ADDIS ABABA UNIVERSTY

SCHOOL OF GRADUATE STUDIES

ADDIS ABABA INSTITUTE OF TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

ENERGY SAVING AND FUEL SWITCHING OPPORTUNITIES IN TABOR CERAMIC PRODUCTS SHARE COMPANY

A Thesis Submitted to School of Graduate Studies of Addis Ababa University as Partial Fulfillment of Requirements for the Award of Masters of Science in Mechanical Engineering (Thermal Engineering stream)

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Advisor: Dr.-Ing. Demiss Alemu

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Certification

This is to certify that Mebratu Markos has done the study on the topic of "Energy saving and fuel switching opportunities in Tabor Ceramic Products Share Company." Therefore; the study is original and has not been done before by any other researcher at the same topic and is enough in scope and quality for the award of masters of Science in mechanical engineering.

Advisor: Dr.-Ing. Demiss Alemu

Signature __________________

Declaration

I, Mebratu Markos, declare that the thesis entitled **“**Energy Saving and Fuel Switching Opportunities in Tabor Ceramic Products Share Company” is my original work under the guidance and suggestion of the Research Advisor. It is offered for the partial fulfillment of the requirements for the award of degree of Masters of Science in mechanical engineering (thermal engineering). This project has not been done before and all sources of material used for the study have been appropriately acknowledged.

Mebratu Markos

Signature __________________

Date __________________

Acknowledgement

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Abstract

Ceramics is defined as inorganic, non-metallic materials those are consolidated and acquire their desired properties under the application of heat. This application of heat in practice takes place inside high-temperature kilns, usually for long period of time making ceramics energy intensive industry. Tabor Ceramic Products Share Company is traditional ceramic manufacturing and energy intensive industry as it produces tiles, sanitary ware and tableware products. It is the only ceramics producing company in Ethiopia located in southern part of the country in Hawasa town. Due to high energy cost from total production cost and using highly inefficient kilns and other energy using equipments the company is in financial crisis. The growing need for ceramic products due to development of the country, increasing fuel cost from time to time and well known energy saving practices in European and Asian ceramic industries which can be easily adapted to our countries ceramic plant as well as the fact that the company is in real need of ways which can reduce its energy cost have necessitated this study.

Several energy saving opportunities in the tabor ceramics factory are obtained by this research and can be directly implemented in the factory. It is tried to classify some of energy saving options based on cost of implementing them and this is done by estimating the capital cost and annual cost of operation as well as saving that could be achieved by implementing the saving option and by calculating the payback period of the measures. The result of the current research has showed that more saving can be achieved by investing more on identified energy saving opportunities. Actually it is not to deny that there are no cost energy saving options that can increase the profitability of the company if implemented and priority should be given to these saving measures. Energy saving measures identified by the current research like reducing thermal mass of existing kiln cars, installing new modern low thermal mass kiln cars, recovering waste heat from cooling zone of tunnel kilns especially from glost kiln, installing high speed burners in kilns, avoiding dummy firing in tunnel kilns, reducing loss of products at each step of production, applying monitoring and targeting system etc can be implemented with low cost there by resulting in huge energy saving which can pay back the investment cost in less than two years time, for most of them the payback period being below one year. But above all the energy saving opportunity that can make tabor ceramics factory competent in local as well as in world market by greatly reducing its specific energy consumption i.e. energy consumed to produce one

ton of ceramic products, is introducing the technology of single fast firing by installing roller kiln for tiles production. This measure will require substantial investment cost and change in process and the reward will be very high; saving of about 50% with payback period of below three years. Finally by considering the technology and trained man power availability of the country it is discovered that it is possible to save energy equivalent to at least 424,429liters of kerosene or about 6million birr [kerosene cost 14birr per liter when this research is done] annually.

The major fuel switching opportunities identified by current research and to be applied in Tabor Ceramics Factory are mainly focused on switching to cheaper fuels that can be obtained within Ethiopia thereby saving the foreign currency the country expends to import petroleum fuels. According to the researcher this can be achieved by using Ethiopian coal as fuel in spry drier which currently uses gasoil, effectively recovering heat from cooling zones of kilns to supply heat required for drying sanitary wares to save fuel used in boilers to produce hot water for mentioned purpose, and as there is plan that Ethiopia will be commercially producing natural gas in coming six years it is wise decision to switch fuel of kilns from current kerosene to natural gas. This will have multi-benefit as experiences from developed countries shows that they have already done this measure because natural gas is environmentally friendly fuel than other solid and liquid fuels and in our case it will save foreign currency for fuel of kilns when produced in Ethiopia.

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Abbreviations

HHV-Higher Heating Value of fuel

LTM-Low Thermal Mass

Pcs-Pieces

BCR-Benefit to Cost Ratio

SEC-Specific Energy Consumption

GJ-Giga Joule

CHP- Combined Heat and Power

ESO-Energy Saving Opportunities

TCF-Tabor Ceramic Factory

UNIDO-United Nation's Industrial Development Organization

Lt-liter

Dep't-Department

S/W-Sanitary Ware

EC-Energy Conservation

T/W-Table Ware

Kg-Kilo Gram

ECC-Energy Conservation Center

M&T-Monitoring & Targeting

KJ-Kilo-Joule

SPP-Simple Payback Period

MJ-Mega Joule

GHG-Green House Gas

Q-Heat Reserve

Kcal-Kilo Calorie

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The conservation of energy is an essential stage we can all take towards overcoming the mounting problems of worldwide energy crisis and environmental degradation. The know-how on modern energy saving and conservation technologies should be disseminated to government and industrial managers, as well as to engineers and operators at plant level in developing countries. It is particularly important that they acquire practical knowledge of the currently available energy conservation technologies and techniques.

After the world energy crisis of 1980s, plenty of energy efficient technologies were introduced in the European ceramic industry sector, resulting in significant energy reduction together with reduction of production time and cost .Ceramics is defined as inorganic, non-metallic materials those are consolidated and acquire their desired properties under the application of heat. This application of heat in practice takes place inside high-temperature kilns, usually for long period of time. Therefore, the ceramics industry is by definition an energy intensive one (others being steel, cement, and glass industries). All these industries are characterized by the lengthy operation of high-temperature kilns and furnaces; not only a high amount of energy is consumed during the production process, but the energy cost is a significant percentage of the total production costs. The implementation of energy saving technologies, therefore, is imperative for reasons that have to do both with the worldwide energy crisis and environmental degradation as well as with product cost reduction. The ceramic sector energy requirements are covered largely by (environmentally harmful) fossil fuels and are therefore frequently coupled with the requirements for reduced emissions and switching to renewable source of energy as necessary.

There is no question that Ethiopia is developing at the rate which is one of the fastest growth rates in the world. This fastest growth has resulted in fast urbanization rate which in turn resulted in high growth of building industry. But modern buildings are unthinkable without floor and wall tiles as well as sanitary equipments. Tabor Ceramic Products Share Company which is the only ceramic manufacturer of the country produces less than 15% of the demand, above 85% of ceramic products is imported. In addition to that it is estimated that the demand for these materials is growing annually by 10% while TCF is facing challenges even failing to operate to its full potential i.e. its operating up to 50% of its designed capacity. The major challenge to the company is the energy consumption and increasing of fuel cost in addition lack of trained man power in respective area specially lack of well trained engineers. There is lack of awareness among the operators of equipment about the value of heat and compressed air i.e. why there are workers who feel uncomfortable due to heating of the room by radiated heat from the kiln increase the compressed atomizing air flow to burner nozzle which will disturb the combustion and cause the cooling of the room.

The ceramic sector is one of well advanced manufacturing sectors in the world being classified as traditional ceramics and advanced ceramics. Advanced ceramics is the field of ceramics manufacturing to be used in advanced equipments like electronics space technology and others while the traditional ceramics which is highly energy intensive one is concerned with the manufacturing of ceramic floor and wall tiles sanitary equipments and table wares. The growing need for ceramic products due to development of the country, increasing fuel cost from time to time and well known energy saving practices in European and Asian ceramic industries which can be easily adapted to our countries ceramic plant necessitated this study. The low cost and no cost energy saving opportunities in TCF will be identified and the saving by implementing those measures is to be estimated. Potential fuel switching opportunities are also to be identified and recommendations are going to be made to the managers of the company in particular and the other concerned body to give due attention in expanding this sector to save the foreign currency wasted by importing ceramic products.

1.2 Problem Statement

Ceramic industry is one of energy intensive industries in which the energy cost accounts 5-25% [1] of the total production cost. However the cost of fuel is increasing from time to time causing increase of production cost. It is known that even easily done housekeeping measures can result in potential saving in energy intensive industries like ceramic industries. The case of Tabor Ceramic Products Share Company is not different from this. Following the fact that old equipments and old practices are being used in the factory and the company producing less than half of it is capacity and suffering from financial loss year from year despite big market for its products, it is assumed that there are so many energy saving opportunities in the factory that can result in increase of profitability of the company and contribute to economic growth of the country. In addition to that the factory relies mainly on petroleum fuels which are very expensive for its energy need in kilns, boilers spry driers and other devices and spends millions for import of fuel annually. Clearly some of the equipments using petroleum fuels can be operated by using cheaper and cleaner fuels like electricity and natural gas and cheaper ones like coal.

The company has not adopted the known energy saving opportunities that are already discovered and applied by ceramic industries in Europe, Japan, USA and other developed nations before decades.

1.3 Objectives of the Study

1.3.1 General objective:

The general objective of this research is to identify the applicable energy saving and fuel switching opportunities in Tabor Ceramic Products Share Company.

1.3.2 Specific objectives:

- ♣ To observe the working conditions of the major energy intensive equipments in the factory like kiln, boiler, spry driers etc.
- ♣ To identify the energy management system of the company
- ♣ To indentify if there is any fuel switching options in the company
- ♣ To analyze the advantage obtained if the expensive fuels replaced with other forms of fuels
- ♣ To identify the practices in the factory that worsens their energy management process
- ♣ To measure the exhaust gas and surface temperatures of energy intensive equipments to analyze whether there is substantial amount of heat lost by heat transfer by convection conduction and via flue gas
- ♣ To analyze the working condition of hot water lines
- ♣ To organize all the obtained solutions to improve energy efficiency and profitability of the company
- ♣ To assess the feasibility of recommended fuel switching options and other energy saving options
- ♣ To recommend the final outcome of the research to the company managers so that they can improve the profitability of their factory

1.4 Significance of the Study

This research will help Tabor Ceramic Products Share Company by pointing out potential areas of energy saving and fuel switching within the factory. By applying the energy conservation measures it would be possible to reduce energy cost which currently accounts about half of total production cost of the company thereby increasing profitability of the company. Since the company produces much below its capacity due to different reasons, one being loss of products at different stage of production which caused increase of cost of production for one ton of finished products, much saving can be achieved by reducing this rejects. Whenever the production capacity of the company increases by applying the energy saving and fuel switching opportunities identified by this research the country will save some of foreign currency for importing ceramic products and fuel. Finally the study has to do with the increase in profitability of the company there by contributing to the countries development. The study will also help the company and other researchers by being standing stone for further detailed study of energy saving opportunities in TCF and other energy intensive industries and equipments.

1.5 Limitations of the Study

The complete and perfect work on this topic would require longer time probably about two years, and the team of experts on different areas like engineers (electrical mechanical chemical), economists and technicians, as well as complete energy audit instruments and enough capital. As no energy audit has been done on the company before and there is lack of some energy audit instruments it was difficult to find some important data on the performance of the major energy consuming equipments. Despite the fact that all the above mentioned things were required for complete work, the work has been done by single person with very small capital and relatively short period of time in absence of some important audit instruments, the research has identified applicable and significant energy saving and fuel switching options in the factory most of which can be applied with little or no cost. There is no need of mentioning that the researcher has made every effort to finish the work in a meaningful manner both for the company and for the academic requirement.

1.6 Research Methodology

The methods employed to achieve the objectives of the research are:

- Literature review of all available energy saving and fuel switching technologies and opportunities already identified and practiced in ceramic industries of developed countries
- Observation of the working conditions of the energy utilizing equipments in the factory
- Measuring some parameters to identify the working conditions of energy intensive equipments: measurements can be flue gas temperature, surface temperature, pressure, velocity (in the case of steam line) and others
- Survey of the energy consumption of energy intensive equipments like kilns in the factory
- Interview with workers of all level in the factory on topics of energy saving
- Questioners to concerned bodies in the factory about their energy consumption trend and energy management
- Analyzing the data
- Obtaining energy saving and fuel switching opportunities

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Energy is one of the most important resources to sustain our lives. At present we still depend a lot on fossil fuels and other kinds of non-renewable energy. The extensive use of renewable energy including solar energy needs more time for technology development.

In this situation Energy Conservation (EC) is the critical needs in any countries in the world. Of special importance of Energy Conservation are the following two aspects: Economic and Environmental impacts.

Energy saving is important and effective at all levels of human organizations – in the whole world, as a nation, as companies or individuals. Energy Conservation reduces the energy costs and improves the profitability. The nation-wide Energy Conservation efforts will contribute to lessening dependence on imported energy such as crude oils.

Private companies are also sensitive to energy costs, which directly affects their profitability and even their viability in many cases. Especially factories in the industrial sectors are of much concern, because reduced costs by Energy Conservation mean the more competitive product prices in the world markets and that is good for the national trade balance, too.

Energy Conservation is closely related also to the environmental issues. The problem is global warming or climate change is caused by emission of carbon dioxide and other Green House Gases (GHG) which are emitted during the combustion of fossil fuels. Energy Conservation, especially saving use of fossil fuels, shall be the first among the various countermeasures of the problem, with due considerations of the aforementioned economic factors.

The conservation of energy is an essential step we can all take towards overcoming the mounting problems of the worldwide energy crisis and environmental degradation. In particular, developing countries are interested to increase their awareness on the inefficient power generation and energy usage in their countries. However, usually only limited information sources on the rational use of energy are available.

The know-how on modern energy-saving and conservation technologies should, therefore, be disseminated to government and industrial managers, as well as to engineers and operators at the plant level in developing countries like Ethiopia. It is particularly important that they acquire practical knowledge of the currently available energy conservation technologies and techniques [2].

In December 1983, UNIDO organized a Regional Meeting on Energy Consumption as well as an Expert Group Meeting on Energy Conservation in small- and medium-scale industries for Asian countries. During these meetings, it was brought out that, for some energy intensive industries; savings up to 10% could be achieved through basic housekeeping activities alone, such as auditing and energy management.

All these experiences brought UNIDO to prepare a regional program on the promotion and application of energy saving technologies in selected subsectors, since 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 ceramic industry [2].

The ceramic industry consumes much energy. It is also noted for great percentage of the energy cost in the total production cost. In the ceramic industry, appreciable amounts of energy could be saved or conserved by preventing of leakage in the kilns and controlling of combustion, modifying the equipment to recover heat from the kiln in the process of ceramic-firing.

2.2 Manufacturing Process of Ceramics [1]

Naturally occurring inorganic substances are heat-treated after adjustment of the grain size and moisture, and some of them are completely molten to be formed into ceramics; while others are formed, heat-treated and made into the ceramic products in the sintered state immediately before being molten. The former product formed in the molten state is known as glass, and the latter product finished in the sintered state includes pottery, refractories, sanitary ware, tiles and cement. These ceramics are called traditional ceramics. By contrast, extremely fine particles of high-purity inorganic substances such as Alumina (Al_2O_3), Silica(SiO_2), Zirconia(ZrO_2) and Silicon Nitride(Si_2Ni_4) are sintered at a high temperature and made into ceramics; they are called advanced ceramics. These advanced ceramics are used in electronic parts and mechanical parts. Tabor Ceramic Products Share Company produces traditional ceramics and therefore the current paper is focused on this group of ceramics.

2.2.1 Basic production process of traditional ceramics

The following main process steps can be distinguished in ceramic manufacturing (Enviros Consulting Limited, 2006):

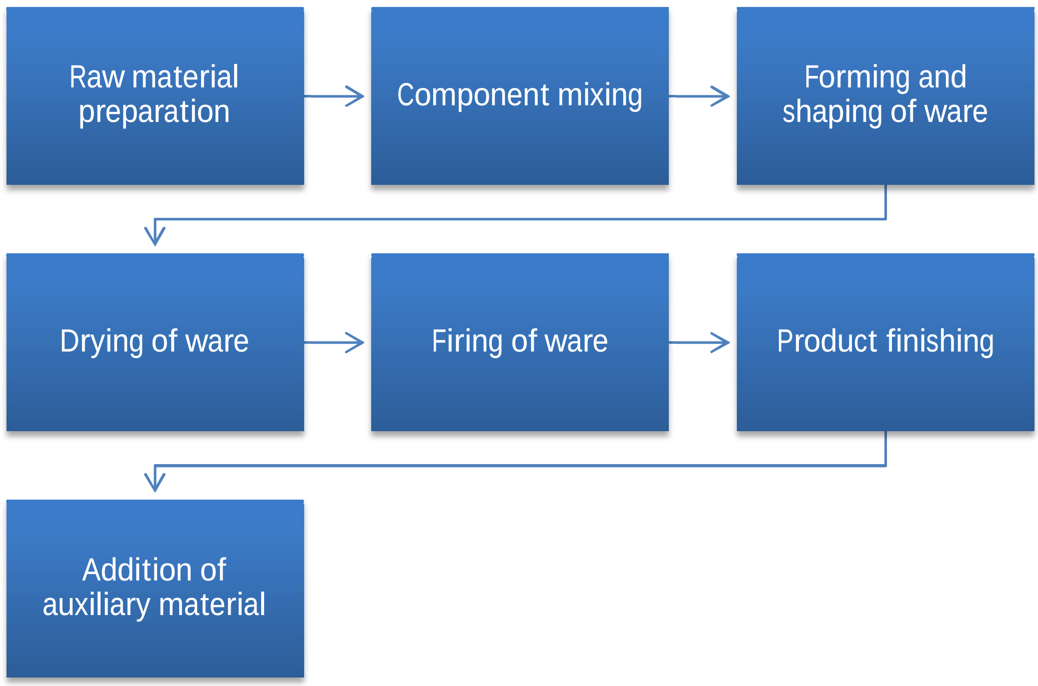

Figure2.1: The basic Production Process of Traditional Ceramics [1]

2.2.2 Raw Material

Natural raw materials contain mixtures of various components. The quality of ceramic products will deteriorate if much iron and titanium are contained, so it is necessary to use the materials containing the least of these elements. The components of the natural raw material vary according to the lot to be produced; therefore, it is essential to set up material acceptance standards to inspect chemical components, refractoriness, ignition loss and other related factors.

2.2.3 Crushing

The ore is crushed to get raw materials, and forming and sintering properties vary according to the grain size, as shown below:

Table2.1: The Effect of Grain Size on Forming and Sintering

Coarse	Poor	Poor
Fine	Good	Good

It can be seen from the above table that the raw material should be crushed to finer particles to get better product. Sintering is the process of using heat and pressure below melting point to bond particles together while forming is giving a shape.

2.2.4 Blending and Kneading

Technical know-how is the most important in this process second to the firing process, and the final product depends on this blending process. The yield, quality and workability are also affected by this process. The major points in the kneading process are how to knead the material uniformly with water and how to mix various materials**.**

2.2.5 Forming

Metal molds and plaster molds patterns are used in most cases of ceramics forming. Since the ceramics will shrink when fired, it is necessary to take it into account when determining the shape of these molds. Thus, special production know-how is required to produce a mold with a complicated shape.

2.2.6 Drying

The drying process is an important process affecting the product yield, and requires a longer time than many of other processes. Inappropriate drying may cause the products to be cut or broken; this makes it essential to find out appropriate conditions of temperature, humidity and time. The waste heat of the kiln is generally used as the heat source for drying. If this is insufficient, the hot air generator is also used to make up for the insufficiency.

2.2.7 Firing

Firing for the pottery and refractory is actually sintering which causes the crystals to be combined with one another. Firing is terminated before the material gets molten. In contrast, if temperature is raised until the fired product is molten completely; the product will be called glass. A kiln is used to manufacture the former product, while a furnace is used to produce the latter.

