Energy Performance Investigation of Ethiopia Tannery Share Company

Salilish Fekadu Alene

A Thesis Submitted to

The Department of Mechanical Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of

Master of Science in Thermal Engineering

Office of Graduate Studies

Adama Science and Technology University

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DECLARATION

First, I hereby declare that this Master of Science Thesis entitled “Energy Performance Investigation of Ethiopia Tannery Share Company” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Salilish Fekadu Alene

Name of student	Signature	Date

RECOMMENDATION OF ADVISOR

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Energy Performance Investigation of Ethiopia Tannery Share Company "prepared under my guidance by Salilish Fekadu Alene submitted in partial fulfillment of the requirements for the degree of Master of Science in Thermal Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Dr. Gezahegn Habtamu		
Name of Advisor	Signature	Date

APPROVAL PAGE

I, the advisor of the thesis entitled hereby "Energy Performance Investigation of Ethiopia Tannery Share Company" and developed by Salilish Fekadu Alene, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Dr. Gezahegn Habtamu

Name of Advisor	Signature	Date

We, the undersigned members of the Board of Examiners of the thesis by Salilish Fekadu Alene have read and evaluated the thesis entitled "Energy Performance Investigation of Ethiopia Tannery Share Company" and examined the candidate during open defense. Therefore, this is to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Thermal Engineering.

Chairperson	Signature	Date
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Dr. Fitsum Salehu		03.Jul.2024
External Examiner	Signature	Date

Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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School dean	Signature	Date
Office of Postgraduate Studies, Dean	Signature	Date

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ABBREVIATIONS

Symbols	Description
AAS	Actual mass of air supplied per kg of fuel
ASME	American Society of Mechanical Engineers
ECO	Energy Conservation Opportunities
EEM	Energy efficient motor
ETB	Ethiopian Birr (currency)
GCV	Gross Calorific Value
HHV	Higher Heating Value
ISO	International Organization for Standardization
LHV	Lower Heating Value
PLC	Private Limited Company
PTC	Performance Test Code
SC	Share Company
SEC	Specific Energy Consumption
SME	Specific Mechanical Energy
SPP	Simple Payback Period

NOMENCLATURES

Symbols	Description
A	Surface area in [m^2]
AEC	Annual Energy consumption [Wh]
AES	Annual energy saving [Wh]
ATEC	Annual thermal energy consumption [Wh];
C	Specific heat capacity [J/kg K]
E	Electrical energy consumed [Wh]
I	Measured current [A]
I	Rated Current [A]
M	Mass of moisture in fuel in kg basis [%]
Pf	Power factor [%]
P	Power input [W]
P	Rated Power [W]
Q	Heat input [W]
RA	Theoretical air required [kg of air/kg of fuel]
S	Surface heat loss [kCal/hr m^2]
Ts	Hot surface temperature [^{o}c]
T_f	Flue gas temperature [℃]
T_a	Ambient temperature [℃]
η	Efficiency [%]

ABSTRACT

In this time of energy crisis and competitive market, company should be able to manage electrical and thermal energy inputs to their systems to be productive locally and internationally. One way to ensure productivity through energy management is to identify energy performances of various equipment in operation and determine energy consumption per products of each system. An energy performance investigation has been conducted on Ethiopia Tannery S.C. The major purpose of the study is to find the company's major energy consuming systems and the corresponding energy performance through data collection and analysis. Both thermal and electrical energy analysis were conducted using a number of data collected and analyzed using system's online and portable instruments. Analysis of energy bills for the past years of both fuel and electricity has been done, and is bench marked with European tanneries. The major energy consuming system of the company were identified to be boiler, steam distribution system, water pumps, electrical motors and lighting systems. The average energy consumption per meter square of leather is found to be 16.4 kWh/m^2 while the minimum average is 5.1 kWh/m^2 and the maximum is 9.4 kWh/m^2, the result of the bench mark needs further study of the process of leather production.

The various thermal energy Saving measures are analyzed and it is found that the factory can save annual cost 799,806.6 ETB and annual cost of 232,082.31 ETB can have saved by using electrical energy Saving measures. Finally, this study reveals that the total possible annual bill saving potential of the factory both thermal and electrical saving is 1,031888.91 ETB. The savings obtained are categorized under immediate, short-term and mid-term saving targets, in order to ease decision making while implementation of the recommendations.

Keywords: - Energy management, energy efficiency, energy analysist, energy conservation

CHAPTER ONE

1 INTRODUCTION

Energy efficiency matters for businesses as well as for the entire country. Businesses benefit from increased profitability. It promotes the efficient use of enhanced domestic resources, lowers energy imports, preserves foreign exchange, and lowers the capital needed for new energy generating industries, and reduces wastage from energy usage [1].

The secret to making decisions in the field of energy management in a methodical manner is energy audit [2]. It helps to identify all the energy streams in a facility and makes an effort to balance the total energy inputs with its utilization. It measures energy consumption in accordance with its discrete functionalities [3].

A thorough energy management program can be defined and pursued with the help of an industrial energy audit. It involves verifying, tracking, and analyzing how energy is used, as well as submitting a technical report with suggestions for enhancing energy efficiency along with a cost-benefit analysis and an action plan to cut down on energy use [3]. Energy (both electric and heat), labor, and materials are frequently considered as the three main operational expenses in any industry. Energy would always score highest when it comes to the manageability of costs or possible cost savings in each of the aforementioned components, making the energy management function a key area for cost reduction [4].

An energy audit will assist in gaining a better understanding of how fuel and energy are utilized in any industry, as well as in locating potential wasteful areas and opportunities for development. It would provide a constructive outlook on quality control, preventative maintenance, and energy cost reduction initiatives—all of which are essential for manufacturing and utility operations [5].

