and, about 45% of global power consumption. Hence, addressing the efficiency of electric motors is an important topic that needs to be tackled.

4.2.2.1. Motor efficiency

Obviously, the shaft power output is always less than the electric power input, and that is due to power losses during the operation of the motor. 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. These losses, which lead to worse efficiency, are mostly due to:

Cooper losses: power is lost as heat in the conductors. The cooper losses vary with the squared current and with the electrical resistance of the conductors.

Iron losses: power is lost as a result of the dissipated magnetic energy that occurs when the motors magnetic field is applied to the induced core (either the stator or rotor).

Mechanical losses: losses mostly due to friction in the motor bearings and moving parts. These losses increase due to rewinding of motors. Hence such losses can be reduced by replacing rewound motors with energy efficient ones**.**

Determining motor system operating conditions is a good place to start in order to identify opportunities that reduce motor related costs, improve performance, and increase reliability.

Although motor systems account for a large portion of the energy used at many industrial facilities, motor system management is often reactive, meaning that improvements are made only in response to obvious problems or motor failures. Adopting proactive, systems based approach is a good first step toward realizing the many benefits of an effective motor management program [28].

Loading of motor can affect its efficiency. Mostly motors that are significantly oversized (under loaded) and properly sized and with standard efficiency are recommended for replacement.

Motor is considered under loaded when it is in the range where efficiency drops significantly with decreasing load. Overloaded motors can overheat and lose efficiency. Many motors are designed with a **service factor** that allows occasional overloading. Service factor is a multiplier that indicates how much a motor can be overloaded under ideal ambient conditions.

To determine the loading of the motors available in YATF measurement has been taken, as shown in Table-10 and it is noted that most of the motors are mismatched (oversized) for the load they are intended to serve.

Also it is known that rewound motor efficiency is less than that of the original motor. More than 50% of the motors in the factory are very old and rewound.

Inadequate maintenance of motors can significantly increase losses and lead to unreliable operation. 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. Providing adequate ventilation and keeping motor cooling ducts clean can help dissipate heat to reduce excessive losses.

In YATF it has been observed that maintenance is done when motor failed to work or burn, there is luck of adequate or regular maintenance schedule and this contributes to decrease in motor efficiency.

4.2.2.2. Motor data analysis

The most significant electric energy consumers are the motor driven systems; it accounts for a large part of the electrical consumption of the whole factory, and presents a continuous operating behavior.

There are around 315 motors installed in the factory in different department with rated power starting 0.2kW to 57 kW. As mentioned in the previous chapter more than 90% of the electrical energy of the factory is consumed by electric motors.

In order to evaluate the performance of these motors different motor data have been collected by taking measurements using proper measuring instruments and nameplate data.

Motor loading has been calculated using Amperage ratio technique, in which load can be estimated by comparing a motor's true root-mean-square (rms) amperage draw against its full-load or nameplate value.

$$\textit{Motor load} = \text{Pele/Prated}$$
$$= (\text{Amps}_{\text{measured}}/\text{Amps}_{\text{nameplate}})*(\textit{volts}_{\textit{measured}}/\textit{volts}_{\textit{nameplate}}$$

Efficiency of all the motors in the factory have been calculated using line Current Methods it use minimum measurements of current and voltage and manufacturer's data to estimate the efficiency. In this current Method the motor efficiency is approximated assuming that the percentage of load is closely proportional to the ratio of the measured current to full-load current.

In this thesis motor master+ international software is used to evaluate the performance of the existing motor and to decide the most energy saving technique which can be applicable for the factory.

Motor Master + international Software

MotorMaster+ Version 4.0 supports motor management functions at medium-sized and large industrial facilities. Designed for utility auditors, industrial energy coordinators, and plant or consulting engineers, *MotorMaster+* supports motor and motor systems improvement planning through identifying the most efficient action for a given repair or motor purchase decision. *MotorMaster+* can be used to identify inefficient or oversized inventory motors and compute the energy and demand savings associated with selection of a replacement energy-efficient model. *MotorMaster+* operates under Microsoft Windows and includes an online help system.

The program is menu-driven, with ample help on-screen. Even if you have never used a computer, you will find using *MotorMaster+* easy. Nothing you do at the keyboard can damage the program. The best way to learn how to install and operate *MotorMaster+* is to follow the instructions on the following pages.[29]

MotorMaster+ software is easy to use and contains a database of new motor price and performance, and features many motor energy management capabilities including replacement analysis, maintenance logging, energy and dollar savings tracking, simple payback period and life cycle cost analysis.

It also incorporates Purchase information, including list price, warranty period, catalog number, motor weight, and manufacturer's address.

The input parameters to this software are company information and motor name plate and measured data (from Table-10); like Power in kilowatts, speed in revolutions per minute, percentage loading, efficiency, annual operating hours, and energy purchase price in $/kWh.

And the output parameters of the software are Energy and demand savings, simple back period, purchase price of the energy efficient motor in dollars, Greenhouse Gas Emissions Reduction report.

Each motor in the factory has been evaluated using the software and the motor purchase price data and motor saving analysis is displayed as shown below in Fig. 13 & 14, which is sample output of the software. Similar simulation has been done for all motors in the factory and the motor saving analysis is summarized in Appendix B.