2.3 Energy Consumption in Ceramic Industry

Two types of energy are used in the ceramic industry; electric energy and chemical energy. The electric energy is used in two different ways; mechanical energy when used in the motor and fan of the machine, and thermal energy when used to heat the kilns and furnaces. The chemical energy of petroleum fuel is all converted into thermal energy through combustion reaction. Energy used in the ceramic industry is predominantly occupied by petroleum energy. The percentage of the energy cost in the total ceramics production cost is between 5 and 20 percent, although it varies according to the product type and fuel price. Reduction of energy cost will contribute to cutting down of the production cost, and increasing of the profit.

The drying and firing processes in ceramic production use much energy; furthermore, electric machineries (e.g. motor, fan) use electric energy. Of these processes, the firing process is the greatest energy consumer. Firing is an essential process in the ceramic production process, and heat (combusted exhaust gas, heat when cooling, namely, waste heat) produced in this process is used as a heat source to dry the formed product or as the secondary air for combustion, thus leading to energy conservation.

2.3.1 Drying Process

The drying process in the ceramic industry is the greatest energy consumer second to the firing process. Drying means loss of moisture from the surface of the substance by evaporation, and the drying speed depends on the temperature and humidity. When the substance is dried and moisture is lost, particles are put close to each other, resulting in shrinkage.

2.3.2 Firing Process

The firing process uses a kiln featuring great energy consumption, and natural raw materials are used to produce ceramics. The green body is dried in the first phase. Normally drying is completed before firing, but it may contain 1 to 2 percent moisture before entering the kiln. This moisture is evaporated before the temperature reaches 200°C. Then, when the temperature is between 300 and 500^{o}C, organic substances contained in the material are carbonized or combusted. The strength of the material is reduced in this period. The water of crystallization of the clay mineral contained in the material is subjected to hydration and decomposition at 500 to 700°C. Since this reaction is an endothermic reaction, heat is absorbed into the gray body, and temperature does not rise. This requires supply of necessary heat in sufficient amount.

The organic substance carbonized at 300 to 500°C is subjected to oxidation from about 800°C and so-called soot removal is carried out. To remove soot completely during this, it is necessary to take time to supply sufficient amount of air. Firing-starts partly at the end of the oxidation period, the strength is increased slightly over that of the gray body. If left cooled, the biscuit ware (unglazed earthen ware) will be produced. This is provided with glazing and glost firing.

2.4 Promotion of Energy Conservation Techniques

Energy conservation in industrial sectors starts from the software including operation control and process control, then extends into the field of hardware including equipment improvement and process improvement. Generally, energy conservation efforts can be classified into the following three steps:

2.4.1 Steps of Energy Conservation Efforts

2.4.1.1 Good Housekeeping

Energy conservation efforts are made without much equipment investment, including elimination of the minor waste, review of the operation standards in the production line, more effective management, improvement of employees’ cost consciousness, group activities, and improvement of operation technique. For example, such efforts include management to prevent unnecessary lighting of the electric lamps and idle operation of the motors, repair of steam leakage, as well as reinforcement of heat insulations.

2.4.1.2 Equipment Improvement

This is the phase of improving the energy efficiency of the equipment by minor modification of the existing production line to provide waste heat recovery equipment and gas pressure recovery equipment or by introduction of efficient energy conservation equipment, including replacement by advanced equipment. For example, energy conservation efforts in this step include an effective use of the waste heat recovery in combustion furnaces and kilns.

2.4.1.3 Process improvement

This is intended to reduce energy consumption by substantial modification of the production process itself by technological development. Needless to say, this is accompanied by a large equipment investment. However, this is linked to modernization of the process aimed at energy conservation, high quality, higher added value, improved product yield and man power saving.

2.5 Classification of Energy Conservation Techniques in the Ceramic Industry

Table2.2: Energy Conservation Techniques in Ceramic Industry [2]

Steps	**Drying process**	**Firing process**
1^{rst} step	1) Combustion control (combustion temperature)	1) Exhaust gas temperature control 2) kiln seal 3) Cooling air 4) Air-fuel ratio 5) Firing management (heat curve, temperature distribution in the kiln, kiln pressure, atmosphere) 6) Loading pattern on the kiln car 7) Clearance between the kiln wall and kiln car 8) Sand seal

		9) Kiln car pushing speed
2nd step	2) Heat insulation	1) Refractory on the kiln car (to be light in weight) 2) Refractory in the periodic kiln (to be light in weight) 3) Form of the tunnel kiln 4) Recovery of heat from the exhaust gas 5) Kiln car pushing speed
3rd sep		1) Conversion from the tunnel kiln to the roller hearth kiln

2.5.1 Energy Conservation Technique in Drying Process

Electric and gas energy are used for material adjustment and forming in the ceramic production process. The greatest amounts of energy are consumed to dry the formed product and by the kiln (tunnel kiln and shuttle kiln) in the firing process. Heat during the cooling in the above kiln is generally used as heat source for the formed products in the ceramic production process. However, this heat alone is not sufficient, and the heat regenerator (boiler, hot air generator) is used to make up for this insufficiency. Therefore, the structure of the drier is so designed that the outer wall is provided with the heat insulation board and wool in order to prevent heat dissipation. To improve the drying efficiency, the jet type drier is also used in recent years, where hot air directly hits the formed product. What should be borne in mind in this case, however, is that the product may be broken or the plaster mould may be cracked if air with excessive temperature or humidity is used; this is because hot air hits the product at a very high speed. Efforts must be made to find out the appropriate temperature and humidity.

2.5.2 Energy Conservation Technique in Firing Process

The kiln including the tunnel kiln and shuttle kiln consumes the greatest amount of energy in the production process. The following describes the energy conservation for the tunnel kiln and shuttle kiln: The first step in promoting energy conservation activities is a correct understanding of the current situation. Namely, correct information on how, where and how much energy is used and wasted will make it possible to determine the target for reducing the energy loss and to initiate the improvements. This is known as "heat balance". The heat balance defines the quantitative relationship between the heat supplied to the thermal equipment (heat input) and the consumed heat (heat output). In all cases, the total heat input is perfectly equal to the total heat output. The degree of economic use of heat in thermal equipment depends on distribution of various types of heat constituting the heat output with respect to heat input.

Normally, many of the tunnel kilns have a smaller internal pressure than the atmospheric pressure in the pre-firing zone; this results in entry of the outer air into the kiln. The incoming air not only increases the volume of the exhaust gas, but also reduces the temperature near the position where it has entered. This will cause temperature difference to occur between the upper and lower parts. Therefore, small clearances must be sealed with fibers or similar materials.

The thermal efficiency of the periodic kiln is 4.6 times poorer than that of the tunnel kiln; this is because the temperature is raised or lowered every time, in other words, the kiln is heated and cooled. This is because the heat to raise kiln temperature is greater than the heat released from the kiln wall surface. The heat reserve Q (kcal) of the kiln is determined by the kiln weight W (kg), the average temperature rise At (°C) of the kiln wall within the heating time, and the specific heat of the kiln material C_w (kcal/kg °C).

CHAPTER THREE

OVERVIEW OF TABOR CERAMICS FACTORY

3.1 Background

Tabor Ceramic Products Share Company is the only ceramics manufacturing plant in Ethiopia located in south nation's nationalities and peoples region in Hawassa town. The plant has started production in 1987 with the designed capacity of 1041 tons of table wares, 938 tons of sanitary wares and 2813 tons of tiles annually.

Figure3.1: One of Buildings in the TCF

The company is divided in to three departments namely tiles department, sanitary wares department and table wares department named and classified based on the type of products of respective departments.

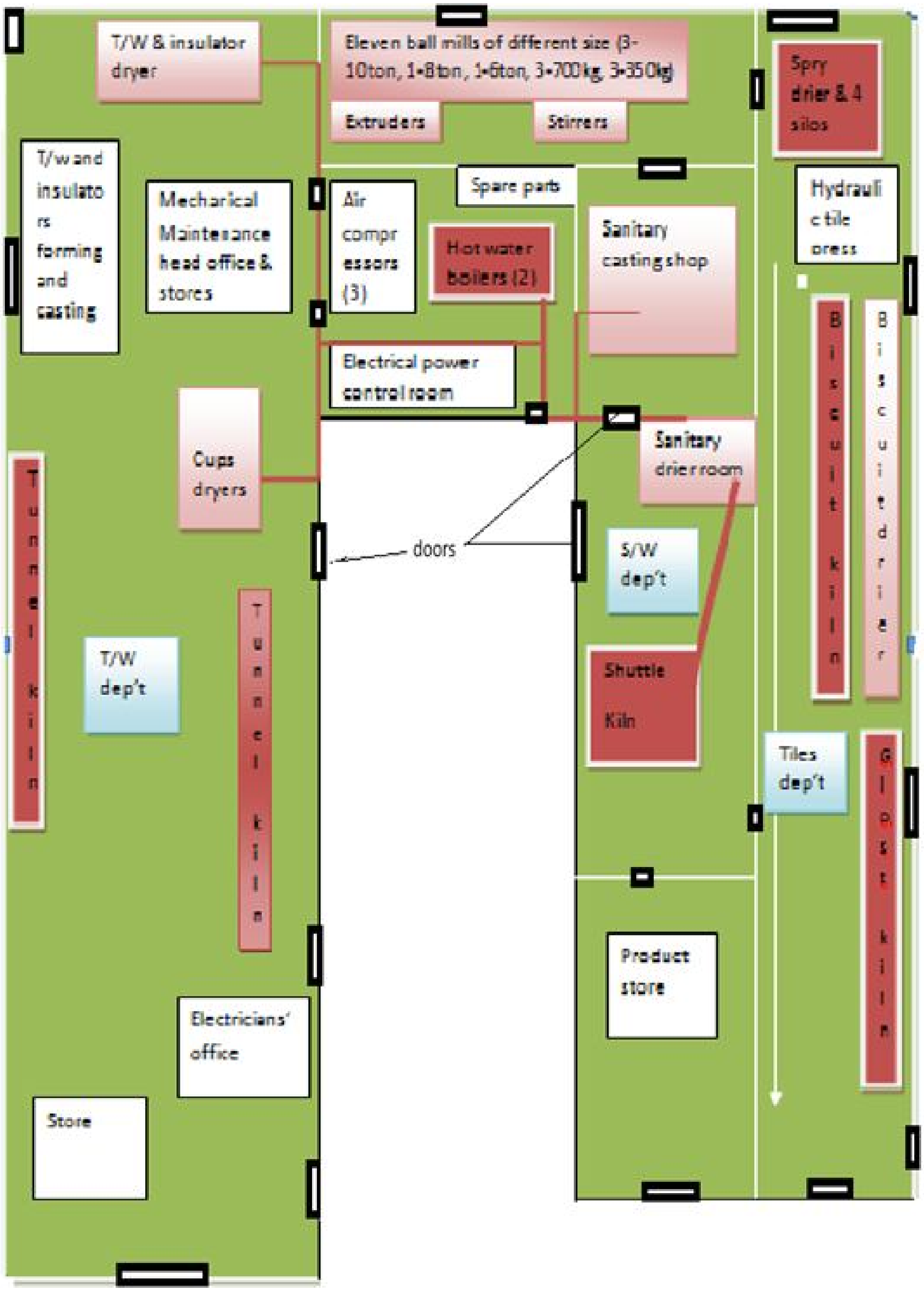

Figure3.2: The General Layout of TCF

As it can be seen from the plant layout above, utility room which consist boiler and air compressor is located on the average distance from end users. There are two hot water boilers as it can be seen from the figure above which produce hot water at the pressure of 7bar and temperature of 125^0C. This hot water from the boilers is used in T/W and S/W departments for drying purpose in dryers and in casting shop. At the back of utilities room there is raw material preparation room which contains ball mills, stirrers and slip extruding/shaping machines. At the right and left of these rooms there are T/W and S/W as well as tiles departments.

3.2 Major Energy Utilizing Equipments of the Factory

3.2.1 Ball Mills

The raw material such as clay, feldspar, quartz, calcite etc. are mixed with water in a proper proportion and grind in a ball mill to make homogeneous mixture. Ball Mill is a batch type of process. After completion of one batch of ball mill, slurry is sent to the underground tanks containing the agitator motor in each tank to maintain the uniformity of mixture. The process in ball mills is called wet grinding. There are about eleven ball mills in the factory which are of different size. Three of ball mills have capacity of 10 tons, one ball mill have the capacity of 8 tons and one other has the capacity of 6 tons, there are also three ball mills which have 700kg and three smallest ones with 350kg capacity.

Figure3.3: One of Ball Mills in TCF

Ball mills are used to mix and grind the raw materials up to the required particle size. Different particle size is needed for different departments and so different grinding time is set depending on for what purpose the product is required. They are operated by using electrical energy i.e. rotated by electric motor.

3.2.2 Spray Dryer

After preparation of slurry of required density it is stored in the underground tanks in which it is agitated to maintain uniformity of slurry. The slurry is then pumped through a hydraulic pump into the spray dryer where it is sprayed through nozzles. The material is dried in spray dryer to remove the moisture added during the grinding process in a ball mill. The moisture in the raw material is brought down to about 5–6 % from 35-40%. The product from spray dryer is stored in silos. A hot flue gas at a temperature of about 450 oC is used as the heating source which is generated by combustion of diesel oil. Spry driers consume up to 700 liters of diesel oil daily working whole the year. Currently there is a movement to replace the diesel oil by coal by the company managers.

3.2.3 Hydraulic Tiles Press

This is the equipment that uses compressed air and electric motor to press and form biscuits from dust from spry drier. There is only one this machine in the company and it was the main cause of the in efficiency in tiles manufacturing line by stopping due to failure and wastage of dust. The press has the capacity of producing six biscuits at a time and in every 2 or 3 seconds time. Tiles hydraulic press produces 6 biscuits every 2-3 seconds time is prone to wastage probably because of in effective maintenance practice. During pressing it produces large quantity of dust probably because of leaked compressed air when the machine operates. This trend pollutes the working environment as well as causes wastage of dust which is expensive resource which has been produced consuming large quantity of heat in spry drier. This machine works 24 hours a day unless for failure of its parts and failure of spry drier causing shortage of dust. Then the biscuits from hydraulic tiles press come are tested by fettling and stacking machines and loaded on cars to be dried in dryer which uses waste heat of biscuit kiln cooling zone. After drying the tiles are fired in biscuit kiln then after that glazed fired again in glost kiln and inspected and finally transported to end users.

3.2.4 Biscuit Drier

This is where biscuits after press are dried before firing in biscuit kiln. This drier has no external energy source except that it uses the waste heat from the cooling zone of the biscuit kiln and they are aligned parallel to one another. It has the capacity of holding 22 kiln cars and eight or nine kiln cars of tiles are dried each day in this drier.

3.2.5 Biscuit Kiln

The biscuit kiln has got its name from the tiles which are also called biscuits after they are pressed and got their shape in hydraulic press machine. The biscuit kiln is used in TCF to fire the biscuits or tiles after they are dried in biscuit dryer. About 40,000 biscuits are fired in biscuit kiln in 24 hours time at this time i.e. about 8 kiln cars of tiles are fired each day one car carrying up to 5000 pieces of tiles. The biscuit kiln is one of major thermal energy consuming equipments in TCF consuming above 1000 liters of kerosene each day working the whole year.

Figure3.4: Biscuits on Kiln Car before Entering in to Biscuit Kiln

3.2.6 Glost Kiln

Glost kiln is used for glost firing which is high temperature final firing of tiles or other ceramic wares once it has been coated with glaze, during which the glaze is melted and fused on to the tiles to give its final product.

Figure3.5: Glost Kiln Exit Door, Kiln Car Leaving the Kiln

This kiln is also the major consumer of thermal energy, averagely 900 liters of kerosene per day working for whole year. A lot of heat is wasted from this kiln by different means like open kiln doors as seen on above picture, heavy and high thermal mass kin cars and cassettes, old kiln cars, waste heat from cooling zone of the kiln, heat going with exhaust gas, radiation and convection loss from the surface. Despite this all wastage of heat no attempt has been made to recover heat from glost kiln. This kiln has thermocouples which are installed to measure the temperatures at different temperature zones of kiln. The maximum temperature of glost kiln in current times which occurs at firing zone is 1110^0C, while it was designed to operate up to 1130^0C.

3.2.7 Sanitary Ware Drier

This is where sanitary products are dried after the moulds are formed in casting shop. This drier uses waste heat from shuttle kiln and hot water from boiler for drying purpose.

3.2.8 Shuttle Kiln

This is the only kiln of its type in TCF. Shuttle kiln is used in the factory for the firing of sanitary products. It is batch type kiln and consumes on average 1500 liters of fuel daily working for about 220 days per year. This is almost the only equipment that the company is satisfied by its operation. Some of the waste heat from this kiln is used in drier of sanitary wares and it seems there is steel much potential of heat saving. The kiln has ten burners on both sides and five kiln cars are fired each day.

3.2.9 Boilers

There are two hot water boilers in the factory one of them being standby while the other operates. They have the capacity of 1170KW, designed fuel consumption of 125 liters per hour. The boiler inside water content is 1600 liters and maximum temperature of hot water is 135^0C while it currently heats water up to 125^0C. The designed water pressure returning to the boiler is 5bar and the maximum allowable pressure for operation of these boilers is 11bar. The return water to the boiler has temperature of 110^0C. The flow rate of water through single pump is $46m^3$ per hour. The hot water from the boilers is used in casting shop of s/w drier of s/w and driers of t/w departments and it is shifted to wherever needed by the help of manually operated valve. They use water treatment to prevent scale formation in distribution lines, corrosion and foam. Currently boilers operate 4-6 hours a day and in this time consume on average 300 liters of diesel oil. The boilers have two burners but only one burner operates in each boiler to save fuel consumption.

3.2.10 Compressors

There are three compressors currently operating in TCF one biggest and relatively efficient one has been operating for three years and the other two are old inefficient noisy and produce less than the amount compressed by single new compressor. Compressed air is the major requirement for the operation of the factory. Compressed air is used in atomizing fuel in combustion process, in pressing machine, inspection lines in tiles department, and has many other applications. Compressors use electric motor that is electric power for the operation.

3.2.11Driers of T/W department

There are driers in table wares department which are cup driers and insulator driers which use hot water from boilers and electric heaters. In current times t/w department is not operating most of the time and kilns of this department are idle also.

3.2.12 Tunnel Kilns of T/W Department

There are two tunnel kilns in this department one is stopped working for long time and the other which is the longest of its kind in the factory, 60m long, operates some times.

3.3 Total Cost of Production in Recent Times in TCF

Total cost of production in the year 2003 is about 39,791,914 birr and the thermal energy cost is about 14,268,666 birr which is about 35.85% of total cost of production [the company performance report of the first nine months, 2003e.c]. Annual telephone water and electricity charge together accounted 1,001,071 million birr which is about 2.5% of total production cost. If electricity cost alone is accounted it is less than 2% of total production cost. Total energy cost including electrical energy cost and thermal energy cost in recent time is about 38% of total production cost. About 93.5% of total energy cost is that of thermal energy and electrical energy accounted only up to 6.5% of total energy cost. The raw material and other packing materials cost in recent year is 4,670,022.5 birr or 11. 73% of total production cost. The cost of workers salary and other related things in the year when this paper is written is 5,971,450 birr which is about 15% of total production cost while the cost of spare parts in the same year is 307,597.5 birr or nearly 0.78% of total production cost. Service reduction cost [*'ye'agelgilot kinash kifiya'*] in the same year is 12,014,831 birr which is 30.2% of total production cost and cost of bank interest rate is 1,382,640 birr or 3.47% of total production cost and for different consumer goods the expense was 1,176,707 birr or about 3% of total production cost [5].

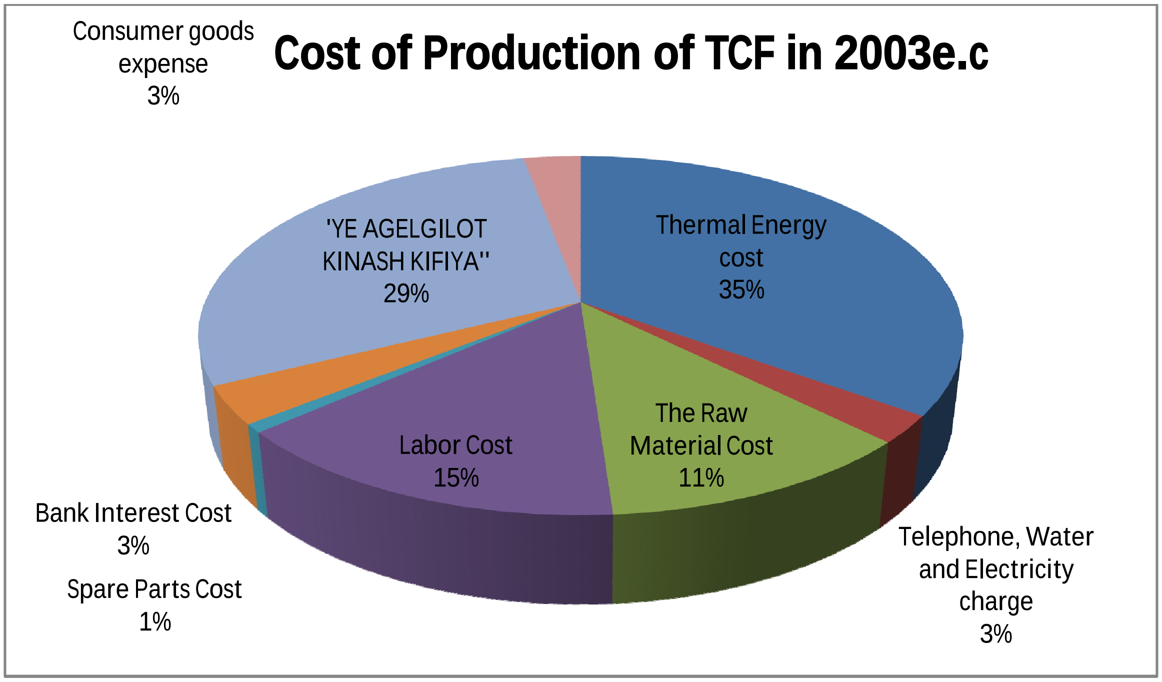

Figure3.6: The Pie Chart of Cost of Production in TCF in 2003e.c

The company produces currently 30% of the designed capacity of table wares 86% of sanitary wares 59% of tiles. In other words the factory is working 58% of its designed capacity. There are about 425 workers in TCF. As it is seen from the above data the energy cost is up to 38% of total production cost while the known range of energy cost in international level in ceramic industries is 10%-25%. This highest energy cost is probably due to inefficient energy utilizing equipments and processes being practiced in TCF. There are three departments in the company as said before namely sanitary department which produces sanitary equipments like bottom outlets cistern urinals etc table wares department which produces cups and electrical insulators mainly at this time and thirdly tiles department which is designed for both floor and wall tiles but currently producing only wall tiles.

3.4 Sanitary Ware Production in TCF

Sanitary is the general nomenclature given to ceramic wares used for sanitary facilities, water supply, drainage, sewerage, and sanitary treatment of excretion for the purpose of comfortable living. Because of the incombustible, waterproof, non-abrasion, and chemical resistant properties all sorts of ceramic products have played a constructive role for comfortable living. The major raw materials of sanitary ware are ball clay, kaolin, feldspar and quartz. Some of the products are wash basin, water closet, squats pan, urinal, pedestal, bidet and other accessory materials such as toilet roll holder, tooth brush holder, towel and soap holder etc. Sanitary ware, especially, is closely connected with housing, and so it has developed considerably with the structural improvement and modernization of dwelling. Accordingly, this industry has always grown by keeping pace with improvement in living, and it is now indispensable for sanitation in modern housing. It is believed that the demands for sanitary ware products will further increase together with the increasing demands of new construction. The country's requirement for ceramic sanitary wares is met through both domestic production and imports. Tabor Ceramics Factory, which is located in Hawassa, remains the sole ceramic sanitary ware producing plant in the country. The annual production capacity of the plant is 940 tons of different ceramic sanitary wares and fittings, including WC pan bottom, WC pan horizontal, cistern, eastern closet, wash basins of 14", 22" and 25", bidet, and pedestal. In the raw materials preparation stage raw materials are roughly crushed by the jaw crusher and roll crusher, and then sieved into designated particle sizes, weighed, and then mixed with the required amount of wooden to be micro-reduced by a ball mill. The slip is further sieved and passed through the magnetic filter so that it is free from iron impurity as well as being uniform in particle size. Shaping is done by the casting mold method. The prepared cast slip is kept one day under gentle agitation. Next, the slip is poured into a casting mold to be dehydrated and solidified into the shape of sanitary ware. The molded ware taken out of the mold is dried for a suitable length of time under the proper temperature moisture. Glazing is usually sprayed on the bodies either manually as in TCF or automatically by using a glazing bath. Glazing is also done by dipping the molded ware in to a tank filled with glazing medium. When glazing is completed the molded ware is ready for firing. There are different types of firing kiln: the simple box kiln, the shuttle kiln, the tunnel kiln, etc.

Figure3.7: Green Bottom Outlet Manufactured in TCF before Glazing

In order to save fuel or energy used for firing and control the draft pressure, temperature etc. inside the kiln, the firing process shall be intermittent. Therefore, it is suggested to use shuttle kiln for the plant as it is most efficient and economical one. There is only one shuttle kiln used in sanitary firing in TCF. After the final inspection will be carried out for crack, dirt, pinhole, and others, flash tact is conducted. Then the items will be palletized and wrapping using polypropylene for dispatch. Sanitary ware is characterized by consumption of up to 15% of total energy consumption in ceramic industry and the practice in TCF is not different.

The production process of sanitary ware making plant involves the following major manufacturing operations:

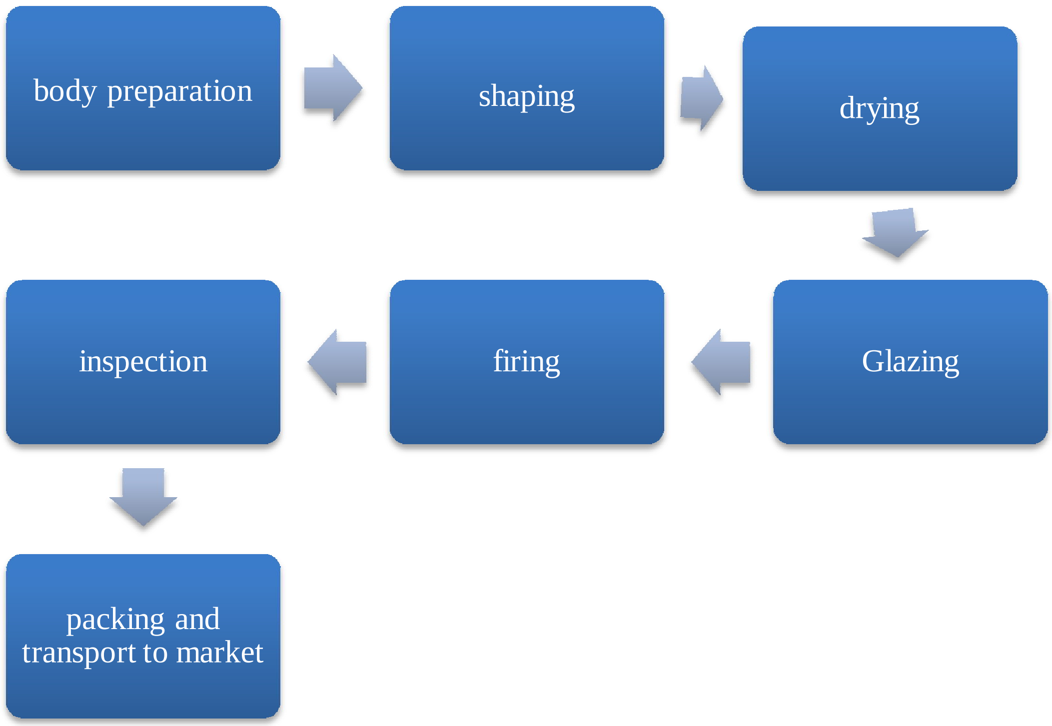

Figure3.8: The Main Processes in Manufacturing Sanitary Wares

3.5 Tiles Manufacturing in TCF

Tiles department accounts for more than 58% of the designed total manufacturing capacity, and more than 75% of total energy consumption of the company. The main manufacturing stages of tiles are raw material preparation spry drying and granulation biscuit forming by pressing drying primary firing of biscuits glazing secondary firing inspection packing and transport to users. The raw materials used in this department are plastic clay kaolin quartz lime stone and feldspar. The front end loader loads the raw materials in to storage hopper from which the raw materials are conveyed to ground flat form balance by the raw material handling conveyor, then the raw materials are weighted by weighting truck by using electric hoist. After that the raw materials enter in to the ball mill type 398.38 then the products enter vibration screen type 344.01/361.03 then to stirrer type 009,09П then to spry drier after that the dust coming out from it is conveyed by transporting belt conveyor to bucket conveyors and by rubber conveyors it is distributed in four silos. Then by the help of different conveyors it reaches hydraulic tile press.

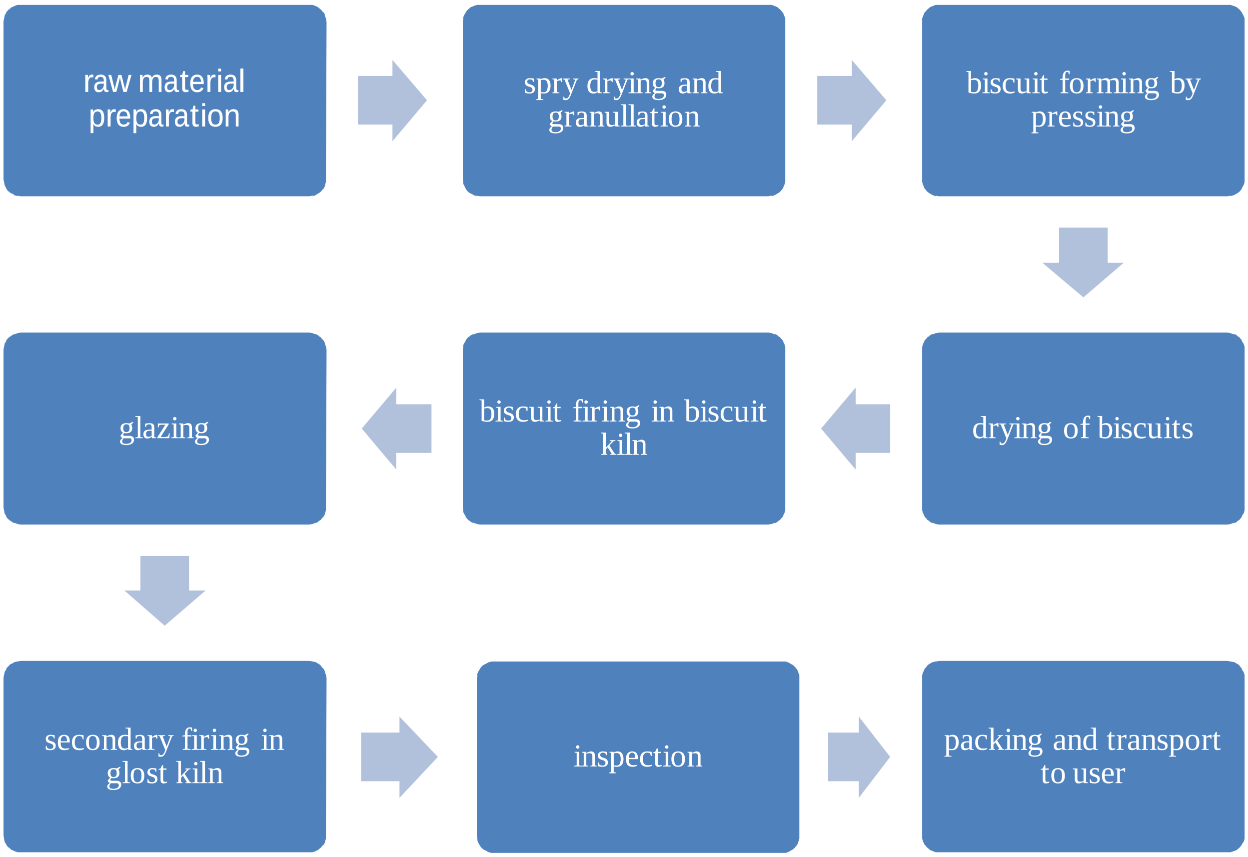

Figure3.9: Major Processes in Tile Manufacturing in TCF

3.6) Table Wares Manufacturing in TCF

The production process of table wares is the same as that of sanitary wares in that they both use casting of slip which has come out from extruders then drying that cast take out from mould dry it glaze and finally finish the production by firing. There are driers which are designed in some different way than other dep't driers and especially cup driers which are located above the ground near the roof and they use radiators which exchange heat b/n the green bodies to be dried and hot water from the boiler.

CHAPTER FOUR

IDENTIFIYING AND ANALAYING ENERGY SAVING AND FUEL SWITCHING OPPORTUNITIES

4.1 Potential for Saving Energy in Tiles Line of Manufacturing

To determine the energy saving potential in tiles production line, the recent report of nine months performance shows that about 1317.5 tons of tiles are manufactured in nine months time (the first nine months of 2003e.c report) while consuming 395,743liters of kerosene and 199,361liters of gas oil which are equivalent to 21,426.723GJ of energy [5]. The specific energy consumption of tiles line is there for 16.26GJ/ton. The international bench mark SEC in tiles manufacturing is 1.9GJ/ton [7]. The potential of saving in TCF to reach on international frontrunner is given as:

$$S_{potential} = \left(1 - {}^{SEC_b}/_{SEC_t}\right) * 100\%$$

Where: $S_{potential}$- Potential for Saving energy in Tiles Line of Manufacturing

SEC_b-International Tiles Benchmark specific energy consumption (1.9Gj/ton)

SEC_t-Specific energy consumption of TCF tiles dep't (16.26Gj/ton)

$S_{Potential}$=1- (1.9Gj/ton)/ (16.26Gj/ton)*100%=83.3%

According to the above result there is potential for saving huge amount of energy while producing the same amount of product. About 83% potential of reducing energy consumption means reducing 18,920GJ of energy while producing 1317.5tons of tiles or in other words using 2,507GJof energy to produce the mentioned amount of tiles, or using only 71,626 liters of kerosene to produce the same amount of product or else it is equivalent to saving 540,571liters of kerosene in nine months time while producing 1317.5tons of tiles. Achieving this dramatic saving in Ethiopia with available technology and man power can be difficult for the time being when considering different factors. But even if the trials are done to reduce SEC up to 10GJ/ton which is far away from the international bench mark the saving will be high for the case of TCF. Let's see potential of saving when the SEC is lowered to 10GJ/ton from current 16.26GJ/ton. Even lowering to this amount will result in energy saving of about 39% in tiles manufacturing, which is equivalent to saving 10,312GJ of energy or 294,642 liters of kerosene in a year only in tiles manufacturing line while the amount produced is kept constant.

Knowing this potential for saving energy in tiles line of manufacturing, and the practice in the factory the following section deals with methods to make this saving opportunity real:

4.1.1 Optimization of Kiln Car Loading for Biscuit Kiln

The minimization of space b/n the products by proper planning can facilitate improved loading of the biscuit kiln. This is nothing but loading the kiln cars to their maximum potential. This has become one option to reduce SEC in tiles dep't by enabling firing of more tiles while fuel consumption of the kiln is constant. Since firing in biscuit kiln does not involve the use of cassettes many tiles are loaded in single kiln car and further increasing of the number of biscuits loaded in single kiln car is possible from the conditions observed in TCF. Workers who do loading of biscuits on kiln cars should be told that loading cars to their maximum possible capacity is good for things that have to do with increasing profitably of the company.

Table 4.1: Operating Data of Biscuit Kiln of TCF

No.	Item	Units	value
1	Kiln car pushing speed	Hrs/car	3 hours/kiln car
2	Fuel consumption daily	Liters/day	750 liters/day
3	Operating hours	Hours/year	8040 hrs/year *
4	Total fuel consumption	Liters/year	251, 250 liters/year
5	Total production	Pieces/year	13, 400,000 pieces/year
6	Number of cars per day	Cars/day	8 cars/day
7	Number of pieces per day	Pieces/day	40,000 pieces/day
8	Number of pieces per car	Pieces/car	5000 pcs/car

9	Number of cars per year	Cars/year	2680 cars/year
10	Shifts that TCF operates per day	Shifts/day	3
11	Fuel consumed	Liters/pieces	0.0187 liters/pcs
12	Fuel used	-	Kerosene
13	Fuel cost	Birr/liter(birr/m^3)	14.15 birr/liters
14	Annual fuel cost	birr/year	3,555,187.5 birr/year

- * For maintenance reason and due to other factors the biscuit kiln may not be operational for a month in one year

With their current capacities each kiln car holds 5000 biscuits, either by slightly modifying the kiln cars or just by adding biscuits without any modification it can be possible to increase the number of biscuits in single car.

By adding up to 1000 more tiles to single kiln car in biscuit kiln by optimizing loading of kiln car the annual production from biscuit kiln will be 16,080,000tiles which will reduce specific fuel consumption to 0.0156 liters/pcs for biscuit kiln. If this is done about 50250 liters of kerosene or 711,037 birr can be saved in one year by considering the cost of fuel when this research was done. The saving by optimizing loading of biscuit kiln will be equivalent to saving 1,758.75GJ of energy per annum.

4.1.2 Reducing Rejects from Biscuit Kiln

But the above table [table 4.1] shows the possible number of products from biscuit kiln firing in one year. If the kiln works for the whole year without stop the number of tiles fired, the fuel consumption as well as operating time will be more than that indicated in the table above. In addition to that all fired products in this kiln do not become successful product for further operation. Rather substantial amount of tiles fail when coming out of biscuit kiln due to different reasons like unfavorable loading condition, unfavorable temperature distribution inside the kiln, lack of care to products by workers and using inefficient inspection system and crack caused by fettling machine. Even some times much loss occurs as in the case when raw material is not well prepared, but the log sheet of the factory shows that commonly the loss after firing in biscuit kiln is in the range of 14%-36% while the most frequent loss occurrence is above 20%. By taking the average loss after firing in biscuit kiln to be 25%, numbers of tiles which are rejected after firing in biscuit kiln are 3,350,000 from the total 13,400,000 fired annually in this kiln. This is equivalent to using 62,645 liters of kerosene to fire useless product annually in biscuit kiln alone. Actually it may be difficult to completely avoid wastages but reducing can do much to improvement of profitably of the company. If the amount of rejects after firing in biscuit kilns is reduced to 10% the loss due to rejected tiles will be reduced to 25,058 liters of kerosene equivalent, which means it would be possible to save up to 37,587 liters of kerosene or 1,315.545GJ of energy annually.

4.1.3 Avoiding Dummy Firing in Biscuit and Glost Kilns

In addition to the above problems that cause wasteful operation of biscuit and glost kilns dummy firing is also the most serious cause to ineffectiveness and high energy consumption. Dummy firing is the one in which kiln cars are fired without tiles loaded on them. The main reason for dummy firing is that stopping the biscuit kiln and or glost takes a long time to completely cool it down and takes up to 7-9 days to heat up cooled kiln to start up normal operation.

Dummy firing is done when there is problem in raw material preparation system in tiles manufacturing line like shortage of raw material, failure of pressing machine, problem in the system of spry drier etc. For example dummy firing was being done for months in the year 2011 and before that due to failure of pressing machine and failure of fuel pump in spry drier. During dummy firing kiln cars without tiles on them are fed in to kiln continuously and firing is done by supplying up to 75% of fuel required during normal operation. In TCF dummy firing occur frequently in both glost and biscuit kilns due to d/t reasons like raw material shortage, failure of parts causing stopping of operations of equipments like die pressing machine and spry driers and others. During dummy firing each of biscuit and glost kilns consume up to 600 liters of kerosene daily. Experiences in the factory show that dummy firing occurs at least for thirty days in a year. In principle dummy firing should never exist and be avoided with any cost. The amount of kerosene (fuel used in both glost & biscuit kilns) used to fire kiln cars and kiln structure without tiles, during dummy firing, is about 36,000 liters or equivalent to 1,260GJ of energy. So avoiding the occurrence of dummy firing means saving at least this much energy/money per annum.