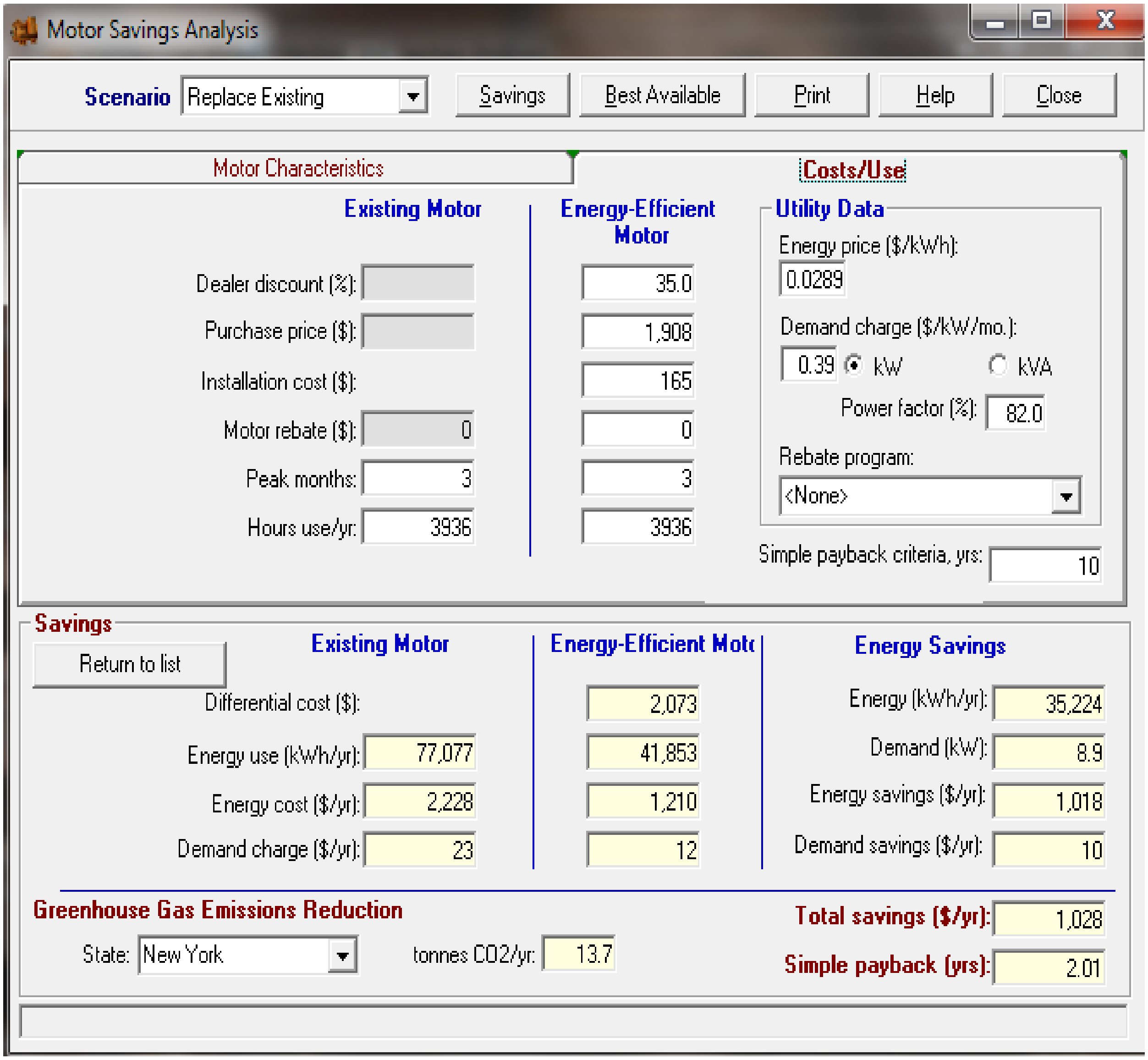


Figure 13 Cost comparison of the energy efficient and the standard motor

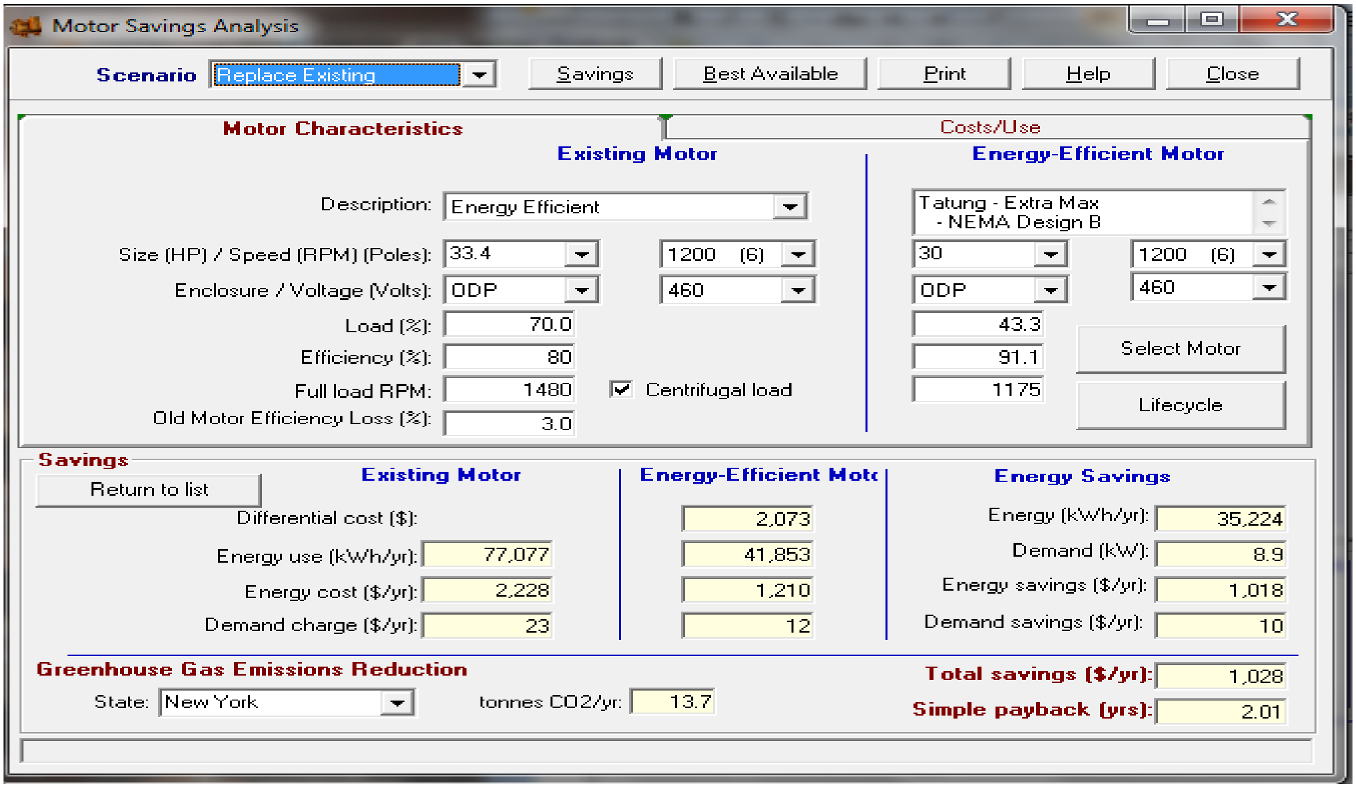


Figure 14 Motor saving analysis

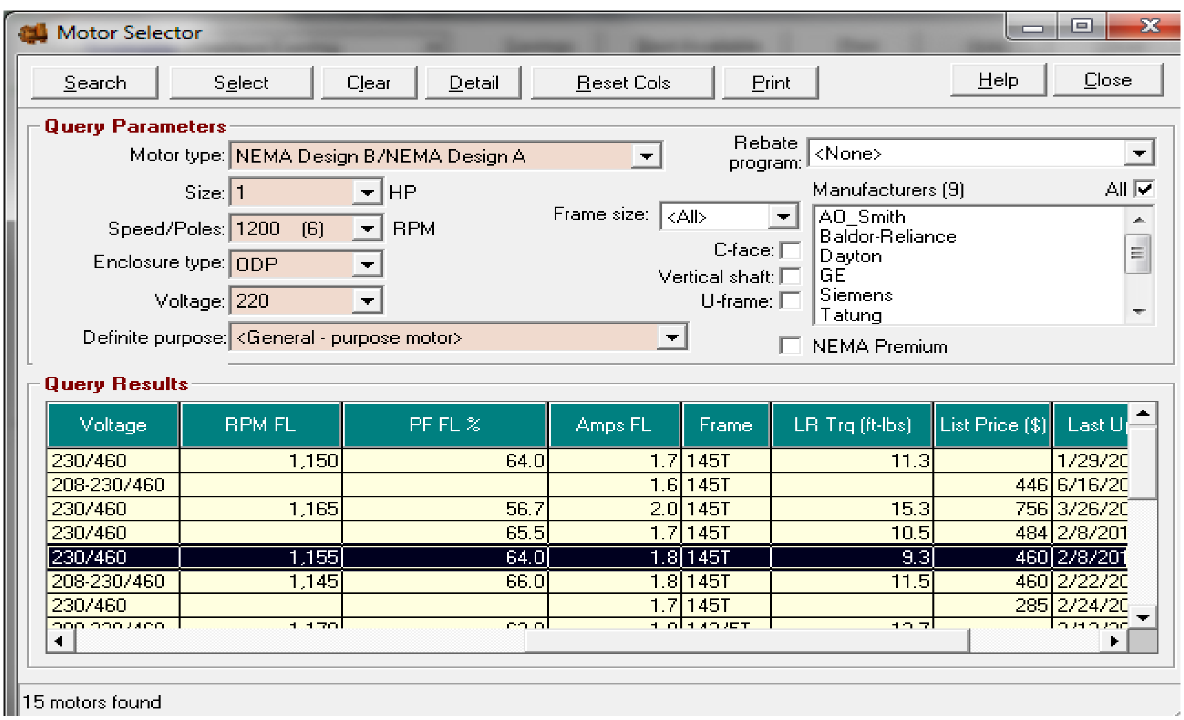


Figure 15 Motor selection

Based on the output of the software it can be decided for replacement or maintenance to improve the efficiency.