4.1.4 Optimization of Kiln Car Loading for Glost Kiln

Table4.2: Base Energy Consumption Data for Glost Kiln

No.	Item	Units	Value
1	Kiln Car pushing speed	minutes/car	46-60, but the frequently used pushing speed is 46
2	Fuel consumption daily	Liters/day	On average 1000
3	Operating hours	hr/yr	8040*
4	Total fuel consumption	Liters/year	335,000
5	Total production	Pieces/year	11,758,500
6	Number of cars per day	Cars/day	30
7	Number of pieces per day	Pieces/day	35,100**
8	Number of pieces per car	Pieces/car	1170
9	Number of cars per year	Cars/year	10,050
10	Fuel consumed	Liters/pieces	0.0284
11	Fuel cost	Birr/liter	14.15
12	Annual fuel cost of glost kiln	Birr/year	11,376,600

*It is assumed that glost kiln can stop for at least a month in one year due to different reasons like maintenance and shortage of raw materials or due to failure of pressing machine or spry drier.

**The number of tiles fired in glost kiln are 28800 when using kiln car pushing speed of 60 minute and the number is 37200 when using kiln car pushing speed of 46 minute per kiln car. Number of tiles fired differs also due to type of cassette used i.e. old cassettes hold 14 and the new ones 15 tiles. The above number is selected by considering the frequency of all the above conditions.

Huge amount of energy can be saved from glost kiln by different means. One of those options to save energy consumption by glost kiln is by optimizing kiln car loading. It has been observed that each kiln car is not loaded to its current capacity mainly because of using broken cassettes. The random inspection on different kiln cars of glost kiln has shown that from the 40 cassettes put at the top of other 40 cassettes about 10 cassettes on average contain up to 10 tiles on average. Which means on average 5.5 tiles are missing from 10 cassettes in single kiln car i.e. 55 tiles from a car and 1650 tiles are missing per day due using of broken or defected cassettes. When we change this to one year it becomes 552,750 tiles in one year. Which will reduce specific fuel consumption of glost kiln: the saving will be 15,463.8 liters of kerosene per year. Or the saving only by using the cassettes which can be loaded to their maximum capacity is 510.305GJ per year. This is no cost measure.

Another opportunity to save energy and improve performance of glost kiln is by using new cassettes which have the capacity of holding up to 18 tiles. This is possible as it is evident from the structure of the current cassettes. The cassettes can be designed to hold at least 18 tiles as it is said by experienced workers of TCF on glost kiln. This is possible because of the fact that the current cassettes are manufactured by the workers within the company without considering the acceptable gap between tiles in a cassette, the material suitable for this purpose and the thickness of each shelf. In addition to the above reasons there is large clearance between the top of the top cassette and the kiln wall which can hold up to six additional tiles still leaving enough clearance at top b/n cassettes and wall at top for movement of hot gas. In the above case the number of tiles fired per day will be 43200. Annual production will be 14,472,000 pieces. The specific fuel consumption in this case will decrease further. The additional tiles that can be fired in one year are 2,713,500; or 77,063.4liters of kerosene can be saved annually: which is equivalent to saving 1,082,740.77birr. The saving will be equivalent to saving 77,307.692liters of kerosene per year, or else 2,705.769GJ of energy per year.

4.1.5 Introduction of New Firing Schedule (Reducing the Firing Time) of Biscuit Kiln

Table4.3: Some of Data for Biscuit Kiln

No	Item	Units	Value
1	Average fuel consumed for biscuit kiln	Liters/hr	31.25
2	Fuel consumed	Liters/day	750
3	Operating hours	Hr/year	8040
4	Total fuel consumed per year	Liters/year	251,250
5	Cost of fuel	Birr/liter	14.15
6	Cost of fuel per year	Birr/year	3,555,186
7	Possible decrease of firing time	Hr/car	0.6

It is possible to decrease the firing time of single kiln car of biscuit kiln at least by 0.6 hours per car. In this case additional two cars will be fired per day i.e. 10 cars will be fired unlike 8 cars per day when using pushing speed of 3hours/car. By current loading capacity of biscuit kiln cars the additional biscuits that will be fired are 10,000 wall tiles a day. Of course decreasing the firing time required for single car is associated with increasing fuel consumption to supply enough heat to fire the tiles. But there will be substantial saving due to reduced specific energy consumption. From the experience the daily fuel consumption can be increased to 815 liters per day on average. With this new firing schedule total number of tiles which can be fired in one year is 16,750,000 tiles. The amount of fuel consumed in one year in biscuit kiln will be 273,025 liters. The specific fuel consumption in this case is 0.0163 liters/pc. As it can be seen even if the fuel consumption of biscuit kiln is increased by about 65 liters per day due to increased kiln car pushing speed the specific energy consumption is reduced when compared with the current

0.0187 liters/pc. 8040 liters of kerosene or 281.4GJ energy can be saved annually by taking this measure.

4.1.6 Introduction of New Firing Schedule (Reducing the Firing Time) of Glost Kiln

Table4.4: Glost Kiln Data

No	Item	Unit	Value
1	Average fuel consumed for glost kiln	Liters/hr	About 42
2	Fuel consumed per cycle	Liters/day	1000
3	Operating hours	Hour/year	8040
4	Total fuel consumed per year	Liters/year	335,000
5	Cost of fuel per liter	Birr/liter	14.15
6	Cost of fuel annually	Birr/year	474,025
7	Possible decrease of firing time	Minutes/car	46 constantly

From the experience it is clear that when using pushing speed of kiln car is 46 relatively daily fuel consumption increases. But also the production also increases. The pushing speed currently practiced in TCF for glost kiln is 46-60 minutes per kiln car. By making the pushing speed 46 minutes per kiln car for glost kiln throughout the year 39,680 tiles can be fired in one day; 13,292,800 in one year. Specific fuel consumption is reduced to 0.0252 liters/pc and 1,534,300 additional pieces can be fired in one year by using pushing speed of 46 minutes/car and 4,908.12liters of kerosene can be saved annually w/c is equivalent to saving 171.78GJ energy annually.

4.1.7 Optimization of Dryer of Tiles Department

Table4.5: Drier Data of Tiles Dep't

No	Item	Units	value
1	Fuel used	-	Hot air from biscuit kiln
2	Electricity consumption	KWh	-
3	Daily operating time	Hours/day	24
4	Operating days per year	Days/yr	335

There is one dryer of biscuits after pressing in die pressing machine. The entire tiles manufactured in TCF are dried in this drier. The heat to it is supplied by the duct from the cooling zone of biscuit kiln. Currently eight cars of biscuits are dried daily in this drier while the capacity is 22 cars from one end to the other. As there is opportunity to increase production by increasing pushing speed in both biscuit kiln and glost kiln there is and must be the same opportunity of increasing the amount dried in one day in this drier. The current practice shows that the heat supply to the drier from biscuit kiln is done simply by connecting a duct to another duct from cooling zone which takes out heat to the atmosphere. By optimizing this heat supply from cooling zone and by supplying more heat to drier from cooling zone of the biscuit kiln it is possible to dry up to 10 cars of biscuits per day. By slightly increasing the pushing speed and properly controlling temperature and humidity of the drier room the drying operation can be optimized and loss after dried in this drier can be minimized. The optimization of the drier is useful for many reasons: first it will be possible to reduce the amount of heat wasted to atmosphere from the cooling zone of the biscuit kiln there by increasing the efficiency of the kiln second it will be possible to dry enough quantity of tiles to be used in biscuit kiln and glost kiln to increase production of this tiles by optimizing their operation and the optimization of the driers room temperature and humidity will help in reducing failure of products which have been occurring due to unfavorable conditions in drier room. The optimization of tiles drier may involve capital investment to effectively recover more heat from the cooling zone of biscuit kiln and also may involve proper temperature and humidity control of drier. The optimization of drier is must to implement other energy saving options which involve more and continuous production of tiles. As the drier uses waste heat from cooling zone of biscuit kiln it is difficult to quantify the saving that can be obtained from optimizing the drier.

4.1.8 Energy Saving by Monitoring & Targeting (M&T) System

Energy monitoring and targeting is primarily a management technique that uses energy information as a basis to eliminate waste, reduce and control current level of energy use and improve the existing operating procedures. It builds on the principle "you can't manage what you don't measure". It essentially combines the principles of energy use and statistics. This measure can result in high energy saving and productivity improvement of especially tiles department of the factory. The current practice is just measuring and recording the amount of fuel used in each shift by specific equipments like spry drier biscuit kiln and glost kiln. There are five stages to monitoring and targeting.

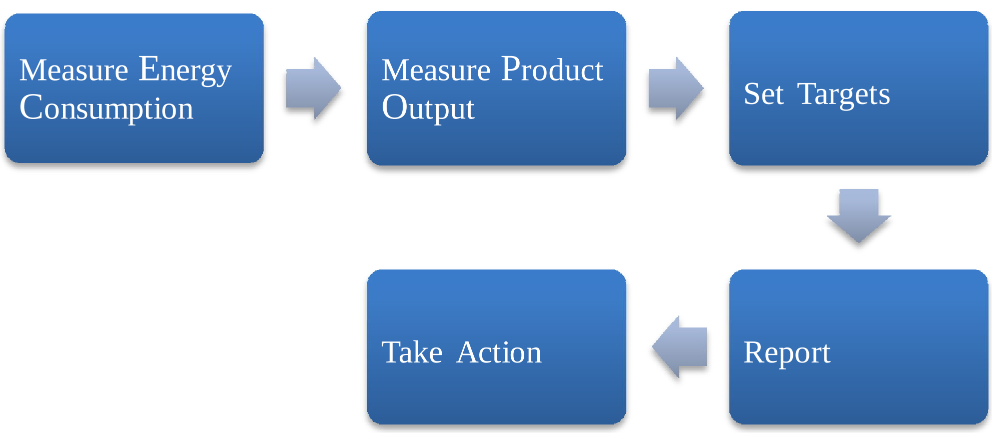

Figure4.1; Stages of Monitoring and Targeting

M & T system involves:

- Measuring energy consumption over specified period of time
- Relate energy consumption to a measure of output
- Setting targets for the reduced consumption
- Regularly comparing the targeted energy consumption with the actual energy consumption

- Taking actions to correct the variance in energy consumption
- Energy cost savings
- Improve product costing
- Improving budgeting
- Better preventive maintenance
- Improve product quality
- Avoid wastage

The reports by different operators about the operation of a month show that the major wastage is done at different stages of manufacturing due mainly to failure of machines causing the products to be below the standard. For example it is common to see reports like, 'due to the failure of hoist slip is not well mixed and caused the increase in loss of products', 'the slip texture was below the standard and caused the loss of the whole product of the same day' due to problems in equipments which prepare slip, 'slip is mixed with scrap due to problems in hoist causing high loss', 'press machine caused loss due to mechanical and operational problems', 'mill failed causing stopping of production of insulators, tiles, sanitary wares', 'scrap transporting cars tire or other failure hindered the production process of insulators as their manufacture needs huge amount of scrap recycling'. Problem of raw material car, reduced quality of raw material, failure of raw material hoist which can possibly cause the stopping of the whole factory, no raw material transport track, and old peg mills failed and stopped, ball clay for sanitary line is finished, raw materials not timely supplied, problem/failure of diaphragm pump, due to press machine failure tiles manufacturing stopped totally for some specified period of time, due to stopping of table ware kiln products couldn't be fired etc. The above are common daily weekly or monthly reports by workers, operators, and supervisors of TCF to concerned top managers. These seemingly minor problems caused and are causing inefficiency and loss in the company. By M&T measures it will be possible to save a lot of energy and improve the productivity of tiles and other manufacturing line. Since no this type of practice is done in this department before and a lot of wastage is done due to guessing the operating situation of equipments rather than doing scientifically by measuring and calculating. Better measuring practice and installation of newer measuring instruments and knowing the optimum working conditions of the spry drier the drier the biscuit and glost kiln and proper air fuel ratio will help reduce the wastage of product at different stages of manufacturing. All the listed measures related to M & T system are very low cost or no cost measures that will result in big savings. Up to at least 10% saving is possible by practicing this measure in tiles department alone and if we consider only annual thermal fuel cost in this department the saving will be 1,161,362 birr with current fuel price or equivalent to 82,075liters of kerosene or 2,872GJ energy annually.

4.1.9 Heat Recovery from Cooling Zone of Glost Kiln

Hot air from the cooling zone of biscuit kiln is being used for drying biscuits of tiles department. As mentioned above the tiles department has only one dryer and uses waste heat from cooling zone of biscuit kiln only for drying purpose. But by adding waste heat via flue gas from biscuit kiln its production capacity will increase. But waste heat from cooling zone as well as waste heat via flue gas is not recovered from glost kiln while the drier and casting shop of sanitary department uses hot water from boiler for drying purpose in addition to heat recovered from shuttle kiln. By using heat wasted with flue gas and heat from cooling zone of glost kiln it will be possible to avoid the cost of producing hot water by boiler and the cost of electric heating. Exhaust gas from the glost kiln has the temperature usually in the range 90-110^{0}C and hot air from the cooling zone has the temperature on average 97^{0}C. The designed working pressure of glost kiln is -0.04mba but the current operating pressure is -0.03mba, atomizing air pressure 0.5bar and maximum possible temperature of 140^{0}C. There are two big tubes at the top of glost kiln which remove hot air to atmosphere one is relieve tube which is located at the top of firing zone and the other is hot air tube at the top of cooling zone which leads waste heat to top of the house assisted by big electric fans. The tubes surface temperature is very high which is because they are aluminum metal sheets. That means there is huge heat loss from these tubes too by radiation convection

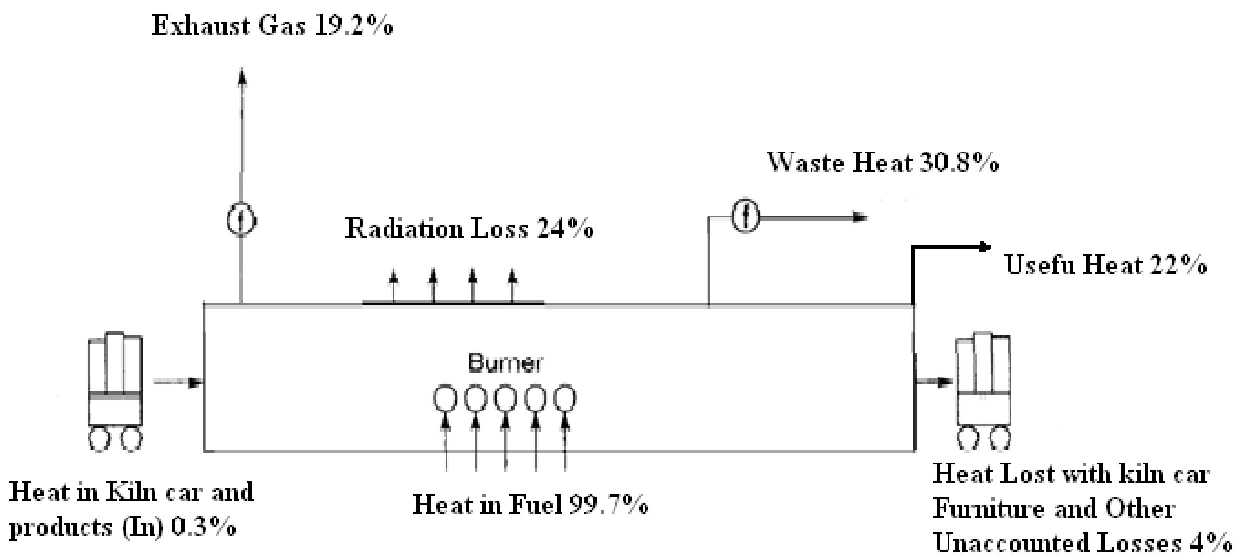

Figure4.2: Heat Flow of Glost Kiln of TCF

The above heat flow figure shows that about 30.8% of heat supplied to glost kiln goes as waste heat from cooling zone of the kiln [Fig4.2 shows heat flow of average glost kiln]. By observing the working condition of glost kiln of TCF one can realize that the waste from cooling zone can be even above 30.8%. The waste heat in the glost kiln of TCF is wasted from cooling zone assisted by fan which uses big electric motor, and from the firing zone via the tube named relieve tube. It is surely possible to say the wastage in the case of TCF is above the one shown in the figure above.

Now let's see the heat that has done useful work from the total supplied heat to the glost kiln of TCF in the first nine months of 2003e.c. The amount of heat supplied during the mentioned period was 7,717.5GJ [5].

$Q_{useful} = m_{total} x C_p x T_{max}$

Where: Q_{useful}-Heat energy which does useful work

M_{total}-Total fired mass during the mentioned period (1,317,500Kg)

C_p-Specific heat capacity of fired material (0.94KJ/Kgk)

T_{max}-Maximum firing temperature inside the kiln (1383K)

Q_{input}-Total heat input in to the kiln (7,717.5GJ)

E_{th}-Thermal efficiency

Substituting the above indicated values in the formula above, the useful heat is;

Q_{useful}=1,713GJ

Now let's see the thermal efficiency of this equipment;

$$E_{th} = \frac{Q_{useful}}{Q_{input}} x100\%$$

=(1,713GJ/7,717.5GJ)*100%=22.2%

The aim of current analysis is to show that there is feasible and clear opportunity to avoid the use of boilers in TCF to produce hot water to be used in drier and casting shop of S/W as well as T/W departments replacing it with waste heat recovered from glost kiln. That is possible b/c boilers of TCF have consumed 2,062GJ of energy in the year 2003e.c while 4,158GJ of energy is lost from cooling zone of glost kiln of TCF in the same year. So it is clear that recovering atleast half of this heat can supply heat for drying in S/W & T/W dep'ts by replacing the use of boiler for drying in TCF.

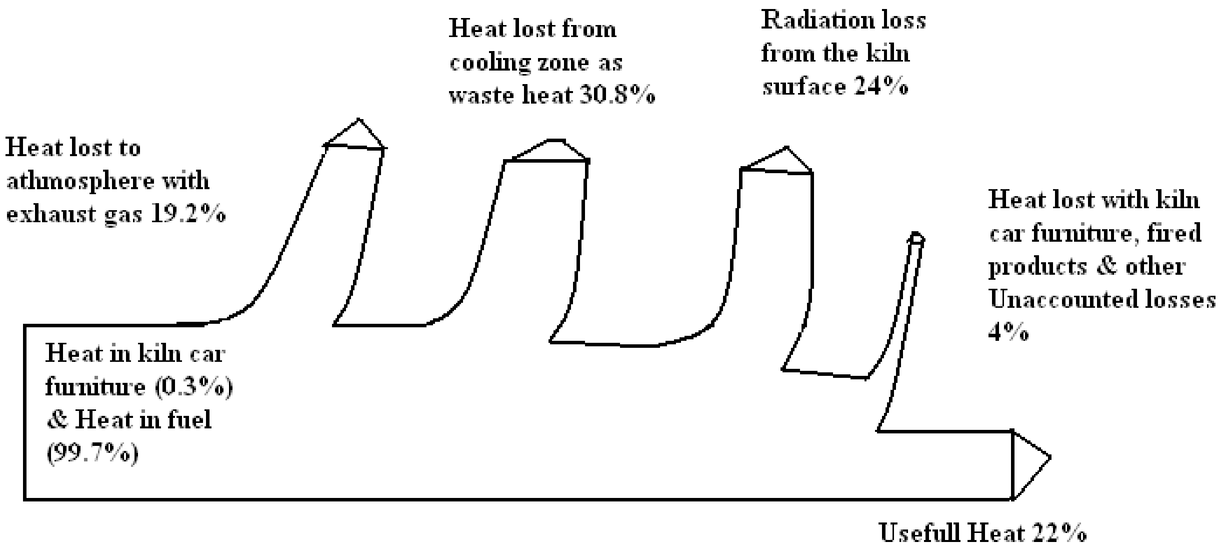

Figure4.3: Sankey Diagram of Glost Kiln of TCF

4.1.10 Better Maintenance of Kiln Cars

Table4.6: Data for Glost and Biscuit Kilns

No.	Item	Units	Figure
1	Fuel consumed	liters/day	1750*
2	Operating hours	Hours/year	8040
3	Total annual fuel consumption	liters/year	586,250
4	Total kiln cars	Cars/day	38
5	Fuel consumed	Liters/car	46
7	Cost of fuel used in kiln	Birr/m^3 (birr/liter)	14.15

*****Fuel consumption is for both biscuit and glost kilns because they use similar kiln cars

Kiln cars of both biscuit kiln and glost kiln are as old as the company i.e. they have working for about sixteen years and they are very heavy as they are made from high thermal mass materials. The cars are made of brick and are cracked due to very long service. It seems that there is no awareness of the concerned body about the fact that reducing the mass of the kiln cars and periodically maintaining them can result in tremendous energy saving. As it is mentioned above the loading capacity of kiln cars when entering biscuit kiln and when entering glost kin is different despite the fact that the cars are the same. After all still now they are using the old cars and cassettes which are as old as the factory. Due to this the cars are cracked broken and most of the cassettes are not working to their designed capacity. Kiln cars and cassettes at the exit from glost kiln has the temperature of 120^0C single kiln car including 80 cassettes weights about 765 kg. Tiles at the exit have the temperature of up to 100^0C. The amount of heat going with kiln cars in one year is number of kiln cars fired in one year multiplied by specific heat of brick multiplied by temperature difference at inlet and exit of cars. Maintenance of cars and reducing some amount of its mass will result in saving of energy. The dimension of the tiles manufactured in TCF is 150x150x5mm. In the case of glost kiln the maintenance of kiln car would mean maintenance of cars plus cassettes because there are cassettes not working with their full potential. For glost kilns the saving by replacing defected cassettes which are on average 10 in single kiln car causing missing of up to 60 tiles per kiln car and 804,000 wall tiles per year; which is the amount of tiles which is fired in 22 days: the amount of tiles which will need about 16,500 liters of kerosene to be fired. By using cassettes which hold their designed capacity it is possible to save up to 577GJ per year.