For example the output of the selected motor (motor for carding machine), Fig.13 shows the purchase cost saving of proper sized and energy efficient motor the total price is 2073 dollar (1,908 motor purchase cost and 165 dollar installation cost). This cost will be back after two years with energy saving of 35,224kwh/yr and cost saving of $ 1,028 per yr with reduction of co_2 emission by 13.7ton/yr. Since the motor price of the software database was updated in 2010, fifteen percent additional cost is added to the price of the motor given by the manufacturer which is shown on the motor saving analysis in Appendix–B in order to accommodate possible price increments since 2010. The output of the software clearly shows the kilowatt hour energy savings per year and the number of years required to recover the investment in energy efficient motors.

For the selected motor (motor for carding machine), the payback period is reasonable, hence recommended to replace.

4.2.2.3. Efficiency Improvement Opportunities of Motors in YATF

When working energy-efficiency improvements to a facility motor systems must be considered in order to attain optimal savings and performance.

There was vibration and noise heard during operation of the different motors in the factory indicating that the motor was not smoothly operating and there is a room for improving the efficiency of the motors. There is opportunity to save energy in motors of the factory as most of them are very old and with standard efficiency. More than 50% of the motors have been rewound; Rewinding of motor decreases its efficiency.

The energy efficiency can be improved by taking different measures on the motor system. Some of the measures which can be applicable in YATF are discussed below.

- **Replacement of existing inefficient motors with efficient motors**

Energy-efficient motors (EEM) 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. 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.

Most of the motors in the factory are very old and rewound more than two times, hence the best way to improve efficiency such motors is to replace the existing inefficient once with high efficiency motors. There is definitely a cost in replacing motors. However, the cost incurred can be recovered through energy saving with a small and reasonable payback period. As per the analysis of the software (Motor Master+) 38 inefficient and more than two times rewound motors with less payback period are recommended to replace. This will help the factory to use electric energy more efficiently.

❖ **Improving maintenance schedule**

Inadequate maintenance of motors can significantly increase losses and lead to unreliable operation. 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. Providing adequate ventilation and keeping motor cooling ducts clean can help dissipate heat to reduce excessive losses. The life of the insulation in the motor would also be longer: for every 10^{0}C increase in motor operating temperature over the recommended peak, the time before rewinding would be needed is estimated to be halved [26].

In YATF there is no regular motor maintenance schedule; it has been observed that Most of the electric motors are exposed to dirt, Lubrication is not done often enough and maintenance is done when motors fail to work. Proper motor maintenance schedule is required in the factory to minimize energy losses.

In the manual prepared by U.S. development of energy it is declared that the savings associated with an ongoing motor maintenance program are significant, and could range from 2% to 30% of total motor system energy use.

It is important to have a good maintenance program which should include periodic checking with proper checklist including:-

- Inspecting 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).

- Checking 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.
- Lubricating 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
- Checking 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.
- Ensuring 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.

Sample checklist has been prepared as shown in Appendix-D

❖ **power factor correction**

Motors and other inductive equipment in a plant require two kinds of electric power. One type is working power, measured by the kilowatt (kW), which is the actually powers of the equipment that performs useful work.

Secondly, reactive power, inductive equipment needs magnetizing power to produce the flux necessary for the operation of inductive devices. The working power (kW) and reactive power (kVAR) together make up apparent power which is measured in kilovoltamperes(kVA).

Induction motors are characterized by power factors less than unity, leading to lower overall efficiency (and higher overall operating cost) associated with a plant's electrical system. Capacitor Banks connected in parallel (shunted) with the motor are typically used at individual motor location or for groups of motors near distribution board to improve the power factor. The impacts of PF correction include reduced kVA demand (and hence reduced utility demand charges), reduced I2R losses in cables upstream of the capacitor (and hence reduced energy charges), reduced voltage drop in the cables (leading to improved voltage regulation), and an increase in the overall efficiency of the plant electrical system. It should be noted that PF capacitor improves power factor from the point of installation back to the generating side. It means that, if a PF capacitor is installed at the starter terminals of the motor, it won't improve the operating PF of the motor, but the PF from starter terminals to the power generating side will improve, i.e., the benefits of PF would be only on upstream side[30].

Low power factor does not imply lost or wasted power, just excess current; it is signals inefficient utilization of electrical power. The energy associated with the excess current is alternately stored in the windings' magnetic field and regenerated back to the line with each AC cycle. This exchange is called reactive power. Though reactive power is theoretically not lost, the distribution system must be sized to accommodate it, which is a cost factor [32].

AC voltage causes the current to flow in a sine wave replicating the voltage wave. However, inductance in the motor windings somewhat delays current flow, resulting in a phase shift. This transmits less net power than perfectly time matched voltage and current of the same RMS values. Power factor is the fraction of power actually delivered in relation to the power that would be delivered by the same voltage and current without the phase shift; it measures how effectively electrical power is being use.

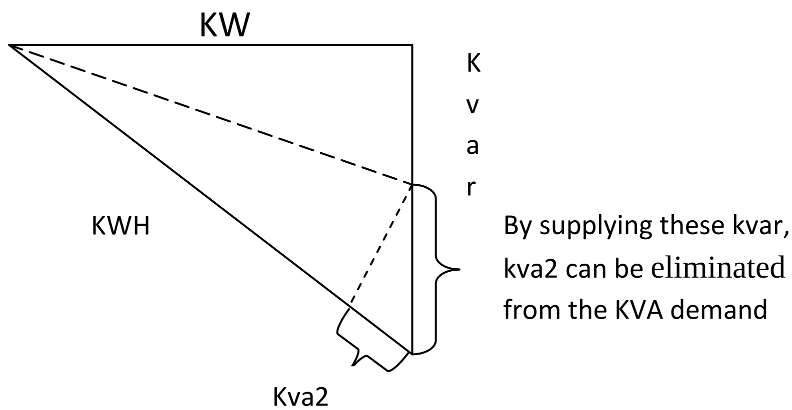
Induction motors, especially those operating below their rated capacity, are the main reason for low power factor in electric systems. Low power factor means the industries are not fully utilizing the electrical power they are paying for. Electrical utilities usually charge a high cost to industries or commercial customers where there is a low power factor.

By connecting a capacitor bank the power factor of equipment can be improved thus reducing the losses, resulting in increasing energy saving.

When apparent power (kVA) is greater than working power (kW), the utility must supply the excess reactive current plus the working current. Power capacitors act as reactive current generators. By providing the reactive current, it reduces the total amount of current the system must draw from the utility.

The size of capacitor required for a particular motor depends upon the no-load reactive kVA (kVAR) drawn by the motor. Proper size of capacitor has to be selected as higher capacitors could result in over-voltages and motor burn-outs.

$$PF = \frac{kW}{kVA}$$



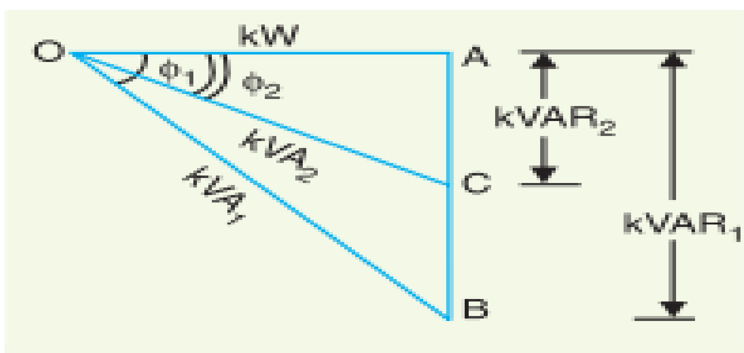


Figure 16 Power Triangle for PF correction [30]

As indicated in the above Fig, Capacitors help to reduce the kVA required for any given load, by shorten the line that represents the kVAR.