4.1.11 Installing Kiln Door

At the exit of glost kiln the hot gas leaving the kiln has the temperature up to 130 ^{0}C on average when the environmental temperature is 24^{0}C. Both the glost and the biscuit kilns are tunnel kilns which operate in continuous manner and they have no kiln door at inlet as well as at exit. The geometry of door for both kilns is the same and the side gap between the kiln cars and the kiln wall is up to 10cm, the gap at the top of the kiln car and the wall is 12cm, the height of the door is 183cm the gap between the side of the car and the wall is up to 14cm at the cassettes. The width of the door is 87cm; the height of single cassette is 34cm and width 6cm. The gap between the tiles on cassettes is 2cm. It may not be possible to build kiln doors for tunnel but it is possible to reduce the wastage due to unclosed door by some other means like using that heat for other purpose and so on. Or else it is possible to build the door that is removed when the kiln cars are coming out. The other option to reduce waste of energy due to open kiln door is by sealing the door, leaving the way only for cars coming out. Doing this will be much easier and can result in substantial saving that will pay back the cost in months. The management has to consider this problem and do something in no time to increase its profitability but reducing energy cost.

4.1.12 Insulating Specially Hot Areas on Kilns

There are points in glost kiln and biscuit kiln which contribute for wastage of huge amount of heat by radiation and convection. On some other points there is direct leakage of hot air from the kiln via openings on the kiln. The points on the glost kiln and biscuit kiln on which burners are installed are the major points for this lose. Due to the reasons like fuel saving and others most of burners in heating zone and cooling zone of both biscuit and glost kilns are not working. But for glost kiln alone there are at least 18 burners operating at a given period of time and for biscuit kiln even above that. The problems with these points are they are causes for huge heat loss through them due to their conductive nature i.e. they are steel surfaces and openings. Total heat transfer area for each burner location is roughly above 1.77 m^2 including all exposed hot surfaces on burner fitting on the kiln wall. The average temperature of these hot surfaces is up to 160^{0}C and this is for at least 50 burners for both biscuit and glost kilns. This is only for burners in the firing zone of the kilns. The burners on the heating zone of glost kiln are spark ignited burners and currently not operational to save fuel. There are inspirational quotes on the walls of offices and in the factory to inspire workers and one is “The Time is Always Right to do what is Right”. If it is believed that time is always right to do what is right then it is right to start taking measures to improve energy consumption trend of the factory to adopt known energy conservation technologies and practices in ceramic industries around the world and improve the productivity of the company. Insulating the above mentioned very hot surfaces on kiln huge amount of energy can be saved. Since glost and biscuit kilns are located near the doors, they are exposed to cold air from the outside especially during the night which facilitates the loss of heat from the kiln by radiation and convection. By controlling the circulation of the external cold air in to and out of kilns room and effectively maintaining the hot surfaces on kilns a lot can be saved. The management has to consider this too. It is known from experiences that in tunnel kilns the loss due to radiation is above 30% revealing that reducing this even by 5% can result in large fuel saving in a year.

4.1.13 Installing High Speed Burners in Kilns

There are on market various models of burners and combustion techniques, which allow significant energy saving compared to conventional burners. High speed burners that create intensive turbulence in interior of the kiln and hence improve heat transfer. High speed burners are extensively used for last three decades in developed countries and could result in energy saving of 10-15% compared to traditional burners. Both biscuit as well as glost kilns of TCF use traditional old burners which have served more than 15 years. Incase replacing of those old traditional burners with newer high speed burners is done for both glost and biscuit kilns by taking conservative 10% saving, about 58,625liters of kerosene or 2,051GJ energy can be saved annually.

4.1.14 Installing Law Thermal Mass Kiln Cars for Biscuit & Glost Kilns

By using LTM materials for kiln car construction it is possible to reduce the mass by 70% [1] but reducing thermal mass of the kiln car by even 20% can result in saving up to 35% on average. The other advantages of LTM kiln cars are increased capacity and longer service life, increase in production, reduction in cycle time and fuel saving. Suggestions to reduce the mass of kiln cars:

- Replace the old refractory brick with new type refractory brick (low heat capacity)
- Use perforated plates. It is recommended to use new generation silicon nitride or bonded silicon carbide
- Use ceramic fiber blanket at the base of the car instead of refractory brick base

As said before the kiln cars of TCF have been working for 15 years and they are old. In addition to that the cars are very heavy, made of very high thermal mass materials. Since the fuel consumption rate of kilns is directly proportional to the mass to e fired, reducing the mass to fire can do great job in reducing consumption trend of the kilns. If it is known fact that reducing the mass of kiln cars by 20% can result in saving of 35%, this measure should take place in no time in TCF. For the case of TCF reducing the mass of kiln car by 20% can be done within the factory by maintaining the existing cars and replacing the base with relatively light weight thermal materials. This can involve buying some low thermal mass fiber materials. Incase thermal mass of kiln cars is reduced by 20% the saving that can be achieved from biscuit kin and glost kilns is equivalent to 205,187liters of kerosene equivalent or 7,181GJ energy in a year. With current fuel price the amount that can be saved by implementing this measure is equivalent to 2,903,403birr annually.

4.1.15 Fast Firing and Installing Roller Kilns

Based on the experience of the last 25 years the term ``fast-firing process'' is only applicable for firing cycles ranging from 30 min to 4 h. One of the most important technological innovations was put forward in late 1970s: the use of single-layer roller kilns for the firing of tiles [1]. Roller kilns convey ware through the firing zone in a single layer using ceramic or metal rollers and automatic feed-in and exit tables. Fast firing kilns with roller, table or belt conveyance have taken the place of tunnel kilns with tray or car conveyance [1]. In fast-firing kilns as few refractories as possible are used so that heat is transmitted directly to the ware. The ratio of ware to refractory is 1:1. These kilns have been used most widely for tile production resulting in the elimination of kiln furniture, dramatically shorter firing times and a high level of automation. The temperature, pressure and atmospheric curves are automatically regulated, together with the movement and the mechanical variables.

The mass ratio of ware to furniture lies from 1:1 to 1:2.2. In comparison to tunnel kilns the SECs can be reduced by at least 50% to figures around 8 GJ/t. In general, roller kilns offer the most economic and energy efficient means of firing for all the ceramic sub-sectors. Their only disadvantage is the high cost of the refractory ceramic rollers: damages induce high maintenance costs and that is why the weight of the ware to be fired is of major importance.

Investment in roller kilns is often associated with a change from double firing (separate biscuit and glost firing) to single firing. The elimination of one or two firing steps greatly reduces energy consumption, capital investment in equipment and processing time. The example of the radical change in the production process of the Spanish tile industry from 1985-2000 is mentioned here: single-fired wall and floor tiles accounted for only 13% of the total Spanish tile production in 1982 and double-fired ones for 76%. In 1995, the figures were completely reversed: double-fired tiles accounted for only 2% whereas the percentage of single-fired ones was raised to 82%!

Substitution of double firing with single firing in roller kilns has reduced the firing cycle from 72h to 72min and the SEC to 3 GJ/t., the design of roller kilns for tile industries is very advanced and the SECs can be close to the theoretical minimum of 1.7 GJ/t for single firing. At present the fast firing of tiles especially the single firing of glazed and unglazed tiles is done all over the world in roller kilns.

This is the most important energy saving opportunity in TCF that can enable the company to compete with international producers of tiles and at least help the company to dominate the local market. Lowering SEC to 1.7GJ/ton of products is possible by using single firing by installing roller kiln. But by taking the conservative higher SEC of up to 3GJ/ton the annual saving from tiles production line alone will be up to 500,000liters of kerosene equivalent or 7,075,000birr annually by considering cost of a liter of kerosene when this research was done i.e. 14.15birr/liter. Installing this modern and efficient kiln will result in saving of 17,500GJ energy per year in tiles dep’t alone.

4.2 Energy Saving Potential of Sanitary Production Line

As seen from the industrial energy benchmarking table which is obtained from a paper named Global Industrial Energy Efficiency Benchmarking by UNIDO and published in November 2010, the international bench mark specific energy consumption in S/W production is 4.2GJ/ton

[7]. While the most recent data shows that TCF has used about 254,198 liters of kerosene and 20,213 liters of gas oil to produce 643 tons of S/W products. In other words about 9665.024 GJ of energy is used to produce 643 tons of S/W which means more than 15GJ of energy is used to produce one ton of sanitary products /SEC is 15GJ/ton/. This is better SEC value attained in recent time and the department had SEC records which are even worse.

Potential for saving considering the international bench mark which is 4.2GJ/ton is given as:

$$S_{potential} = \left(1 - {}^{SEC_b}/_{SEC_t}\right) * 100\%$$

Where: $S_{potential}$- Potential for Saving energy in Sanitary Line of Manufacturing

SEC_b-International Sanitary Benchmark specific energy consumption (4.2GJ/ton)

SEC_t-Specific energy consumption of TCF Sanitary dep't (15GJ/ton)

$S_{Potential}$=1- (4.2Gj/ton)/ (15Gj/ton)*100%=72%

This means there is 72% opportunity of energy saving or said in other way about 6958GJ of energy can be saved by keeping the current production. This is equivalent as saving about 198,823liters of kerosene while producing 643 tons of S/W or saving about 2,783,527birr in nine months by current fuel cost (14birr/liter). Attaining of the international bench mark SEC may not be possible for TCF due to different reasons but even if it is possible to reduce SEC to 8GJ/ton the saving will be so much, about 47%. There is huge potential for saving in S/W production line of TCF even in the case SEC is reduced to 8GJ/ton which is equivalent to 129,787 liters of kerosene. The specific energy consumption of sanitary production in TCF in recent times is by considering fuel used in boilers to produce hot water more than 75% of which is used for drier and casting shop of S/W which is by considering its daily operation in summer times when the temperature of the environment decrease and humidity increase causing problems in drying process and in casting shop. So on average boilers operate from a year four months daily for 4 up to 6 hours consuming up to 300 liters of diesel oil and on winter or remaining 8 months boilers operate for 2 or 3 days a week for 4 or 6 hours a day. In this way the annual fuel consumption of boilers is about 60,000 liters of diesel oil per year, of which about 45, 000 liters are used in S/W production. The amount of fuel that is used in firing S/W products in one year in recent time in the year in which this research is done is about 360,000 liters of kerosene. The amount produced with this consumption of energy was about 804 tons of sanitary ware products. Kerosene has HHV of 46.2MJ/Kg and diesel has HHV of 44.8MJ/kg. The density of kerosene is 817kg/m^3 or 0.817kg/liter. So there is consumption of 13,588.34GJ of energy is used from kerosene and since the density of diesel oil is 0.832kg/liter 1,677.3 GJ of energy is used from diesel oil. Totally about 15,265.65GJ of energy is used to produce about 804tons of sanitary wares. That means SEC of sanitary wares production in TCF is about 19GJ/ton of product and this is for the year in which the department has manufactured with full potential by using 101% of attainable production in the department. For example in last year [2002e.c] the production in the department was about 370.126tons in which case the specific energy consumption is as high as 49.7GJ/ton. SEC is directly related to using the capacity of production and producing with maximum possible capacity can result in minimum SEC possible without considering any other ESO. Where a plant in whole or part is used at full scale, will have a lower specific energy consumption (SEC) compared to working below its designed capacity. Even this high SEC is clear indicator of huge potential for energy saving opportunity (ESO).

How can this saving in the production of S/W be achieved? The following part deals with this question.

4.2.1 Installing Law Thermal Mass Kiln Cars for Shuttle Kiln

The mass ratio of kiln furniture to ware is usually above 6:1 and there is scope to reduce this ratio by better design of furniture and use of new materials. Novel kiln car furniture known as low thermal mass kiln (LTM) cars based on ceramic fibers encapsulated in mechanically strong cordierite/mullite shell are on market offering similar strength and stability performance as traditional materials with the advantage of much thermal mass reduction. Use of LTM bases regularly achieves reduction of thermal mass of up to 70% compared with conventionally constructed bases, resulting in significantly lower fuel consumption, running costs, repairs, downtime and maintenance. Types with fiber lining have replaced conventional brick lined chamber or shuttle kilns. Recently in response to customer demands for light weight high strength low thermal mass refractory with excellent thermal shock resistance, extremely porous refractory objects are appeared in market with densities from 50% to 10% of theoretical without significant sacrifices in strength [1].

Shuttle kiln is the kiln which is used for firing S/W products. It is clear that much of energy used in kilns is used for heating the kiln surface as well as the kiln car because due their high thermal mass kiln cars consume considerable amount of heat energy supplied to kiln. There for the mass to be heated is directly proportional to the amount of heat used. As the shuttle kiln of s/w department of TCF is as old as the factory i.e. it has been working for more than fifteen years and the factory uses old kiln cars which are made of high thermal mass materials, there by contributing to the wastage of heat and loss of the company there is great potential to reduce the energy consumption of this kiln by reducing the mass of kiln cars and replacing with law thermal mass kiln cars. Suggestions to reduce the mass of kiln cars:

- Replace the old refractory brick with new type refractory brick (low heat capacity)
- Use perforated plates. It is recommended to use new generation silicon nitride or bonded silicon carbide
- Use ceramic fiber blanket at the base of the car instead of refractory brick base

By using LTM materials for kiln car construction it is possible to reduce the mass by 70% [1] but reducing thermal mass of the kiln car by even 20% can result in saving up to 35% on average. The other advantages of LTM kiln cars are increased capacity and longer service life, increase in production, reduction in cycle time and fuel saving. But due to different limitations let’s say the possible fuel saving in shuttle kiln of TCF by installing LTM kiln cars is 30% and this is equivalent to reducing fuel consumption of this kiln by 108,000 liters of kerosene per year. This is equivalent to saving 3,780 GJ of energy per year. The saving is equivalent to 1,528,200 birr per year by current fuel cost.

Table4.7: Data for Shuttle Kiln

No.	Item	Units	value
1	Fuel consumed	(liters/day**)**	1500
2	Operating hours	Hours/year	5280
3	Total annual fuel consumption	(liters/year)	330,000

4	Total kiln cars	Cars/day	5
5	Fuel consumed	Liters/car	300
6	Type of fuel used	-	kerosene
7	Cost of fuel used in kiln*	(birr/liter)	14.05

*The cost of fuel represents the one during the time when this research is done.

4.2.2 Optimization of Kiln Car Loading of Shuttle Kiln

Optimization of kiln car loading means loading the kiln cars to 100% of their potential and thereby reducing SEC by producing more products with a given energy usage. This is no cost energy saving opportunity and by knowing this great attention should be given to the way the kiln cars are loaded.

Table4.8: Energy Consumption Data for Shuttle Kiln

No.	Item	Units	Value
1	Kiln type	-	Shuttle kiln
2	Fuel consumption daily	(Liters/day)	1500
3	Operating hours	Hours/year(hr/yr)	5280
4	Total fuel consumption	(Liters/year)	360,000
5	Total production	Pieces/year	135,600
6	Number of cars per day	Cars/day	5
7	Number of pieces per day	Pieces/day	565
8	Number of pieces per car	Pieces/car	113
9	Number of cars per year	Cars/year	1200

10	Fuel consumed	Liters/pieces	2.67
11	Fuel cost	Birr/liter(birr/m^3)	14.15

By increasing the number of products loaded on each kiln car by at least five, the average number of products on each kiln car will increase to 118 and number of products that will be fired in one day for this case will be 590 and in one year the number of products that will be fired with this modified loading will be 141,600. This will reduce specific fuel consumption of this specific equipment to 2.54liters/pcs. The firing of 141,600 pcs would require 375,929.2 liters of kerosene but by optimizing the loading on kiln car as said above it will be possible to save about 15,929 liters of kerosene in one year, which is equivalent to saving 557.515GJ of energy per year. With the current cost of fuel used the saving is equivalent to saving 225,395.35 birr per year.

4.2.3 Implement Periodic Inspection and Adjustment of Burners in the Shuttle Kiln/Installing High Speed Burners

Usually due to high oxygen content in firing high wastage of fuel results. Air fuel ration should be adjusted to the optimum value in all burners to save wastage by high oxygen content in firing area. The adjustment of proper/optimum air-fuel ratio in burners is usually better done by supplier of the burners. Periodic inspection and adjustment of burners is better done after every six month interval. By implementing periodic inspection and adjustment of burners can result in saving of up to 15%. The first one is almost being implemented in the factory but since the burners being used in the shuttle kiln are old and traditional ones it is more rational to replace them by newer high speed burners to gets satisfying result in energy saving.

Table4.9: Data for Shuttle Kiln

No.	Item	Unit	Value
1	Total number of burners	-	10
2	Number of burners currently working	-	10
3	Daily fuel consumption when operating	Liters/day	360,000

	with all burners		
4	Fuel used	-	Kerosene
5	Operating hours per day	Hours/day	22
6	Operating days per year	Days/yr	240
7	Operating hours per year	Hours/yr	5280
8	Annual fuel consumption when operating with all the burners	Liters/yr	360,000
9	Annual fuel consumption when operating with currently working burners	Liters/yr	360,000
10	The current burners are working for	years	15

The next option in the case of saving in burners is by using high speed burners. There are on market various types/models of burners and combustion techniques, which result in significant energy saving when compared to conventional burners. High speed burners which create intense turbulence in the interior of the kiln and thus improve heat transfer are extensively used in ceramic industries around the world since a long time and could achieve saving of fuel consumption by 15%. So by implementing either of the above two options for the burners of shuttle kiln in TCF, even though the next option is the most recommended, since in both cases it is possible to save fuel consumption of the kiln by 15%, the saving will be 54,000 liters of kerosene per year of 1890 GJ of energy per year. By the current cost of the fuel used the saving is 764,100 birr per year.

4.2.4 Heat Recovery from Cooling Zone of Glost Kiln

There are two major areas of thermal energy consumption S/W line of manufacturing the first is when firing in shuttle kiln and the other is to produce hot water in boilers to be used in drier and casting shop rooms. Unlike tunnel kilns shuttle kiln have no heating, firing and cooling zones, firing is done in batches, and the waste heat and flue gas are directed to the environment via single duct. The good thing in shuttle kiln of TCF is they have recovered some part of heat wasted to the environment from the kiln to be used in drier of this dep’t. But due to the fact that shuttle kiln is batch type equipment, i.e. it may be idle when drying is needed, and in summer times due to heat recovered is wasted on its way to the dryer room by convection and radiation b/c of no insulation there is need of producing hot water in boiler to fill the gap. But if proper heat recovery is done, waste heat from kilns can and could supply 100% energy needed for drying and in casting shop [1]. The good news in this case is that huge amount of heat is being wasted from the cooling zone of glost kiln of TCF and this kiln is located very near to dryer and casting shop of S/W dep’t as can be seen from the company lay out figure.

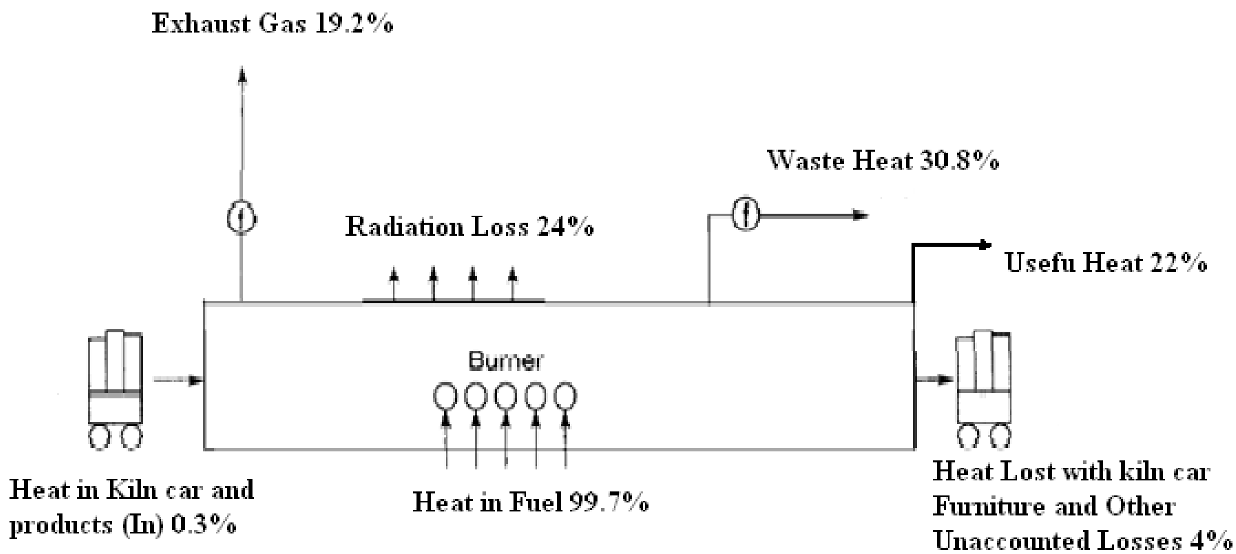

Figure4.4: Heat Flow of Glost Kiln of TCF

The above heat flow figure shows that about 30.8% of heat supplied to average glost kiln goes as waste heat from cooling zone of the kiln. By observing the working condition of glost kiln of TCF one can realize that the waste from cooling zone can be even above 30.8%. The waste heat in the glost kiln of TCF is wasted from cooling zone assisted by fan which uses big electric motor, and from the firing zone via the tube named relieve tube. It is surely possible to say the wastage in the case of TCF is above the one shown in the figure above.

The aim of current analysis is to show that there is feasible and clear opportunity to avoid the use of boilers in TCF to produce hot water to be used in drier and casting shop of S/W as well as

T/W departments replacing it with waste heat recovered from glost kiln. The nine months report of the company of the most recent time shows that the boilers have used about 43,418liters of gas oil in nine months time to produce hot water which was used in S/W and T/W departments. With the HHV of 38,000KJ/lt of gasoil, the boilers have used 1,649.884GJ of energy. The annual fuel consumption of glost kiln by considering different factors is at least 300,000liters per year. Of which at least 118,800liters is wasted as waste heat from cooling zone. With HHV of kerosene which is the fuel for glost kiln in TCF the wastage as waste heat is 4,158GJ of energy in one year. The amount which is lost from cooling zone of glost kiln in nine months time is about 3,118.5GJ of energy which is about twice of the energy needed by boilers to supply hot water for driers of T/W and S/W dep't. The amount of saving that will be achieved by implementing this measure is equivalent to saving 20,213liters of gasoil which could have been used by boilers in producing hot water to be used in drier and casting shop of S/W production line. To implement this saving measure the ducting system is already there, hot water lines and return lines can be used completely this purpose except that about 20m long tubing would be required to connect waste heat tube with the existing lines and there is fan that currently drives hot air to the atmosphere and with small modification by providing the valve control system the measure can be real. This will be the most reliable conservation measure since glost kiln operates throughout the year without stopping there by being able to supply heat from its cooling zone at any time needed by driers and in casting shops. It is equivalent to saving 960GJ energy in a year time in S/W production line alone.

4.2.5 Optimization of Drier and Casting Shop of S/W Dep't

This will involve reducing leakages of cold surrounding air to drier room, proper insulation of ducts, maintaining uniform temperature and humidity level, installing the devices to measure decisive parameters like temperatures and humidity, knowing the optimum conditions for drier operation and others. By optimizing the drier and casting shop operation it would be possible to save the fuel needed by at least 5%. As these equipments have consumed 20,213liters of gasoil in nine months time the 5% saving would mean saving about 1,010 liters of gasoil or 48GJ of energy in a year for sanitary production line.

4.2.6 Applying Monitoring and Targeting (M&T) System in S/W Production Line

For the case of energy saving, M&T is a systematic procedure for detecting (and helping to diagnose) wasteful use of energy, it can also mean financial monitoring of utility accounts automatic meter reading and associated reporting/analysis techniques Monitoring and Targeting can prevent things w/c unexpectedly go wrong (or are done incorrectly) from time to time and avoid malfunctioning of energy-using systems; when energy using systems malfunction they are more likely to use too much, rather than too little, energy. Some of the benefits of M&T are it help detect and diagnose hidden, avoidable costs, improve budget forecasting and tracking, valuable precursor to energy surveys, objectively quantify savings, advanced benchmarking.

By applying proper M&T system it can be possible to save at least 5% of total energy consumption in S/W line of production. The saving will be equivalent to, by applying M&T, 603GJ of energy in a year.

4.3 Energy Saving by Horizontal Technologies

Horizontal technologies are the technologies commonly applied not to just the ceramics industry but across all industry. Ceramic companies concentrate in principle on the drying and firing process when investigating opportunities to save energy and they rarely account for horizontal technologies. However, most of these technologies do not require heavy capital investment; do not incur risk and have very attractive payback periods. In general, tile manufacturers are more interested to horizontal technologies than other sectors, since for tiles the firing and drying processes have already been optimized to a huge extent but in the case of TCF since no optimization is done in firing and drying process of tiles manufacturing energy saving by horizontal technologies will be additional opportunity to be applied in all lines of manufacturing contributing to profitability of the company. Horizontal technologies will mainly focus on electrical energy saving and optimization of boiler operation. The nine months performance report of TCF shows that the cost of electrical energy accounts only below 2% of total production cost. However this doesn’t mean that the company uses little electrical energy for production of its products and there is no potential for reducing the cost of electrical energy either. There are well-known electrical energy saving technologies and methods which have been applied and proven effective in the ceramic industries of developed countries before decades and can be applied without any doubt in TCF to increase the efficiency of the systems using electrical energy. The major electrical energy using systems of TCF are ball mills, compressors, extruding and shaping machines, pressing machine and lighting. Electrical energy saving can be done by applying monitoring and targeting (M&T) systems, by optimization of compressed air system, reduction of grinding time, lighting control, installation of variable frequency inverters.

4.3.1 Motors and Variable Speed Drives

Electric motors account for a high percentage of electricity consumption in ceramic industries powering equipment for clay preparation and shaping and driving fans for the drying and firing processes [1]. Cost analysis reveals that the capital cost of a standard motor will represent only about 1% of the motors energy running costs over its lifetime and highlights the importance of higher efficiency motors. If the application is appropriate, the extra expenditure will be repaid within two years and the continuing savings will add directly to profits over a typical lifetime of at least 10 years. In TCF the case is not different that very high percentages of electrical energy consumers are electric motors. Electric motors are used in raw material preparation in ball mills, compressors and fans as well as in pressing shaping equipments. There are relatively older and less efficient motors operating and the practice in the company shows that even when the motors fail to operate they are re-winded and installed again. The experiences in developed nations shows that replacing electric motor with newer and more efficient one will result in the saving that can repay cost of installing within two years time and will directly add to the profit of the company in other eight years time assuming the life of new motor to be ten years.

4.3.2 Installation of Variable Frequency Inverters

When high output is not required, variable frequency inverters are convenient on discontinuous ball mills allowing adjustment of the mill motor speed as a function of the material grinding curve. In this way, the grinding cycle can be optimized and reductions (15-25%) both in grinding times and energy consumption are possible.

4.3.3 Re-use of Waste

The sectors of ceramic wall tile, sanitary ware and tableware result in wastewaters coming essentially from the grinding operation and the glazing and deco-rating operations. This sludge can be beneficially re-used within the same factories by adding them to the raw materials composition. About 20% of this sludge can be recycled. One way is to add them to the raw materials (especially in wet-grinding processes), but in order not to affect the slip behavior, their percentage there is kept below 2% of the slip. Other possibilities include their re-use in the glaze or their supply to other sectors [1].

4.3.4 Monitoring and Targeting

Very often, the greatest barrier to improved energy efficiency is the lack of management information available on process energy consumption. Monitoring and targeting is a disciplined approach to energy management that ensures that energy resources are used to the maximum economic advantage [1]. It consists of two fundamental aspects: continuous and detailed measuring of energy consumption in each part of the plant and analysis of the data and fixing of energy saving targets in current case mainly to electrical energy saving as M&T is already analyzed for thermal energy saving. Energy saving possibilities can be determined through energy audits. The improvements to take place may include changes in the operation modifications of the plant or investment in more efficient processes and equipment. Cost-effective measures are implemented when financial and other constraints permit and a target is set for the expected improvement of the efficiency in energy use. Progress toward the target is monitored and when it has been reached and performance has been sustained at the new level, the targets can become the new standard. M&T as in the case of saving thermal energy can also be applied in saving electrical energy in TCF.

4.3.5 Boilers and Steam Distribution

A typical industrial boiler is approximately 75-80% efficient: 15-20% of the energy consumed is lost in flue gases, 1% in radiation losses and 1-6% in blow down losses [1]. The greatest savings can be achieved by installing heat exchangers. Modern insulation keeps the radiation losses below 1% whereas the greatest savings can be made by paying careful attention to the steam distribution network and by insulating steam pipes. The combustion analysis of TCF boiler showed that the boiler efficiency is 78%. The surface temperature of the boilers while they are operating is not much above environmental temperature revealing that surface loss too is not much above 1%. But much loss occurs due to the fact that hot water leakage occurs at different points in the distribution line, at valves, at the water pumps and there are also problems in the insulating system of the distribution line. The boilers of TCF are hot water boilers which produce hot water at the temperature of 125^0C and at the pressure of 7bar which when returning to the boiler has the temperature of 110^0C and pressure of 5bar. There are two boilers of the same capacity and only one operates at a time. Even if the researcher recommends avoiding the use of boilers to produce hot water to be used in drying of products in S/W and T/W dept's, there are still energy saving opportunities that can be applied immediately to result in energy saving in operation of boilers. The first one is avoiding leakage of hot water. Hot water at the temperature of 125^0C and pressure of 7 bars has specific energy of 525.3845KJ/kg density of 939.26kg/m^3 internal energy of 524.639KJ/kg and the specific volume of 0.001064m^3/kg. Hot water at temperature of 110^0C and pressure of 5 bars has the density of 951.1219kg/m^3 enthalpy of 461.62KJ/kg and specific volume of 0.001051m^3/kg. The practice in the boiler operation shows that the boiler operates for 4/6 hours a day depending on the need and the water inside the boiler as well as feed water cools down to the temperature of below 18^0C at atmospheric pressure. At this condition the water has density of 998.597kg/m^3 enthalpy of 75.64KJ/kg. The boilers have no system of heat recovery from exhaust gas and by doing heat recovery to heat feed water to boiler large amount of energy can be saved. The water inside the boiler as well as the feed water can be preheated to the temperature 70^0C at least by exhaust gas from biscuit kiln or glost kiln or by both of them. This will require only installation of pipes and valves to control the flow of water and the existing pumps can be used to circulate water through the line or additional pump can be installed as necessary.

The major leakages of hot water occur on the way to end users b/c of relatively higher pressure. At the pumps and valves continuous flow of water was observed and such a large loss is obvious due to the average feed water requirement by boiler each day it starts which is up to 0.5m^3. The amount of heat loss with this amount of water is 469.9kg*525.3845KJ/kg=246890.9774KJ of energy daily. During the annual operation of boilers about 49378.1954 MJ of energy is wasted with hot water leakage from different parts during boiler operation. The leakage of about 500 liters of hot water daily is equivalent to leakage of 1299.426liters of gas oil annually; there for completely avoiding leakage of hot water by proper maintenance and inspection of pumps, valves and distribution lines it will be possible to save about 49.378GJ of energy annually.

The second option is to save energy of heating cold water by preheating water before normal operation. By heating up water to 70^0C the enthalpy will increase to 293.075KJ/kg from 75.64KJ/kg. By considering the boiler inside water alone i.e. 1.6m^3 of water, 998.597kg/m^3*1.6m^3=1597.76kg of water is contained inside the boiler; by heating this amount of water to 70^0C before boiler start operation 217.36KJ/kg*1597.76kg=347289.1136KJ energy can be saved each day boiler operates or 69457822.72KJ energy can be saved annually which is equivalent to saving 1828liters of gasoil each year or 69.5GJ of energy annually.

Another opportunity is to use hot air from compressors as combustion gas rather than using cold environmental air. And also in summer times and since the boiler operates during night times in which the environmental temperature is relatively lower, the experience in TCF shows that when environmental temperature is low as in summer times fuel consumption of boiler significantly rises which reveals that there is significant loss of heat from distribution lines. Especially there are distribution lines which are directly exposed to wind and cold air from the environment and something must be done to avoid this loss due to cold air leakage in to the rooms of distribution line and proper insulation of them.

4.3.6 Automation and Control

Automation of a specific process allows for tighter control of the process variables and thus operation closer to the theoretical minimum of specific consumption. Successful examples are the automation of the spray-drying stage, the control of temperature and humidity curves in the dryers and the corresponding temperature, pressure and atmosphere composition control in the kilns [1]. Control of the kiln parameters is nowadays realized with the aid of advanced expert systems, which by extensive on-line measurements can guide operation towards conditions of maximum energy efficiency. These on-line measurements can be further combined with dedicated modeling tools of the kiln operation, which can greatly help in designing kiln operation under optimum heat and mass transfer conditions [1].

4.3.7 Compressed Air System Optimization

Compressed air is a convenient and often essential utility, but it is very expensive to produce. In fact, most of the energy used to compress air is turned into heat and then lost. At the point use, compressed air costs more than ten times the equivalent quantity of electrical energy, at this price; it should never be wasted and only be used when necessary. Energy saving in the area of compressed air can be achieved by keeping the inlet air cool, dry and clean, avoiding the pressure drops at the intake, working at minimum possible pressure, recovering of the cooling heat from compressor and by matching the capacity of the compressor to the demand. Since the boiler and compressor are very close to each other hot air from cooling of compressors can be used as combustion air for boilers and also can be used as combustion air in kilns when boiler is not operating. The cost of compressed air makes it an expensive resource and the way to achieve the best savings is to minimize the demand and then to optimize the supply. Savings up to 30% can be made by inexpensive good housekeeping measures such as making end users aware of the cost of generating compressed air and enlisting their help in reporting leaks. A significant amount of energy is wasted through leakage. Typically, leak rates are up to 40% (i.e. 40% of the generating power is wasted in feeding leaks). A 3mm diameter hole in a system at 7 bars will leak about 11 liters/sec; with more leaks, the wastage will increase significantly causing the loss of large amount of money in a year. Simple leak surveys and maintenance can produce dramatic cost reductions and, in some cases, leak reporting and repair have enabled companies to shut down some compressors for all or most of their operating time. Some of the ways to reduce leakages of compressed air are Simple and repeated walk around surveys, with leaks tagged and repaired as soon as possible, isolate redundant pipe work which is a common source of leakage, measure losses due to leakage and target reductions. Reducing use is another option to reduce cost associated with usage of compressed air in a given industry; Compressed air is often misused because everyone assumes it's cheap. Check every application to see whether it is essential or simply convenient. Stop the use of compressed air for ventilation or cooling – fans are cheaper and more effective, Fit high efficiency air nozzles –the payback can be as short as four months, consider the use of electric tools instead of compressed air tools, do not use compressed air for conveying granules or products. Optimizing the supply is another option of increasing efficiency of compressed air system. The higher the compressed air pressure, the more expensive it is to provide the air. Twice the pressure means four times the energy cost. The real needs may be lower than you are supplying. In some cases, the machine rating is for a 7 bar supply but pressure reducers are fitted inside the machine. Check that compressed air is not being generated at a higher pressure than required, switch off compressors during non-productive hours. They are often only feeding leaks or creating them, check that compressors are not idling when not needed– they can draw up to 40% of full power when idling, position air inlets outside if possible – it is easier to compress cold air, If there is a machine or area that requires compressed air longer than the rest, consider zoning or a dedicated compressor so that others can be switched off, Investigate electronic sequencing to minimize compressors going on and off-load, and maintain the system – missing a maintenance check increases costs. The longer the compressed air pipeline, the higher the pressure loss over the pipeline and the greater the cost of the system; so improving distribution is another option in optimizing compressed air system and it includes making sure that pipe-work is not undersized as this causes resistance to airflow and pressure drops, Avoid sharp corners and elbows in pipe-work as these cause turbulence and thus increase pressure drops. The last option not the least in optimizing compressed air usage is by reducing air treatment cost. Test filters regularly to make sure the pressure drop does not exceed 0.4 bars. Replace the filters if the pressure drop is higher than 0.4 bar; the cost of power to overcome this drop is usually greater than the cost of a filter, manual condensate traps are often left open and act as leaks; consider replacing them with electronic traps.

Compressed air is not free and it is possible to save at least 30% of the costs of compressed air by simple management systems and maintenance. As said before there are three compressors of different age and capacity operating in TCF. Two are the older ones, as old as the company about 15 years, less efficient, noisy etc. The newer one has worked for three years and has efficiency and capacity above that of the other two. I feel that by close follow up of the system and applying options to avoid the wastage of compressed air it could be possible to reduce and or avoid the running of older compressors and thereby reduce the cost of producing compressed air substantially.

4.3.8 Cogeneration

Typically, a process plant requires both heat and electric power. The traditional pattern is to buy fuel and convert it on site into steam and hot water via a boiler. The electric power is provided separately by thermal power stations owned either by the national authority or the plant operator. This conversion of fuel to electricity in the conventional power station also produces large quantities of heat that cannot be used and are rejected to waste. The most recent consumption data indicate that in order to obtain a kg of final product of ceramic tile, overall around 5700 kJ of energy are necessary and this in turn, corresponds to around 6846 kJ of primary energy [1]. However, if power generation is located where the heat produced is also used, the output then represents more than four-fifths of the original heat in the fuel and the combined cost of heat and electricity is lower than when buying separately. This is the cogeneration concept: the exploitation of a single source of energy for the generation of both electricity and process heating. Co-generation or Combined Heat and Power (CHP) refer to the joint production of electrical power and useful thermal energy, such as low-temperature heat or steam. Co-generation is the coupling of the generation of electricity with the efficient use of the by-product of electricity generation: heat. Even if it is not the priority energy saving option for the company at hand, its consideration after all the other energy saving options are applied will further increase the profitability of the company. Cogeneration is not the new technology; it has been practiced by front runners in ceramic industry; Italy and Spain, before decades and greatly reduced the cost of production. The adoption of cogeneration does not modify or reduce the distribution and the amount of energy required in the production cycle, but shifts the weight away from external supplies with low efficiency to an internal, highly efficient supply, making possible to repay its original cost in less than three years.

4.4 Fuel Switching Opportunities in TCF

Energy savings can be achieved with the use of substitute low-cost fuels and the introduction of low-cost additives used as free energy producers. As alternatives to the expensive fuels such as fuel oil, coal and gas, the use of very low-cost fuel stuffs often regarded as ``waste" has been explored. For example, sawdust, if correctly processed and graded and used at a correct humidity level, can be an excellent low-cost fuel, easy to use and control. Many plants around the world use it as a cheap fuel in brick and tile production. Other waste such as olive cake, rice straw, etc. can also be employed. Alternatively raw materials with high calorific value such as coal shale, or waste-paper pulp can be mixed with the fuel and reduce energy consumption. There are some fuel switching opportunities in TCF, some are already considered by the factory management while others are identified by the researcher as potential opportunities of fuel switching to reduce the energy cost of the company. The following part deals with those fuel switching opportunity areas of TCF.