During the energy audit study of the factory, it was noticed that the factory is paying for lower power factor penalty around 11% of the total electric cost as shown in table 13 below. Hence power correction is necessary for the factory.

- **Power Factor Assessment of YATF**

During the energy audit study of the plant, it was found out that the factory is considerably paying for lower power factor. Table 13 shows the average annual power factor penalty of YATF. This shows that the factory is paying over 11 percent of the total cost of electricity for power factor penalty. And hence, it is evident that power factor correction is a necessity for the factory.

Table 14 Average PF penalty of YATF

KWh/year (average)	KVARH/year (average)	Total electricity cost/year (Birr)	PF penalty/year	Percentage of PF Penalty against Total Cost (%)
146,538	116,910	1,140,000	11,200	11.7%

- **Design of Power factor correction for YATF**

Design of PF correction involves selection of capacitor capacity, Cable size, Fuse capacity, Breaker capacity, panel type etc.

Designing of capacitor bank is to calculate the requirement of reactive power in the power system to maintain the unity power factor.

Care must be taken in sizing and placing power factor correction capacitors. Leading power factor, greater than 100%, must be avoided. The capacitors should only be on line when the load requires kVAR and disconnected when the load is reduced.

The objective is to determine the required reactive power QC (kvar) to be installed, in order to improve the power factor cosΦ and reduce the apparent power . For $\Phi_2 < \Phi_1$, we will get: cosΦ' > cosΦ and $\tan\Phi_2 < \tan\Phi_1$.

QC can be determined from the formula: QC = P. (tanΦ1 – tanΦ2), which is deduced from the diagram.

QC : power of the capacitor bank, in kvar

P : active power, in kW

tanΦ1: tangent of the phase angle - before compensation,

$\tan\Phi2$ ‘: tangent of the phase angle - after compensation

The parameters Φ and tanΦ can be obtained from the billing data, or from direct measurement in the installation.

In this thesis the data for estimating the required kvar has been taken for the billing data and total electric power consumption of the factory. Based on the Kwh and Kva reading of the meter of the factory the average PF of the plant has been calculated as follow:-

$$\text{Tan}\Phi1 = \text{Kvar1/Kw}$$

$$\Phi = 39^0$$

$$\text{PF} = \cos\Phi = 0.78 \text{ Or}$$

$$\text{PF} = 146{,}538/\sqrt{[146538)^2 + (116{,}910)^2]}$$

$$\text{PF}=0.78$$

Acceptable PF= 0.90

KWh= **1,356,187.36**

P= 1925kW

Required reactive power kvar2= P. $(\tan\Phi_1 - \tan\Phi_2)$

Kvar2 = 1,347

At YATF the power factor of the plant is 0.78 which is out of the acceptable range of Ethiopian Electric Utility (EEU) and power factor correction is required to bring the PF to the acceptable range.

The addition of the capacitor will improve line power factor and subtract the non-working current from the lines. This reactive current will now supplied by the capacitor rather than the utility.

To design the Protection of Capacitor Bank, the Capacitor Charging Current (Ic) should be calculated as follow

Leading KVAR supplied by each Phase =1,347/3=449Kvar/Phase

Capacitor Charging Current (Ic)= (Kvar/Phase x1000)/Volt, (volt=line voltage)

$$Ic = (449/\ 380/\sqrt{3})*1000$$

Ic= 682A

Capacitance of Capacitor= (Ic)/ Xc

$C = kVAR / (2 \pi f V^2)$ in microfarad

$= 1,347/(2x\ 3.14\ x\ f\ x\ v^{2)}$

C=2970.78μF

Protection of Capacitor Bank

Size of HRC Fuse for Capacitor Bank Protection:

- **Size of the fuse =165% to 200% of Capacitor Charging current [34].**
- Size of the fuse=2×682Amp
- Size of the fuse=1364Amp

Size of Circuit Breaker for Capacitor Protection:

- **Size of the Circuit Breaker =135% to 150% of Capacitor Charging current [34].**
- Size of the Circuit Breaker=1.5×682Amp
- Size of the Circuit Breaker=1023Amp

Sizing of cables for capacitor Connection:

Capacitors can withstand a permanent over current of 30% +tolerance of 10% on capacitor Current, hence Cables size for Capacitor Connection=1.3 x1.1 x nominal capacitor Current [34].

Inadequate rating of cable may cause Capacitor terminal over heating. Hence proper cable sizing has to be considered for a particular step depending on the rated current and the operating temperature.

- **Reducing system losses:-**

Low voltage, resulting from excessive current draw, causes motors to be sluggish and overheated. As power factor decreases, total line current increases, causing further voltage drop. By adding capacitors to the system and improving voltage, you get more efficient motor performance and longer motor life. Losses caused by poor power factor are due to reactive current flowing in the system. These are watt-related charges and can be eliminated through power factor correction. Power loss (watts) in a distribution system is calculated by squaring the current and multiplying it by the circuit resistance (I^2R) [32] By improving power factor of an industry, power system losses in the distribution system can be reduced.

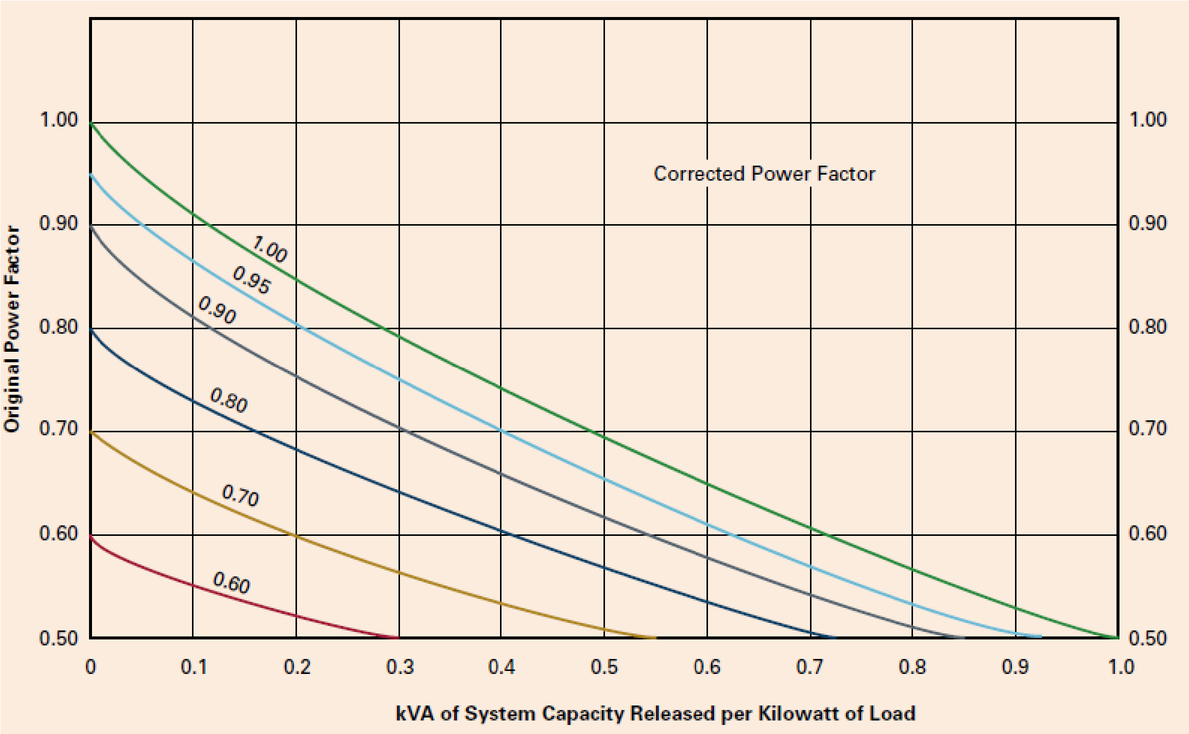


Figure 17 system kVA released by improving power factor [33]

The percentage of line current reduction and loss reduction which can be achieved by improving PF at least to the acceptable range of Ethiopian Electric Utility can be calculated as follow:-

% line current reduction = 100*(1-present PF/improved PF)

= 100*(1-0.78/0.9)

= 13.3%

% loss reduction = 100[1- (present PF/improved PF)^2]

=100*[(1-(0.78/0.9)^2]

= 24.8%

Where 0.78 is the existing PF of the factory and 0.9 PF which is acceptable by EEU.