4.4.1 Using Coal in Spry Drier Instead of Current Diesel Oil

Spry drier is the equipment which is used to dry the slip in to the dust by spraying the slip over the fame from the combustion of fuel in spry drier. This equipment is used in tiles manufacturing line as the raw material preparation is done by wet grinding and the formation of biscuit tiles by dry pressing requires dry dust with the moisture content of not more than 2%. The practices in developed nations show that they use low cost fuel stuffs often regarded as ‘’waste’’ like saw dust as fuel for spry drier. This is possible because even the maximum working temperature of spry drier of TCF is 450^0C with little effort it will be possible to get this temperature by the firing of those low grade inexpensive fuels. But there is the work in the company to switch the fuel of spry drier from diesel oil to coal. But this trial has faced challenges: when firing the spry drier with the coal the coal was unable to supply the heat/temperature required by the spry drier to work effectively. As saw dust, wood and other low grade fuels are used in spry drying in other countries [1], there cannot be the reason for the coal of Ethiopia not to supply enough heat for spry drying in TCF. The picture below shows when the engineers and other workers of the company are trying their new coal fired spry drier and for the time being it failed to give the expected result. The coal used was the one from Ethiopia, and has the calorific value of 4000KJ/kg, high moisture content. But some of workers told the researcher that they have ordered some high grade coal from south Africa to be used for this purpose thinking that the failure of their trial to coal fire spry drier is due to low calorific value of the coal used, but that may not be the cause.

Figure4.5: Checking of Coal Fired Spry Drier in TCF

The main problem is not associating the science with the practice; the combustion chamber for the firing was probably manufactured by common sense rather than based on design and reasoning of the size, shape, capacity and others to get the required result. The combustion chamber for coal, shown in the picture below, is manufactured within the company. By making the system more optimum and scientific rather than by working using common sense it will be possible to fire the spry drier continuously by using the coal from within the country.

As there is only one spry drier for tiles manufacturing line any stopping of the drier for trying of anything newly done greatly causes the loss of company by causing dummy firing in biscuit and glost kilns, down time of equipments after it and so on.

If sawdust and other low grade fuel like wood are used as fuel for spry drier in developed nations, coal from Ethiopia even it has low heating value should provide heat needed by spry drier. The switching of fuel of spry drier from diesel to coal will have important meaning if it is done in a manner that will save the foreign currency to import fuel for this purpose. This will have great meaning on the economy of the company as well as the country by saving currency for oil import. It will have more economic meaning again if it uses the coal from Ethiopia, even if of low grade, rather than using imported coal. The spry drier of TCF consumes, on average, 700 liters of diesel oil per day.

Figure4.6: Coal Firing Chamber Manufactured in TCF for Spry Drier

4.4.2 Electric Water Heating in Boilers Instead of Using Diesel Oil

The annual report of the TCF shows the rate of electric energy usage in the company is very low when we see cost wise. Electric energy accounts only less than 2% of total production cost of the company. Once it was tried to replace the fuel of boilers, diesel oil, by electric energy in TCF just by using electric coils in the factory which are used in electric kilns in the laboratory of the company. This is still the work by guessing/wishing it could work rather than based on rational reasoning of the amount of heat required by water to be heated to required temperature and pressure, the capacity of coil, heat that can be obtained from them etc. Because of this reasons the trial of using electric coils to heat water in boiler failed and no another trial has been done since then to make the idea of replacing diesel oil of boiler by electric energy real. This switching will have great economic benefit to the company as well as to the country by avoiding the import of high cost fuels. This can be real by first knowing the amount of heat that should be supplied by the coil and by finding the coil with the require capacity and installing them. No much investment will be required for this purpose except the cost for the coils and installation cost since the coils will only replace the coils already inside the boiler to transfer heat b/n water and heat from combustion.

4.4.3 Using Recovered Heat for Drying

This is indirect fuel switching, using the waste heat from the cooling zone of glost kiln for drying sanitary ware and table ware products. This will avoid the cost of producing hot water in boilers by using expensive fuel and thereby increase the profitability of the company. The analysis in parts above this showed that the amount of heat waste heat from cooling zone of glost kiln alone is three times more than the heat supplied by hot water from the boiler to be used in driers. The fact that glost kiln works most of the year and twenty four hours a day makes this switching more economical and important: making it to be there when ever drying is needed. This will have great advantage in pollution reduction as well.

4.4.4 Using Natural Gas Firing in Kilns Instead of Using Kerosene

Most of the practices in developed nations show that fuel switching from liquid fuels to natural gas was done before decades based on the fact that natural gas is more clean and efficient fuel. The investment to make this switching real can be relatively high but it can do much to improve the profitability of the company and mitigating the pollution of the atmosphere. It is advisable if the company apply this option after doing economic feasibility of doing this switch and after determining the payback period of the associated investment.

4.5) Cost Analysis of some Identified Energy Saving Options

4.5.1 No Cost Measures

As said before these measures do not involve any capital investment. They mostly rely on better management and control of existing processes and equipments. The following no cost measures which can do a lot in energy saving and reducing production cost of TCF have been identified by this research. Implementing these measures will directly add up to the profit of the company since they incur no related cost. The payback period and benefit to cost ratio for these measures is zero as there is no capital investment associated with these measures.

4.5.1.1 Introducing New Firing Schedule in Glost Kiln

As it was said in part 4.1 of this paper the commonly used pushing speeds of kiln car in glost kiln are 46-60 minutes per kiln car. Using fastest pushing speed results in increased fuel consumption as well as increased production, but it causes reduction of specific fuel consumption of glost kiln there by resulting in saving of 4,908.12liters of kerosene which is equivalent to 69,448birr annually.

4.4.1.2 Introduction of New Firing Schedule in Biscuit Kiln

Experiences and calculation of the situation shows that there is certain firing schedule in kilns which can result in maximum possible profitability as far as firing schedule is concerned. The amount of energy saving that can be achieved by introducing and applying new firing schedule in biscuit and glost kilns is shown in the analysis part and there is no capital investment associated with this measure too. The saving associated with this measure is 8040 liters of kerosene 113,766birr annually with current fuel cost.

4.4.1.3 Optimizing Loading of Glost Kiln Car

Loading currently working cassettes to their maximum potential in TCF can result in significant saving of energy. As it was seen during the initial survey in the factory most of the cassettes are not fully loaded due to different reasons like using broken cassettes, not carefully loading and others. But the analysis made above in section 4.1 shows that significant amount of fuel can be saved by using normally working cassettes and loading them fully. The saving that can be achieved by this measure is equivalent to 15,463.8 liters of kerosene per year or 218,040birr per year.

4.5.1.4 Optimization of Loading Kiln Cars in Biscuit Kiln

The experienced workers in TCF say that it is possible to increase the amount of biscuits loaded in kiln cars before firing in biscuit kiln but they never did. But increasing the number of tiles loaded in single kiln car is possible and can result in significant saving which is equivalent to saving 50250 liters of kerosene or 711,037 birr annually with no related cost to it.

4.5.1.5 Optimization of Kiln Car Loading in Shuttle Kiln

Optimization of kiln car loading means loading the kiln cars to 100% of their potential and thereby reducing SEC by producing more products with a given energy usage. This is no cost energy saving opportunity and by knowing this great attention should be given to the way the kiln cars are loaded. The analysis in section 4.2 shows the saving up to 15,929 liters of kerosene in one year, which is equivalent to saving 557.515GJ of energy per year can be achieved by implementing this measure seriously. With the current cost of fuel used the saving is equivalent to saving 225,395.35 birr per year.

4.5.2 Low, Medium and High Cost Measures

Low cost measures are those energy efficiency options with small capital investment which will yield a payback period of less than one year and very high benefit to cost ratio which is very good. Sometimes it also includes some management strategies such as awareness training. Capital investment needed for minor modifications or metering purposes. Medium cost measures are those which involve substantial investment and extensive management strategies. The payback period will be between one and three years and benefit to cost ratio above one but less than that of no cost measures benefit to cost ratio. High cost measures involve very high capital investment and major changes in the process and technology. The reward will be huge amount of saving but the payback period is relatively longer-three years and above and low BCR.

4.5.2.1 Reducing Rejects from Biscuit Kiln

As it was said before there is on average 25% loss of products after firing in biscuit kiln in TCF. Problems or unfavorable working conditions of machines in inspection line, problems in temperature distribution inside the kiln, leakages of cold air in to the kiln, lack of care to products by workers, last but not least problems in raw material preparation are among the causes of the failure. Actually it is difficult to completely avoid loss of products after firing in biscuit kiln but from the situations observed in TCF it is possible to reduce the loss to at least 10% from current 25%. This, however, will involve some investment to periodically maintain and or replace machines in inspection line-as this are very simple machines whose malfunctioning greatly cause the loss of products, to train workers the importance of each single tile after fired in biscuit kiln and the cost associated with them as they passed all the manufacturing line from raw material preparation to biscuit firing, to control temperature distribution inside the kiln more closely and carefully-this will involve testing the thermocouples which has been serving for at least 15 years and replacing them as necessary or maintaining them, giving great care to raw material preparation-realizing the dust has acquired its required properties before die pressing. These measures will reduce the loss after biscuit firing at least to 10% from current 25%. The rough costs to implement these modifications are:

- Replacing/maintaining inspection machines-50,000birr
- Training workers for 2-3 days (those who work in inspection, loading, transport of biscuits etc)- 50,000birr
- Controlling temperature distribution seriously (maintain and or replace the existing thermocouples)-60,000birr
- Realizing the quality of dust for biscuit production (training laboratory staff and raw material preparation workers about the importance of quality raw material preparation and maintaining the laboratory equipments which are not giving service)-100,000birr
- Yearly cost for maintaining thermocouples and inspection machines-40,000birr
- Total cost to reduce rejects/loss after fired in biscuit kiln-300,000birr
- Annual saving in case when loss after firing in biscuit kiln is reduced to 10%-37,587 liters of kerosene or 531,856birr [cost of a liter of kerosene 14.15birr when the research was done]
- $n_{payback} = \frac{C_{initial}}{R_{annual-}C_{annual}}$

Where: $n_{pay\text{-}back}$-Simple payback period of investment in years

$C_{initial}$-Initial investment cost of the project

R_{annual}-Annual revenue or benefit associated with the project

C_{annual}-Annual cost associated with the project

- $N_{pay\text{-}back}$ =260,000birr/491,856birr/year=0.53year

4.5.2.2 Avoiding Dummy Firing in Biscuit and Glost Kilns

The worst of all practices observed in TCF regarding energy usage is dummy firing-the condition in which the kiln and the kiln car is fired without use full products or tiles inside. Said simply it is firing the kiln and kiln car only. The potential reasons for this can be shortage of raw material for producing tiles, failure of the whole or part of raw material preparing equipments like ball mills, stirrer, spry drier, and hydraulic die press. Dummy firing should be avoided with any cost and preventive maintenance should be done to avoid failure of the fore mentioned equipments and spare parts should be bought and some decisive equipments like fuel pump of spry drier and fans, nozzles and other which are necessary should exist as at least two so that immediate replacing is to be done when the other fails. Last but not least the supply of all necessary raw materials should e secured. Rough cost estimate to do the mentioned measures:

- Cost of preventive maintenance (it may involve hiring well qualified maintenance engineer, necessary equipments for preventive maintenance etc)-100,000birr
- Cost of buying candidate equipments to replace existing ones in case later fail-500,000birr
- Securing the supply of enough raw material-this will require the concern and responsibility of concerned body and will not require extra cost for raw material
- Annual cost for maintenance of newly bought equipments-50,000birr
- Total cost of investment to avoid dummy firing- 650,000birr
- Total annual saving in case dummy firing in glost and kiln is avoided-36,000liters of kerosene annually or 504,000birr per year [cost of kerosene when these research was done is 14.15birr/liter]

$$n_{payback} = \frac{C_{initial}}{R_{annual} - C_{annual}}$$

Where $n_{pay\text{-}back}$- Simple payback period of investment in years

$C_{initial}$-Initial investment cost of the project

R_{annual}-Annual revenue or benefit associated with the project

C_{annual}-Annual cost associated with the project

$N_{pay-back}$ =600,000birr/454,000birr/year=1.32years=16months

4.5.2.3 Better Load Management in Glost Kiln

This one will involve designing and producing new cassettes with the capacity of 18tiles per cassette within the factory. As said before the current cassettes have the capacity of 14/15tiles and most of them are defected. There are however two types of cassettes in TCF, first one is the one which is as old as the company and which was manufactured somewhere abroad and imported. This one is relatively light in weight and stronger. The second one is the one manufactured in TCF and it is relatively heavier and brittle. We have already seen that the amount of mass to be fired is directly proportional to fuel consumption of kiln. Therefore reducing the mass of cassettes while enabling them to hold three or more tiles has double advantage; first energy saving due to reduced mass and second energy-saving due to increased production. A previous experience in TCF shows that they have manufactured cassettes from the raw materials there in the factory. Now by extending that experience and assisting the manufacturing of cassettes proper design and material selection that will give the best possible result, it is possible to produce these new cassettes for glost kiln and the following investment will be required.

- The budget requirement for the design of the cassettes-50,000birr
- Cost for special raw materials-200,000birr
- Preparation of raw materials, casting, drying and firing of the cassettes can be done in TCF by labor and processes already there; these will involve no extra cost
- These cassettes, as they will have lower mass than the ones currently being used, will have double advantage: energy saving due to reduced thermal mass and due to increased production
- The saving due only to increased production of tiles when these cassettes are put to work is 77,307.692liters of kerosene per year or 1,082,298 birr per year [considering cost of kerosene per liter when these research is done i.e. 14.15birr per liter]

- There is no annual cost associated with these measure as cassettes do not need maintenance as once made and are expected to serve for at least 14 years as experiences show
- $n_{payback} = \frac{C_{initial}}{R_{annual} - C_{annual}}$
- Where: $n_{pay\text{-}back}$ -Simple payback period of investment in years

  $C_{initial}$-Initial investment cost of the project

  R_{annual}-Annual revenue or benefit associated with the project

  C_{annual}-Annual cost associated with the project

- $N_{pay\text{-}back}$ =250,000birr/1,092,298birr/year=0.23years=2.7months

5.4.2.4 Optimization of Tiles Drier

This will involve the use of existing fan effectively to drive more heat from cooling zone of biscuit kiln into the drier and installation of humidity measure as well as realizing that the thermocouple that measures temperature distribution inside the drier. Driving more heat to drier will help increase the temperature of the drier which in turn will reduce drying cycle thereby improving production. This is low cost investment with very attractive payback period of less than half a year. The fact that investment required for this measure is as low as installing humidity measuring equipment and maintaining existing systems and the benefit is in many ways makes this very important measure that should be done in no time.

4.5.2.5 Implementing Monitoring and Targeting [M&T]

This is low cost measure and can result in huge saving in case applied properly. Its meaning and what it involves are explained in detail in section 4.1 of this document. The main aim of this part is to roughly estimate cost of implementing M&T and saving then after. The savings that can be achieved by properly implementing this measure in tiles manufacturing line is up to at least 10% and if we consider only annual thermal fuel cost in this department the saving will be 1,161,362 birr with current cost f fuel.

- Avoiding dummy firing by preventive maintenance and any other means is saving loss of 36,000liters of kerosene or saving money equivalent to 509,400birr by current fuel cost.[cost f kerosene when this research is done was 14.15birr per liter]
- If the current failure rate/loss of tiles after firing in glost kiln is reduced from current 17% to 10% it will be possible to save up to 880,621 birr per year or 62901liters of kerosene.
- The cost related to implementing monitoring and targeting is training workers and maintaining effectively the existing equipments, usually relating energy consumption and production setting targets to reduce consumption and increase production etc. The investment to practice M&T will not cost more than 500,000birr for tiles line of manufacturing.
- Implementing M&T with the above mentioned cost will give advantages beyond mentioned above and the payback period will actually be lower than the one calculated using the above savings.
- $n_{payback} = \frac{C_{initial}}{R_{annual} - C_{annual}}$

=500,000birr/1,390,021birr/year=0.36years=4.3months

4.5.2.6 Heat Recovery from Glost Kiln

The waste heat from cooling zone is significantly large to supply the drying need of S/W and T/W products which is currently being supplied by hot water boilers. The analysis in section 4.1 and practices in developed countries ceramic industries shows that waste heat from cooling zone of glost kiln can supply 100% heat required for drying purpose. In the case of TCF this can be done by little investment and can result in saving of money related to operating boiler to produce hot water for drying. Investment and saving y implementing this measure are shown below:

- Motor and fan to drive the hot air is already there, the lines for hot water can be used for leading of hot gas from cooling zone of glost kiln to the point of use with little maintenance at valves and couplings. The only thing that will e needed is duct to connect the exit of cooling zone with the hot water line and duct and fan to lead the hot gas after end use to atmosphere, and installation cost. This together will not cost more than 200,000birr as all aluminum ducts can be obtained from within the company and the cost is for fan to drive hot air to atmosphere after end use.

- Benefit by using recovering of heat by considering only cost of fuel for boiler operation, and by avoiding cost of boilers operators, cost of maintaining boilers, chemicals for water treatment, is equivalent to saving at least 25,266liters of diesel oil annually or about 555,857birr annually by considering current cost of diesel oil.
- When accounting all the savings associated with implementing this saving opportunity the payback period will actually be lower than that indicated below.
- $n_{payback} = \frac{C_{initial}}{R_{annual-C_{annual}}}$

=200,000birr/555,857birr/year=0.36years=4.3months

4.5.2.7 Installing High Speed Burners in Biscuit & Glost Kilns

As for both kilns the currently working burners are some which are located in firing zone only very few in heating zone, the replacing of current burners with high speed burners will involve buying some of mentioned burners. The saving after implementing the installation is calculated in section 4.1 by taking least possible saving incase traditional burners are replaced by new these burners and is at least 829,543birr per year. Assuming the cost of this burners and installation cost to be 1,000,000birr the payback period of this investment is:

$$n_{payback} = \frac{C_{initial}}{R_{annual-C_{annual}}}$$

=1,000,000birr/829,543birr/year=1.2years=14.5months

4.5.2.8 Installing Law Thermal Mass Kiln Cars for Biscuit & Glost Kilns

As shown in section 4.1 this saving opportunity is also one of major energy saving opportunities identified in TCF and should be implemented in no time. This can be done either by completely replacing the currently working high thermal mass kilns with newer low thermal mass ones or reducing the mass of the existing kiln cars by maintaining them. Considering the current financial capacity of the company it would be more feasible if maintaining of the existing cars is done in the way to reduce its mass by 20%. This is b/c maintaining the existing kiln cars can be done with relatively lower investment and can result in the huge saving as shown in section 4.1.

- To reduce the mass of the existing kiln car, it would be necessary to buy low thermal mass linings and together with the replacing the existing bricks on the cars the cost for cars of biscuit as well as glost kiln could be as high as 1.2million birr.
- The saving after kiln car weight reduced by 20% is equivalent to 205,187liters of kerosene in a year and with the price of this fuel when the research is done the saving is equivalent to 2,903,403birr annually.
- $n_{payback} = \frac{C_{initial}}{R_{annual} - C_{annual}}$

=1.3million birr/2,903,403birr/year=0.45years=5.3months

4.5.2.9 Fast Firing and Installing Roller Kilns

Installing roller kilns to adapt fast firing is the best option of reducing energy cost of the company very significantly. It has also many other advantages b/c it avoids the use of current biscuit and glost kilns which are very inefficient. The annual saving with current production rate of tiles after installing roller kilns will be above 500,000liters of kerosene equivalent. In addition to that the high rate loss of tiles in each step of firing in biscuit and glost kilns due to unfavorable conditions in these kilns will be history when firing with roller kiln. These measures will save the company from the crisis which it is faces due to increasing energy cost and using highly ineffective, wasteful kilns, all other mentioned energy saving opportunities being temporary and slight remedies for the crisis of the company. The saving by working with roller kilns will be at least 7,075,000birr annually by considering cost of a liter of kerosene when this research was done i.e. 14.15birr/liter. The saving that comes together with installing roller kiln is in many ways than that indicated here and the payback period will be and the real

- Assuming the cost of installing single roller kiln to be 20million birr the payback period of this investment will be:
- $n_{payback} = \frac{C_{initial}}{R_{annual} - C_{annual}}$

=20miilion birr/7,075,000birr/year=2.82years

4.5.2.10 Installing Law Thermal Mass Kiln Cars for Shuttle Kiln

Among other kilns in TCF this is relatively efficient and operates in a way that at least satisfies the workers of the company including the management staff. This however doesn’t mean there is opportunity to make it operate more efficiently. One of the opportunities to save energy in shuttle kiln is to reduce the mass of kiln cars of the kiln. As said in section 4.2 of this paper the reduction of thermal mass of kiln by 20% can result in 35% reduction of energy consumption of the kiln. Reducing the mass of kiln cars by this amount can be done in the factory with little investment.