4.2.3. Boiler and steam pipe assessment and efficiency improvement of fuel consumption at YATF

4.2.3.1. Boiler and Steam pipe Assessment

The type of boiler used by the factory is fire tube steam-generator with capacity of steam production of 5 Ton/hr at temperature of 150^{o}c and 5bar pressure and it uses furnace oil to generate the required steam. Steam pressure is regulated manually based on the steam demand of the end use system

The data related to steam generation and utilization of the boiler were collected by taking some measurements, interview and visual inspection.

- **Boiler Efficiency**

Efficiency of boiler reduces with time, due to poor combustion, heat transfer fouling and poor operation and maintenance. ON-OFF losses, radiation losses

The overall boiler efficiency depends on many more parameters apart from combustion and thermal efficiencies. These other parameters include ON-OFF losses, radiation losses, and convection losses, blow down losses etc.

The first step to running a more energy-efficient boiler is to measure its current efficiency as a baseline and determine if its efficiency is within a good operating range as compared to the boiler specifications [24].

Two methods are used to find out boiler efficiency, namely direct method and indirect method of efficiency calculation. The direct efficiency calculation method is closer to reality as compared to indirect efficiency on account of uncovered losses such as radiation losses. This method is important for quickly evaluation of boiler efficiency and it needs few parameters for computation and it doesn't require more instruments for monitoring and measurement.

On this thesis work direct efficiency calculation **(**input/output) method has been used to calculate the efficiency of the boiler.

This method calculates boiler efficiency by using the basic efficiency formula,

η= (Energy output)/(Energy input) X 100.

In order to calculate boiler efficiency by this method, the total energy output of a boiler will be divided by total energy input given to the boiler, multiplied by hundred.

Calculation of boiler efficiency using the direct method is,

$\mu = [m_s(h_{gs}-h_{fs})/m_f*GCV] *100$ [24]

where

m_s = quantity of steam generated (kg/hr)

m_f = quantity of fuel used per hour(kg/hr)

GCV= Gross calorific value of furnace oil

h_{fs} = Enthalpy of feed water

h_{gs}= Enthalpy of super heated steam

The data related to steam generation and utilization of the boiler was collected by taking some measurements and from other references.

m_s- Is quantity of steam generated (kg/hr) = 3,193kg/hr

m_f - Is quantity of fuel used per hour(kg/hr) = 309 Kg/hr

GCV- Gross calorific value of furnace oil is, 41,420 KJ/kg

h_{fs} - Enthalpy of feed water is = 384.96 kJ/kg (at 80 ^oC)

h_{gs}-Enthalpy of super heated steam is = 2762.83kJ/kg (at 5bar)

Substituting the above data in the given Equation, the efficiency of the boiler is [3193Kg/hr(2762.83kJ/Kg-384.96KJ/Kg)/309Kg/hr*41420]X100

$\mu = 59.3\%$

- **Steam pipe**

Uninsulated steam distribution and condensate return lines are a constant source of wasted energy. Lines insulation can typically reduce energy losses by 80% up to 90% and help ensure proper steam pressure at plant equipment. Any surface over 120°F should be insulated, including boiler surfaces, steam and condensate return piping, and fittings.

Insulation frequently becomes damaged or is removed and never replaced during steam system repair. Damaged or wet insulation should be repaired or immediately replaced to avoid compromising the insulating value. Eliminate sources of moisture prior to insulation replacement. Causes of wet insulation include leaking valves, external pipe leaks, tube leaks, or leaks from adjacent equipment. After steam lines are insulated, changes in heat flows can influence other parts of the steam system [30].

Steam is produced by boilers and distributed to the steam using equipments by piping arrangements and valves. Steam leaks most frequently occur at faulty valves or traps, pipework flanges and joints. In YATF it has been observed that some of the steam pipes are not insulated and some are poorly insulated which results in energy loss especially at the flange and valve points with visible steam leakage. The steam leakage identified during the factory visit in some uninsulated pipe parts is shown in Fig below.

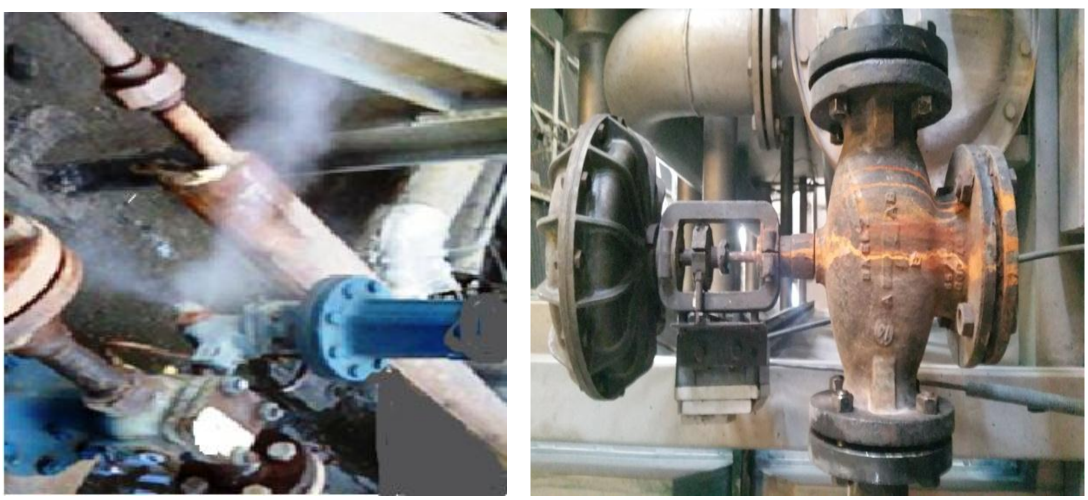


Figure 18 Steam leaks

Figure 19 properly insulated pipe

Figure 20 poorly insulated pipe

4.2.3.2. Energy Saving Opportunities in Fuel consumption at YATF

As discussed in the previous chapters, around 75% of the energy cost of the factory is fuel energy cost. Hence improving fuel energy-efficiency should be prime concern of the plant. The recorded history in YATF shows that energy management was poor and energy efficiency improvement activities were not applied in the factory. However, currently the factory utility department starts implementation of some measures to improve the fuel consumption of the factory. There are various cost-effective energy-efficiency improvement opportunities applicable for textile industries. Some of the measures which can be applicable in YATF to improve the fuel consumption of the factory with minimum cost are discussed below.

1. Maintenance of Boiler and steam pipe

Inadequate maintenance can lower compression efficiency, increase air leakage or pressure variability and lead to increased operating temperatures, poor moisture control and excessive contamination. Regular maintenance will reduce these problems and save energy. Regular and adequate maintenance is ECO with low cost or no cost. Appling regular maintenance schedule involve a small investment, but can provide significant savings of energy and costs.

Currently in YATF is some measures are undertaken by the factory utility department to improve the fuel consumption and management support is required to get required achievement.

- **Boiler**

Fuels may leave a certain amount of deposit on the **fireside of the tubes.** This reduces heat transfer dramatically. Tests show that a soot layer just 0.8 mm (0.03 in.) thick reduces heat transfer by 9.5 percent and a 4.5 mm (0.18 in.) layer by 6.9 percent! As a result, the flue gas temperature rises – as does the energy cost [30].

A good maintenance program consisting of routine inspection and cleaning is essential to maintaining the efficiency of a boiler, and can go a long way towards keeping fuel costs low. Maintaining the boiler at peak efficiency requires keeping the boiler surfaces as clean as possible. Boilers should be opened regularly for checking and cleaning to remove scale from boiler.

Boiler surface temperature is high relative to the ambient temperature. As a result, boiler lost heat energy to the environment.

To minimize heat loss through radiant heat loss from the boiler casing, proper insulation techniques and the maintenance of insulation layers are required. Insulation must be ensured, through regular maintenance, to be free from contamination by water or other liquids which can affect its ability to retain heat. Cleaning and insulating boiler surface is taken as ECO. Establishing regular maintenance may only involve a small investment, but can provide significant savings and costs.

In the boiler efficiency guide prepared by Japan energy center it is mentioned that 0.03 inch thick dust can reduce the efficiency of boiler by 12% & this can lead to increase cost of fuel by 15% and 3% drop in efficiency increases fuel costs 3.8%. This shows that by improving the existing boiler efficiency of the factory to the standard boiler efficiency range by establishing a regular maintenance schedule the fuel cost can be reduced by around 20% and this can prove result obtained by comparing the factory with the benchmark plants.

- **Steam Pipe**

Opportunities for energy saving in steam distribution include checking for and repairing leaks, identifying redundant pipework and ensuring that the system is adequately insulated

Steam and condensate pipe work in the plant is poorly insulated, with large runs of uninsulated pipe work observed. The area around the uninsulated steam pipe externally hot and is difficult to walk around, this shows heat loss through the uninsulated pipes. Insulation of the pipework will reduce excessive heat losses and further reduce boiler load. Steam leaks were identified during the site visit as result energy is being wasted with the steam leakage in the factory and this should be minimized so that the energy consumption of the factory can be minimized.

Steam Leaks are one of the most visible forms of energy waste in the factory. These pipes with visible leaks should be repaired to reduce the energy lost and this can be done with minimum cost.

In the textile factory, appreciable amounts of energy could be saved or conserved by regularly cleaning the boiler surface, insulation of steam pipes, using properly treated water, regular checking of the seam traps.

2. Feed water quality improvement

Water is an excellent solvent in which many compounds readily dissolve. It is also an excellent medium for transporting suspended and colloidal material. However, the presence of these impurities and contaminants makes appropriate water treatment and conditioning regimes essential to provide water of a suitable quality for the effective operation of steam boiler plant and systems [35].

The quality of boiler feed water affects the overall boiler performance. Deposits (called scale) on the waterside of the boiler tubes can damage heat transfer. Also it reduces boiler efficiency, restrict water circulation and lead to serious mechanical and operating problems. Scale causes the tubes metal temperature to rise, which increases the flue gas temperature. In extreme cases, the tubes fail from overheating.

The boiler in YATF was burnt due to malfunctioning of the water treatment plant, water was not properly entered to the boiler as the water pipes and water filters were blocked with scale accumulation due to use of untreated water. Scale deposit in the water side of the boiler due to use of untreated water has significant effect on energy loss and reduce boiler efficiency. This energy loss can be minimized through repairing of water treatment plant, establishing of regular checking program and controlling level of feed water.

Figure 21Burnet boiler due to use of untreated water

Figure 22 blocked water pipe and filter due to use of untreated water

3. Regular inspection and maintenance of steam traps

Steam traps play an important role in maintaining efficient transportation of steam. Steam traps prevent steam from passing through but allow condensate to pass through. It limits the free flow of unused steam. Malfunctioning of steam trap can allow steam to escape into the condensate return system.

The value of temperature measurements taken from the steam pipe and the return condensate pipe is almost similar which shows that the steam traps are not working properly.

In the factory proper functioning of steam traps are not checked periodically. Checking proper functioning of steam traps and replace the defective parts will be ECO with small or no cost.

Many researches declared the repairing and replacement of steam traps has an average payback time of 0.4 years

Steam loss through faulty steam trap can be estimated using the Napier formula:

Steam loss (lb/hr) = 24.24 x Pa x D^2 [31]

Where:

Pa= Absolute steam pressure in Pa

24.24 = constant

D = Diameter of opening, in.

As per the data gathered from the factory utility department there are around 43 leakage spots with 2.5mm diameter (0.09825 in).

Using Napier formula the steam loss of the factory has been calculated

W = (24.24*72.52*0.09825$^{2)}$ = 16.97lb/hr

= 7.69kg/hr per one trap

Energy required to produce one kg of steam is 540kcal, which is 2259.36 KJ/kg.

This shown the factory is losing energy of 17.37MJ/hr due to steam leakage through one failed trap.

For a trap that is leaking continuously throughout the entire heating season, the cost for the loss of steam in the trap can be determined using the following formulas:

Q = (L x H x E x 10-6 x C)/BE [31]

Where: Q = Energy Lost ($)

L = Lb/Hr of steam lost = 16.97 lbs/hr (for 2.5mm dia spot, 72.52pa)

H = Hours in heating season = 3,744

E = Latent heat of steam at 5bar = 1,256 Btu/lb

10-6 = MMBtu/Btu

C = Cost of gas per million Btu = $10.23 (using online calculation as per the current fuel cost)

BE = Boiler Efficiency = 59.3%

Q = (16.97 x 3744 x 1,256 x 10-6 x 8.23)/0.59.3

Q = 1,107$

Cost for the loss of steam in one traps/yr = 1,107$

If a steam trap maintenance program were to be implemented and the cost to repair or replace of each defective trap and total Cost for the project can be determined as follows:

=(Cost per Trap x Number of Traps)

Cost of 1 trap= (TRAP COST + labor cost) **= 96.25$ average estimated**

Labor cost can be ignored as the factory technicians can do the replacement.

Project cost= 96.25$

The Simple Payback period of the proposed trap maintenance program is:

Simple Payback = Equipment cost/Savings = 96.25/1107= 0.09.

CHAPTER FIVE

5. CONCLUSSION AND RECOMMENDATION

5.1. Conclusion

Based on the findings of the study, the following conclusions were drawn. The introduction and literature review parts of the study clearly mention that how to implement efficient energy management and competence in all types and levels of machinery determine its success or failure in such dynamic environment.

Due to aging and a number of other reasons YATF is consuming more energy than it is supposed to use. In this thesis work the overall energy consumption and efficiency of the main parts of the factory are evaluated. Based on analysis done on the collected data from the factory, areas with energy efficiency problems are identified and opportunities with low or no cost for improving energy utilization which can be applicable for all similar industries have been studied.

Based on the energy evaluation done on the lighting system of the factory results of energy saving opportunities were mainly obtained through improving the installation of the existing lighting systems, use of energy efficient lamps, and lighting control. By improving the installation system reduction of 186 lamps and in the consumption of electricity of around **11.22kW, t**his results in energy saving of **44,161.92kWh/yr**, and a saving of **1,020.7 $/yr** with very small investment for implementation can be achieved. Similarly by replacing the existing lamps by energy efficient lamps saving of **63,166.9kWh**, and USD saving of **36,497.83 $/yr** can be achieved. **8o** lamps in the garment and factory compound were not considered in the deduction considering illumination requirement of the garment area and security of the compound

In the factory electric motors account for **83%** of electrical energy consumption. The major factors affecting the efficiency of the motors in the factory are ageing of motors and inadequate maintenance. By replacing the very old and repeatedly rewound motors with efficient motor the factor can save considerable energy with small payback period without affecting its production. It was found that 11.7% of the electric cost of the factory is penalty for low power factor. Hence by improving the PF of the factory at least to the acceptable PF range 11.7% of the bill payment and demand cost can be reduced.