- The amount of investment to buy some low thermal mass materials to assist reducing of mass of kiln cars by 20% can be up to 800,000birr considering the number of kiln cars f the shuttle kiln are less in number relative to cars used in tunnel kilns.
- The saving by taking the lower conservative value is equivalent to saving 108,000 liters of kerosene per year or with the price of kerosene when this research is done the saving by this measure is equivalent to 1,528,200 birr per year.

- $n_{payback} = \frac{C_{initial}}{R_{annual-C_{annual}}}$
- Where: $N_{pay\text{-}back\text{-}}$ Simple payback period of investment in years

  $C_{initial}$-Initial investment cost of the project

  R_{annual}-Annual revenue or benefit associated with the project

  C_{annual}-Annual cost associated with the project

- $N_{pay\text{-}back}$ =800,0000birr/1,528,200birr/year=0.523years=6.3months

4.5.2.11 Installing High Speed Burners in Shuttle Kiln

Both the importance of using high speed burners over traditional ones as well as the possible saving that can be achieved after implementing this measure are indicated in detail in section 4.2 of this paper.

- The investment to replace the existing burners with newer high speed burners is up to 500,000birr for shuttle kiln since the burners are only 10 in number.
- The saving after implementing the installation of high speed burners will be equivalent to the 54,000 liters of kerosene per year of 1890 GJ of energy per year. By the current price of the fuel used the saving is 764,100 birr per year.

- $n_{payback} = \frac{C_{initial}}{R_{annual} - C_{annual}}$

=500,000birr/764,100birr/year=0.65years=7.85months

4.5.2.12 Optimization of Drier and Casting Shop of S/W Dep't

This will involve reducing leakages of cold surrounding air to drier room, proper insulation of ducts, maintaining uniform temperature and humidity level, installing the devices to measure decisive parameters like temperatures and humidity, knowing the optimum conditions for drier operation and others. By optimizing the drier and casting shop operation it would be possible to save the fuel needed by at least 5%. As these equipments have consumed 20,213liters of gasoil in nine months time the 5% saving would mean saving about 1,010 liters of gasoil or 38.4GJ of energy in nine months for sanitary production line or 1262.6liters of diesel oil equivalent in a year or 27,775birr by current price of diesel oil.

- This will involve little investment like training workers to prevent leakages of cold air to casting shop and drying shop as well as to hot water distribution line by properly closing the doors and to turn off fans of casting shop in case not needed. The awareness training and other necessary investments to implement this measure will cost up to 15,00birr initially and can result in significant saving of energy.
- $n_{payback} = \frac{C_{initial}}{R_{annual} - C_{annual}}$
- Where: $N_{pay\text{-}back}$- Simple payback period of investment in years

  $C_{initial}$-Initial investment cost of the project

  R_{annual}-Annual revenue or benefit associated with the project

  C_{annual}-Annual cost associated with the project

$n_{pay\text{-}back}$ =15,000birr/22,775birr/year=0.6586years=8months

CHAPTER FIVE

RESULTS, RECCOMENDATIONS AND CONCLUSIONS

5.1 Results

There is no question that Ethiopian economy is developing at the rate which is one of the fastest economic growth rates in the world. This fastest economic growth has resulted in fast urbanization rate which in turn resulted in high growth of construction industry. But modern buildings are unthinkable without floor and wall tiles as well as sanitary equipments. Tabor Ceramic Products Share Company is the only ceramic manufacturer in the country and it produces less than 15% of the domestic ceramic products demand. In addition to that it is estimated that the demand for these materials is growing annually by 10% while TCF is facing challenges and failing to operate to its full potential i.e. it's producing up to 50% of its designed capacity because of its inefficient equipments and processes and frequent failures of old machines. The other challenges to the company are the inefficient energy consumption and increasing of fuel price. This is evident from the share that energy cost holds from total production cost in TCF. As seen in chapter three of this paper energy cost accounts almost half of total production cost in the factory and this is extraordinarily high when compared with the expected and average energy cost in ceramic industries around the world which is 5-25% of total production cost [2].

Due to this high energy cost from total production cost of the factory and due to the fact that the price of petroleum fuels is increasing from time to time, the situation of the factory productivity is worsening. Even if the company is the only of its kind in Ethiopia and despite the fact that there is big market for its products locally the company could not become competent with those who import ceramic products from abroad. The company lacks the practical knowledge of currently available energy saving technologies and techniques. However there are numerous energy saving techniques in ceramic industries which have greatly reduced energy cost in production process and were practiced in Europe, Asia, and America before decades. These energy saving options and technologies haven't yet adapted in tabor ceramics factory. That is why the energy intensity (amount (in Gj) of energy needed to produce a ton of products) of each of the production lines i.e. tiles, sanitary wares and table wares is much higher than the international bench mark energy intensity values. The analysis of comparing with international bench mark energy intensity has revealed that the tabor ceramics factory has to save above 70% of the current energy consumption trend to reach on the front runners in tiles, sanitary wares and table wares production. Achieving the existing saving potential fully would require process improvement as well as installing new and modern equipments which would require relatively high capital cost, like installing roller kiln for tiles manufacturing. This will avoid the current double firing of tiles and will help tiles manufacturing of the factory to approach energy intensity of international front runners, 2Gj/ton. The another energy saving options identified by this research will not require much capital cost to apply them they will result in substantial reduction of energy cost in production of ceramic products in TCF. These measures will require the improvement of the existing production process consequently will not need much investment cost. There are also no cost energy saving measures which are identified in TCF; improving/optimizing loading of kiln cars, and optimizing the firing schedule being some. Others which can be implemented with some investment cost and to mention some; installing low thermal mass kiln cars, installing high speed burners, using heat recovery from cooling zone of kilns, avoiding dummy firing, implementing monitoring and targeting (M&T) etc. In addition to energy saving by improving the currently operating equipments and processes, the profitability of the company can be improved also by cheaper fuels which can be obtained easily within the country. In this regard the research has identified some options to take this advantage of saving by using cheaper and locally available fuels. This can be achieved by using coal firing in spry drier replacing the currently used diesel oil firing. The coal for this purpose is available from Ethiopia. Actually it is known that the coal currently produced in Ethiopia is low grade coal with lower heating value, but it can supply enough energy that is needed by the spry drier. This is because the experiences of developed nations show that the spry drier of their ceramic industries use low grade fuels like saw dust, wood and others as fuel in spry drier. Another opportunity to switch fuel is using recovered heat from kilns' cooling zone to drying purposes in S/W and T/W production. The analysis in chapter four has revealed that there is more than twice energy needed for drying purpose in the factory in mentioned departments is wasted from the cooling zone of glost kiln alone. By effectively recovering this heat it can supply 100% energy needed for drying of S/W and T/W products. The experience of frontrunners in ceramic manufacturing too shows this. Finally switching of fuel of kilns from current kerosene firing to natural gas firing is another opportunity to improve the energy efficiency of TCF. There is plan that Ethiopia will be commercially producing natural gas in next five years. There is enough natural gas reserve already discovered for this purpose and the work is already on the way. This is very good news for not only TCF but also all Ethiopian industrial sector. The experience of the models in ceramics manufacturing and common practice around the world most of the kilns of ceramics manufacturers use natural gas to fire their products. The advantage of using natural gas firing in kilns will be multiple; first it is known that natural gas is cleaner and environmentally friendly fuel among fossil fuels and less polluting, secondly it will reduce energy cost of the factory in total production cost thereby increasing its profitability, and thirdly the country will save foreign currency which would have been used for importing fuel.

Even if the cost of electrical energy is much lower (about 5% of total energy cost) when compared to thermal energy cost in the company, there are still opportunities to make it even lower. Similar to thermal energy, the company has not adapted available and known methods of saving electrical energy too. This is evident from the facts that the electrical motors which are major consumers of electric energy of the company are as old as the company. But it is known that installing high efficiency motors pays back the cost within two years and directly adds to the profit of the company then after. The another opportunity is to save electrical energy is by optimizing compressed air system and by installing variable speed drives as well as installing efficient lighting system.

As it can be seen from table 5.1 most of energy saving opportunities can payback investment cost related to them within a year time. The energy saving opportunities in the current paper deal with thermal energy saving mainly b/c it accounts for more than 94% of total energy cost in TCF. For the case of tiles line of manufacturing the installing of roller kiln will avoid the implementation of energy saving options listed from 1-12 in the table 5.1 below because it will avoid the use of biscuit kiln and glost kiln as well as things related to them to produce tiles thereby resulting in new efficient production of tiles by single firing and resulting in the saving of 17,500GJ of energy per year.

Table 5.1 Energy Saving Opportunities, Related Savings and SPP

No.	***Energy Saving Opportunity***	***Annual Energy Saving that can be achieved (GJ)***	***Simple payback period (SPP)***	***Remark***
1	Optimization of Kiln Car Loading for Biscuit Kiln	1,758.75GJ	-	No cost measure
2	Reducing Rejects from Biscuit Kiln	1,315.545GJ	0.53years	
3	Avoiding Dummy Firing in Biscuit and Glost Kilns	1,260GJ	1.32years	
4	Optimization of Kiln Car Loading for Glost Kiln	510.305GJ	-	No cost measure
5	Optimization of Kiln Car Loading for Glost Kiln (new cassettes with capacity of 18tiles)	2,705.769GJ	0.23years	
6	Introduction of New Firing Schedule of Biscuit Kiln	281.4GJ	-	No cost measure
7	Introduction of New Firing Schedule of Glost Kiln	171.78GJ	-	No cost measure
8	Energy Saving by Monitoring & Targeting (M&T) System in tiles dep’t	2,872GJ	0.36years	
9	Heat Recovery from Cooling Zone of Glost Kiln	2,062GJ	0.36years	
10	Better Maintenance of Kiln Cars	577GJ	1.2years	
11	Installing High Speed Burners in biscuit and glost Kilns	2,051GJ	1.2years	
12	Installing Law Thermal Mass Kiln Cars for Biscuit & Glost Kilns	7,181GJ	0.45years	
13	Fast Firing and Installing Roller Kilns	17,500GJ	2.82years	SPP may be much below this value as the cost of installing roller kilns is somewhat exaggerated to

				show that it is feasible to implement even with that high cost
14	Installing Law Thermal Mass Kiln Cars for Shuttle Kiln	3,780 GJ	0.523years	
15	Optimization of Kiln Car Loading of Shuttle Kiln	557.515GJ	-	No cost measure
16	Implement Periodic Inspection and Adjustment of Burners in the Shuttle Kiln/Installing High Speed Burners	1,890 GJ	0.65years	
17	Heat Recovery from Cooling Zone of Glost Kiln	960GJ	0.36years	
18	Optimization of Drier and Casting Shop of S/W Dep't	48GJ	0.6586years	
19	Applying Monitoring and Targeting (M&T) System in S/W Production Line	603GJ	-	Low cost measure with SPP less than one year
20	Boilers and Steam Distribution	119GJ	-	Low cost measure with SPP less than one year

Another advantage of energy saving is reducing the emission of environmentally harmful gases like carbon dioxide. In the case of tiles department the annual emission reduction when implementing the energy saving options listed from 1-12 in table5.1 will be above 1500tons of carbon dioxide and if roller kiln is installed will be 1300tons of carbon dioxide. Implementing energy saving options from no. 14-20 in table 5.1 the emission that can be prevented annually is equivalent to 591tons of carbon dioxide.

5.2 Recommendations

The fast growing economy of Ethiopia has resulted in high rate of construction of modern houses, hotels, commercial buildings, universities and colleges, health centers and others which use large amount of ceramic materials especially tiles and sanitary wares. The studies show that the countries ceramic products consumption is growing at the rate above 10% annually. Despite this the TCF being the only ceramics manufacturer in the country supplies much below the quarter of the countries demand. The remaining which is up to 80% is imported. In the first hand the government of the country should give attention to the ceramics sector, at least there should be enough ceramics manufacturing industries which can supply the whole demand of the country if not export to foreign market. This will improve the countries trade balance, and will open employment opportunity for many Ethiopians.

In case of tabor ceramic products Share Company, it is producing about half of its designed capacity. This has negative impacts on its productivity and profitability. As a company if it has to be profitable and competent in the market, then many improvements need to be done in the factory. As the increasing fuel price, high energy consuming and inefficient kilns and other equipments are the major challenges that are hindering the company's profitability the management of the company has got a big home work of solving these challenges. The energy saving and fuel saving opportunities identified to be applied in TCF should be implemented to save the company from financial crisis which it is facing currently from high energy cost and inefficient equipments. The management of the factory should take the following measures to make identified energy saving opportunities and fuel switching opportunities real in their company:

- The company should have energy management team lead by the energy manager. The team may include in plant department heads, managers, engineers, supervisors, operators and others. They should be provided with every resource needed for their work and their target will be to reduce energy cost of the company, adopt known and new arrival technologies in energy saving in the sector to their company etc. Japan is one of the leaders in industrial sector in the world and every factory in Japan has energy manager that contributed to their success in international market. Not only TCF but also other industries in Ethiopia should learn from the Japanese experience. This measure may involve hiring experienced person in the area of energy saving to lead the team.

- After the first measure the implementation of no cost energy saving opportunities should be done in no time since there is no cost associated with implementing them.
- Then other measures that should follow immediately are like effectively recovering waste heat from cooling zone of tunnel kilns including glost kiln to replace the use of boiler to generate hot water for drying ceramic wares. This measure will at least save the money expended to buy fuel of boiler and cost of operating it. The following measure should be installing LTM kiln cars for tunnel kilns in the factory. The saving that can be achieved by this measure will be highly significant and directly related to the amount the mass of kiln car furniture is reduced.
- All other thermal energy and electrical energy saving opportunities identified by the current research are those known energy saving methods which have been implemented in developed countries ceramics sector before decades and should be implemented in TCF now.
- Among the technologies that helped the developed countries ceramic manufacturers to produce their products at lowest possible specific energy consumption, the technology of fast single firing of tiles in roller kiln takes the lions-share. Since more than half of energy consumption in the factory and production capacity is that of tiles manufacturing it will be the most important measure to reduce the energy consumption and cost of the production.
- Lastly shifting from diesel firing to coal firing in spry drier is already under the way but they are complaining that the domestic coal can’t supply the required heat, but it can since fuels like wood and saw dust could. It was may be b/c of ignoring design consideration and using common sense. Any way the shifting will not have much value to the factory as well as to the country if coal is imported. In addition to that the shifting of fuel of all of kilns to natural gas should be considered since it is cleaner fuel and above all it is going to be produced in Ethiopia commercially in coming five years.

5.3 Conclusion

The energy saving practices in the industries has the advantage of increasing the profit of the industries; conserve the non renewable energy reserves of the world and reducing the emission of polluting (GHG) gases. In the case of Ethiopia much of the national budget is spent for importing petroleum fuels. Unlike the case of developed world in Ethiopia the energy share of industrial sector is much lower and the main consumers of energy are households, transportation sector, and service providers. But now the industrial sector of the country is growing rapidly and it is better if the energy efficiency is given great attention by taking late comers advantage. This will have great impact in the economy of the country. The existing industries as well as other energy intensive institutions should practice energy auditing and at least adapt the available technologies which are being implemented in developed world. The government too has to give attention to energy saving technologies in every sector not less than expanding energy producing plants. The universities and other concerned professional associations have to do their part in this regard by working with the industries helping. Managers of the industries should not overlook the profits that can be achieved by properly implementing energy saving endeavors. The plant level managers and engineers should always update themselves with new arrival technologies and methods in saving energies. Workshops should be prepared at the plant level and also at the national level to train energy managers of the companies and factories.

Lastly the energy saving as well as fuel switching opportunities identified by current research to be implemented in TCF are those which are proved effective after applied in the leading countries in ceramics production technologies like Spain and Italy. They implemented these technologies long ago, and have enjoyed the related reward. However it is not too late for TCF to implement these technologies and enter in to the track of competitors. The increasing productivity of the company will in one way or another help many people. In the first row are above 400 employees of the company. The country will also save some of foreign currency that could have spent for importing ceramic products when the company supplies its products using its full potential. The reward of being energy efficient and using locally available fuel is many to company and to the country development as well.

Reference

[1] C. Agrafiots, T. Tsoutsos, Energy Saving Technologies in European Ceramic sector: a systematic review, applied thermal engineering 21 (2001) 1231-1249

[2] Ceramic Industry Handy manual by UNIDO, Output of a Seminar on Energy Conservation in Ceramic Industry, Energy Conservation Center (ECC), Japan 1994

[3] Energy efficiency in ceramics processing, Practical worksheets for industry, http://www.tangram.co.uk

[4] Craig B. Smith,Dockside Consultants, Inc. Barney L. Capehart, University of Florida. Wesley M. Rohrer Jr, Industrial Energy Efficiency and Energy Management

[5] The Nine Months Performance Report of Tabor Ceramic Products Share Company; Hawassa, Ethiopia 2003e.c

[6] Vilnis Vesma, Monitoring and targeting for industrial energy users, Action Energy / British Ceramic Confederation, 1 September 2003

[7] Global Industrial Energy Efficiency Benchmarking, an Energy Policy Tool, working paper November 2010, UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNDO)

[8] http://www.tangram.co.uk, Energy Management in Ceramics Processing.

[9] Hesse, V.: The problems of energy consumption of tunnel kiln cars in fast firing tunnel kilns. ZI Ziegelindustrie International, 2001, 3, 13-20

[10] Hohlfeld, K.: Reduced kiln furniture weight for H-setters for firing roof tiles. zI Ziegelindustrie International, 2005, 3, 19-28

[11] Coudamy, G.: Energy Saving and optimised firing thanks to new technology: "Entropy+". cfi/Ber. DKG, 2003, 9, E53-E60

[12] Junge, K.: Sintering aids for reducing the final firing temperature and energy saving. ZI Ziegelindustrie International, 1998, 10, 686-687

[13] Vogt, S.: Way to efficient use of energy. ZI Ziegelindustrie International, 1998, 8, 496-501

[14] ETSU, Harwell, et al, Good Practice Guide 164' Energy Efficient Operation of Kilns in the Ceramic Industries', (London: Energy Efficiency Office-Department of

the Environment, 2001).

[15] Arif Hepbasli , Nesrin Ozalp, Development of energy efficiency and management implementation in the Turkish industrial sector, Department of Mechanical Engineering, Faculty of Engineering, Ege University, 35100 Bornova, Izmir, Turkey, 2002

[16] Turner, W. C. ed. 2005. Energy Management Handbook, Fairmont Press, Atlanta, GA.

[17] Martin, N. and Elliott, R. N. 2000. Emerging Energy Efficient Technologies, American Council for an Energy Efficient Economy, Washington, DC.

[18] Taichiro Kawase, Energy saving measures and best practices in ceramics factory, the energy conservation center, Japan, November 28, 2008

[19] Improving Compressed air system performance, a source book for industry, U.S. Department of Energy, Energy Efficiency and Renewable Energy, Industrial Technologies Program,www.eere.energy.gov/industry

[20] Cleaner Production – Energy Efficiency Manual prepared for GERIAP, UNEP, BANGKOK by National Productivity Council

[21] Financial Management, Tata Mc-Graw Hill – Prasanna Chandra.

[22] Rüdiger Köhler, KI Keramik, Energy saving concepts for the European ceramic industry

CERAMIN, Institut GmbH, D 01662 Meißen

[23] Study of Energy Sector in Ethiopia, Embassy of Japan in Ethiopia, 2008

[25] Donald R. Wulfinghoff, PE, The Four Steps of Effective Energy Management, Wulfinghoff Energy Services, Inc. 2004

[26] Waste Heat Recovery**,** Energizing Cleaner Production – a Guide for Trainers, UNEP/InWEnt, 2007

[27] Department of the Environment’s Energy Efficiency Best Practice Programme. 1996.

Energy Consumption Guide 61, “Energy consumption in the ceramics industry”.

Department of the Environment, United Kingdom.

[28] Energy Audit Workbook, Washington State University Energy Program