Fuel energy cost accounts 75% of the energy cost of the factory. Hence improving fuel energy-efficiency reduces the overall energy consumption of the factory. This study suggests energy efficiency improvement opportunities to reduce the fuel consumption of the factory such as regular maintenance of boiler, insulation of steam pipes, using treated water, maintenance or replacement of failed steam traps. As calculated above in Chpter-4, the factory boiler efficiency is found to be 59.3% and by establishing regular maintenance of boiler the factory can improve the boiler efficiency to the standard efficiency 80-85%, which can result in reduction of fuel consumption from 309lt/hr to 230lt/hr and saving of 21% of the fuel cost. Similarly it was found that by replacing one failed steam traps around 17.37MJ/hr energy can be saved with a payback period of around one month.

5.2. Recommendation

Based on the study that has been conducted, the following points are recommended to implement in order to improve the energy utilization in the factory so as to reduce its energy cost.

a. Energy management program with a strong organizational commitment is required to improve the energy-efficiency of the factory through creating awareness on efficient energy use, identify efficiency improvement opportunities, Create an action plan and, coordinating the implementation of the action plan. This thesis showed that unnecessary energy is lost in the factory due to use of low efficient equipments. Hence it is recommended to avoid unnecessary energy consumption and reduce energy cost through establishing adequate maintenance schedule, replacing of old and inefficient equipments, proper installation of lighting.
b. It was found that unnecessary lamps are installed in the factory. Therefore, it is recommended the factory to improve the installation system of lighting and to replace the existing lamps with energy efficient ones.
c. Most of the motors at YATF are very old which have been in service many years, rewound and not regularly maintained. Hence it is recommended that all the

rewound and less efficient motors should replaced with energy efficient ones and to improve the power factor of the factory.

d. As shown in this theses most of the energy cost of the factory is fuel cost. Therefore it is recommended that the factory to pay attention on reducing its fuel cost by improving of boiler efficiency through establishing proper maintenance schedule and insulation of boiler surface, repairing of water treatment.

References

[1]. Sarita Sharma, ‘‘Energy management in textile industry,’’ India, International Journal of Power System Operation and Energy Management ISSN (PRINT): 2231 – 4407, Volume-2, Issue-1,2

[2]. *An Energy audit Manual and Tool, Canada,* Canadian Industry Program for Energy Conservation (CIPEC) & PEEIC

[3]. Patrik Thollander, “Energy audit for the ump library and energy efficiency”, Malaysia, Universiti Malaysia Pahang, 2008

[4]. P. Kaufman and M. Walker “Industrial Energy Optimization: Managing Energy Consumption for Higher Profitability”, October 2009.

[5]. R. Saidur, “A review on electrical motors energy use and energy savings” discusses strategies to save motor energy use.

[6]. “Energy Conservation in Textile Industry”, Japan Energy Conservation Center , 1992

[7]. W.Mungwena1, & C.Rashama2 Strategies for Energy Efficiency Improvement in Zimbabwean Industries Using the Energy Audit, April 2013

[8]. K.B. Ljublijana, “ Energy management in pulp & paper industry”, (2008)

[9]. Ali Hansanbeige,” Energy-Efficiency Improvement Opportunities for the Textile Industry ‘’China, 2010.

[10]. Ronald A.Zettz, “Energy efficiency handbook”, November 1997.

[11]. Raphael Wentemi Apeaning “ Energy Efficiency and Management in Industries – a case study of Ghana’s largest industrial area, Ghana, Linkopings University, May 2012.

[12]. SET, “ Energy Saving and Efficiency Tool”, Dexcember, 2014

[13]. Jatin Gupta “ Electrical Energy Audit of induction motors in a Textile plant”, India, Thapar University, 2011

[14]. Attia Saad E. “Energy Conservation Potential of Measurement & Control Systems and Energy-Saving Equipment In Textile”, Egypt, 2004.

[15]. Walters, A., Santillo, D. & Johnston, P.An “Overview of Textiles Processing and Related Environmental Concerns”, UK, 2005

[16]. Amare Matebu "model development of quality management system for Ethiopian textile industries", 2006.

[17]. Ali Agha & David P. Jenkins "Energy analysis of a case-study textile mill by using real-time energy data",

[18]. McKinney J. "Profiting from Lighting Modernization pamphlet. National Lighting Bureau. Washington", ., 1987, USA

[19]. Abdollah Hasanabadi, Ali Hasanbeigi, &Mohamad Abdorrazaghi "Energy Efficiency Technologies and Comparing the Energy Intensity in the Textile Industry", Iran, 2010

[20]. Mandeep Singh & Jatin Gupta, "Electrical Energy Audit in Textile Plant", India, 2011

[21]. U.S. development of energy, "motor Master user guide", Washington state university corporate extension on energy program, 2003

[22]. Martin Adelaar and Brad Kynoc, "Energy Benchmarking & Best Practices in Canadian Textiles Wet Processing" Canadian 2004

[23]. Dr. Devanand Uttam, " LIGHTING IN TEXTILE INDUSTRY", India, February 2015.

[24]. www.forbesmarshall.com

[25]. McKinney J., 1987. Profiting from Lighting Modernization pamphlet. National Lighting Bureau. Washington, USA

[26]. Indian Bureau of Energy efficiency, Efficiency of Electric motors , India .

[27]. Basel Tahseen, "ENERGY EFFICIENCY IMPROVEMENT AND COST SAVING MEASURES IN SOME DIFFERENT INDUSTRIES IN PALESTINE" Palestine, 2008

[28]. João Granjo, "ESCO Energy Audit – SONAE Industrial", Porto, July 2012

[29]. U.S. development of energy, "motor Master user guide", Washington state university corporate extension on energy program, 2003

[30]. U.S. Department of Energy " Energy Tips' 2006, USA

[31]. Henry Manczyk, "ESTIMATING THE COST OF STEAM LOSS THROUGH THE ORIFICE OF A STEAM TRAP"

[32]. EATON Power business, " Power factor correction guide for the plant engineer", 2014

[33]. Mandalay Technological University ,Power Factor Improvement for Industrial Load by using Shunt Capacitor Bank'', Myanmar. , 2014

[34]. CleaverBooks, "BOILER EFFICIENCY GUIDE", 2010, USA

[35]. Carbon Trust, "Steam and high temperature hot water boilers", 2012, UK

[36]. Jim Custodio "The Impact of Rewinding on Motor Efficiency" , June 2007

Appendix A: Description of the Motors of YATF.

Spinning plant

Section	Type of motor	Qty	KW	RPM
Dryer	Blower comparting	4	37	2800
	Exhaust fun	1	7.5	2800
	spreader row	1	0.37	1400
	Cooling fan spreed	1	0.08	1400
	Feeder motor	1	0.75	1400
	Conveyer motor	1	2.2	1400
	Folder Motor	1	1.1	1400
	Vibrator	1	0.25	1400
	Top Belt Guider	1	0.05	1350
	Bottom Belt Guider	1	0.05	1350
Calander	Feeder motor	1	0.37	1420
	Taker Motor	1	1.1	1400
	Folder Motor	1	1.1	1400
	Upper conveyer	1	4	1400
	Lower conveyer	1	4	1400
Boiler	Fun Motor	1	7.5	2800
	Oil pump Motor	2	2.2	2800
	Furnace pump	1	2.2	2000
	water pump	1	1	2800
	water pump	1	5.5	2800
Pump station	water pump	7	7.5	2800
	softner	1	5.5	2800
Compressor	Compressor motor	1	15	2800
Washing M/c	Washing M/c	6	18.5	1500
			11	1500
	water pump	1	2.2	1400
squeesing	squeesing	2	5.1	
Sizing	Sizing	6	2.25	

Dyeing Section

Section	**Type of motor**	**Qty**	**KW**	**RPM**
Winch m/c in one door	main motor	2	7.5	2820
	Lifter	2	0.75	1400
	Placing	2	1.1	1400
	Take off	4	0.37	1400
	Stirrer	2	0.37	1400
Winch m/c in two door	main motor	3	15	2820
	Lifter	3	2.2	1400
	Placing	3	0.75	1400
	Take off	3	0.75	1400
	Stirrer	3	0.37	1400
Winch m/c in three door	main motor	3	18.5	2820
	Lifter	3	3	1400
	Placing	3	1.1	1400
	Take off	3	0.75	1400
	Stirrer	3	0.37	1400
Winch m/c in four door	main motor	1	22	2820
	Lifter	1	4	1400
	Placing	1	2.2	1400
	Take off	1	0.75	1400
	Stirrer	1	0.37	1400
Squeeser	feeder	1	2.2	1400
	processor	1	2.2	1400
	folder	1	2.2	1400

Garment section

Type of motor	Qty	KW	RPM
swing machin	170	0.4	1400
Bioler	1	48	2800
Atlas Capo camp	1	15.74	2800
Cutter	5	2.2	1400
Age cutting	3	0.16	1400
Heat press	2	0.5	1400
Heat transfer	4	1	1400
Cuvering cutter	2	0.4	1400
Bounding	3	1.6	1400
sachtin	2	2.2	1400
Ironing table	16	0.4	1400

Blanket section

Type of motor	Qty	KW	RPM
Pulling befama	4	20	2800
pressing	1	11	2820
Rolling	1	41.5	2820
Cotton Blend	1	43	2800
Woolen Blend	1	13.5	2800
Carding	2	25.5	2800
Spinning & repair	1	10	2800
Grinder	2	4.4	1400
Arachne	3	5.4	1400
Sourer	5	4.75	1400
inspecting	1	0.4	1400
Cutter	2	0.23	1400
Sniger	20	0.4	1400
Raising	4	15.75	2800
Bell press	1	5	2800
Compressor	1	35	2820
Batenter Boiler	1	57	2820

Knitting section

Type of motor	Qty	KW	RPM
Knitting m/c	4	3.75	**2800**
Knitting m/c	4	4.4	**2800**

Appendix B: Motor Saving Analysis Performed for some Motors of YATF

No	Existing Motor Description	Proposed Replacement Efficient Motor Description	Qty	Price of Effi. Motor+ Cost of Installation ($)	E_{old} ($/Yr)	E_{repl} ($/Yr)	Energy Savings (E_{old} - E_{repl}),$/Yr	COE saving ($/Yr)	Pay Back Period
1	3 –Phase, 25KW, 33.4 HP, 380V, 36A, n=1480 rpm, η=80%, pf= 0.78,50Hz	Tatung - Extra Max - NEMA Design B, 30HP, 380V, 37A, n=1175 rpm, η=92.4%, pf= 0.85,50Hz	4	2073	77077	41853	35224	1028	2.01
2	3-phase, 22.5KW, 220/440V, 7.1/59A, η=89.8%,n=1185 rpm	Teco/Westinghouse - ROLL STEEL ODP NEMA PREM - NEMA Design B, 20 HP, 460V, 24.2A, n=1180 rpm, η=93%, pf= 0.84,50Hz	4	1763	45675	26210	19465	568	3.10
3	3-PH, 20KW, 400/690V, 56/32.5A, n=1175 rpm, cos ϕ = 0.85, η=89.5%, 50 Hz	Tatung - Extra Max - NEMA Design B, 25 HP, 460V, 31.0A, η=91.7%,	2	2324	73085	46738	26347	772	3.01

		n=1465rpm, cos ϕ = 0.86, 50 Hz							
4	3-PH Induction Motor, 7.5KW, 10hp, 380V, 13.79A, N=1455 rpm, ɳ=87%, 50±5% Hz	Teco/Westinghouse - ROLL STEEL ODP NEMA PREM - NEMA Design B, 10 HP, 230/440V, N=1165 rpm, 12.8A, ɳ=91.7%	7	1095	23595	15534	8061	235	3.66
5	3-PH, 1.7HP, 220/380V, 5/3A, ɳ=78.4%, n=1160, 50 Hz	Tatung - Extra Max - NEMA Design B, 1.4 HP, 220/440V, 3.3A, ɳ=90.6%, n=1400rpm, cos ϕ = 0.90, 50 Hz	8	1940	37440	16684	20756	597	3.7
6	3-PH, 0.75KW, 220/380V, 3.5/2.2A, n= 1280rpm, cos ϕ = 0.77, ɳ=71.4%, 50 Hz	GE - Energy $aver ODP - NEMA Design B, 1 HP, 220/440V, 1.8A, ɳ=90.5%, n=1400rpm, cos ϕ = 0.83, 50 Hz	7	660	13190	5948	7222	220	2.1

7	3-PH, 0.55KW, 220V, 2.5A, η=70.9%, n=1710 rpm, cos ϕ = 0.70, 50 Hz	Teco/Westinghouse - ROLL STEEL ODP NEMA PREM , 1 HP, 220V, 1.5A, η=88%, n=2820rpm, cos ϕ = 0.83, 50 Hz	22	1610	19680	8310	11370	370	4.1
8	3-ph, 3.75KW, 380V, 13.79A, η=87%, 50Hz	Teco/Westinghouse - ROLL STEEL ODP NEMA PREM - NEMA Design B, 2 HP, 230/440V, N=1165 rpm, 12.8A, η=91.7%	6	760	22595	14234	8361	212	4.5

Appendix C: Multipliers Factor (K) for direct determination of Kvar required

Before compensation		Reactive power (kvar) to be installed per kW of load, in order to get the requested tanφ' or cosφ'							
tanφ	cosφ	tanφ'	0.75	0.62	0.48	0.41	0.33	0.23	0.00
		cosφ'	0.8	0.85	0.9	0.925	0.95	0.975	1.00
1.73	0.5		0.98	1.11	1.25	1.32	1.40	1.50	1.73
1.02	0.7		0.27	0.40	0.54	0.61	0.69	0.79	1.02
0.96	0.72		0.21	0.34	0.48	0.55	0.64	0.74	0.96
0.91	0.74		0.16	0.29	0.42	0.50	0.58	0.68	0.91
0.86	0.76		0.11	0.24	0.37	0.44	0.53	0.63	0.86
0.80	0.78		0.05	0.18	0.32	0.39	0.47	0.57	0.80
0.75	0.8			0.13	0.27	0.34	0.42	0.52	0.75
0.70	0.82			0.08	0.21	0.29	0.37	0.47	0.70
0.65	0.84			0.03	0.16	0.24	0.32	0.42	0.65
0.59	0.86				0.11	0.18	0.26	0.37	0.59
0.54	0.88				0.06	0.13	0.21	0.31	0.54
0.48	0.9					0.07	0.16	0.26	0.48

Appendix: D Periodic Motor Inspection Checklist

I. Basic Information

Date:	
Department:	
Motor type:	
Motor rating:	
Motor condition (rewound or not)	

II. Motor Checklist

No.	Description	Result	Remark
1	Check wear in bearings and housings, dirt/dust in motor, ventilating ducts		
2	Checking load conditions		
3	Check Lubricating appropriately		
4	Check proper alignment of the motor and the driven equipment		
5	Check size of wiring and terminal box		
6	Check proper connection or installation of motor wiring and terminal connection		