Such an audit program will assist in maintaining focus on fluctuations in energy costs, the availability and dependability of the energy supply, selecting the right energy mix, identifying energy-saving technology, retrofitting for energy-saving equipment, etc. Energy audits, in general, help make conservation concepts a reality by providing technically sound solutions that take organizational, financial, and other factors into account and are completed within a predetermined time frame.

There are various ways to approach the plant's goal of increasing energy efficiency. First of all, energy is needed by plants to run machinery like pumps, motors, lights, compressors, boilers, etc. These crucial utilities need to be well-maintained, function properly, and be replaced as needed. Thus, effective control of cross-cutting machinery or utilities that fuel the plant's production process is a crucial component of energy management in the plant.

The process's adequate and proper operation is a second crucial element. One of the main ways to reduce energy consumption and operating costs in a plant is to optimize processes and make sure the best technologies are in place. [4], [6]

However, a drop in energy efficiency leads to other issues as well as an increase in the factory's energy use.

Therefore, doing an energy audit to improve energy efficiency is crucial to the factory's smooth operation.

Numerous high-energy-consuming industries exist, including the sugar, leather, textile, and cement sectors, among others. One of the industries with the highest energy consumption is the leather sector, which mostly uses fuel and electrical energy. The majority of the energy audits conducted on various sectors focus on thermal energy efficiency, while electrical energy also has a significant influence on the businesses [7].

One of these industries is Ethiopia Tannery S.C., which is located in Mojo, Oromia, some 90 kilometers away from Addis Ababa. In order to produce thermal and electric energy, the factory requires furnace oil and electric energy.

Factors such as boiler size, high steam leakage, and the operation of large motors should be taken into account when assessing the energy efficiency of companies.

Therefore, it makes sense to conduct this audit in order to evaluate Ethiopia Tannery S.C.'s energy usage and to find and suggest alternatives for energy saving that will lower the factory's energy expenses.

1.1 Statement of Problem

In equipment such as furnace/boilers and electric operated devices, industries use thermal and electrical energy. However, there are numerous issues with the industry sectors' ability to use energy effectively. As a result, the factories have to deal with excessive energy costs, environmental issues, non-profitability, and decreased competitiveness. [2–3]. It is nevertheless challenging for businesses, educational institutions, and schools to ensure that energy is used efficiently in their respective fields. [5][6]

The holes (issues) found at the Ethiopia Tannery S.C. Factory were: First, energy is very expensive. Second, the firm uses a boiler that is intended to create 4 tons of steam per hour at 14 bar and 210 degrees Celsius, but it actually needs to produce roughly 2.7 tons per hour at 5 bar and average temperature of 152 degrees Celsius.

This demonstrates how large the boiler is. Thirdly, the majority of the electric motors and pumping systems are running less efficiently, as was noted during the factory tour; there are large steam leaks. Fourth, there is a noticeable discrepancy between Ethiopia Tannery S.C. Factory and the benchmark when comparing their specific energy. Ethiopia Tannery S.C. utilizes 16kwh/m2 of finished leather on average for particular energy consumption, compared to an international benchmark of about 7kwh for tannery factories that use thermal energy and electricity overall [7]. As a result, this research study the factory's energy use and makes recommendations for better energy-saving strategies and actions to raise the plant's productivity.

1.2 Objective

1.2.1 Main Objective

The primary aim of this study is to evaluate the energy consumption of Ethiopia Tannery S.C. factory and to suggest energy-saving strategies and opportunities in order to lower the firm's energy expenses.

1.2.2 Specific Objectives

The specific energy audits involve:

- Identifying the machinery, equipment, and systems that consume the most energy.
- Identifying the different types of energy utilized and conducting a thorough energy audit of energy-wasting systems to evaluate the factory's energy performance
- Determine the factory's prospects for energy conservation.
- To carry out the technical and financial assessment of the potential for energy conservation that have been discovered.
- To suggest potential energy-saving methods and put out a plan of action.

1.3 Scope and limitation of the study

In order to evaluate the principal energy-consuming systems performance in the factory, a preliminary and detailed energy audit was conducted, along with measurements on the chosen machinery and equipment. The study's primary objective was gathering historical data on energy costs and production capacity. Using historical energy and production data, the preliminary audit work in this thesis project will look into and provide a hint as to whether energy inefficiency exists. The next step is to undertake a detailed energy analysis to pinpoint the causes of inefficiencies, the locations of inefficiencies, and the losses incurred; this will indicate potential areas for energy conservation and help create an action plan for them. The area of energy management is very vast and within the limitations of time, equipment and resources, it will not be possible to discuss all the aspects in the study.

1.4 Significance of the study

The owner, management, employees, and other stakeholders in Ethiopia Tannery S.C. may find it eye-opening to conduct such a study and take seriously the company's current energy performance and the options available for reducing energy costs, waste, and additional benefits obtained by implementing the identified energy-saving opportunities into practice. This research will also provide a foundation for future applications of energy-saving measures for the remaining industries and factories, supporting the Ethiopian Energy Authority's energy regulation endeavor. Generally speaking, the purpose of this study is to assess the energy performance of factories and to become aware of energy-saving measures.

1.5 Outline of study

This thesis is composed of 9 chapters with the following details. Chapter 1, introduction, the problem statement, and the general and specific objectives of the thesis and the scope of research and its significance. Chapter 2- presents the literature review. Chapter 3, discusses brief on methodology used to conduct this research. Chapter 4, discusses about energy performance analysis of boiler and steam distribution system. Chapter 5, presents energy performance analysis of electrical motors and lighting systems. Chapter 6, deals of energy performance analysis of air compressor and water pumps. Chapter 7, discusses about economic and technical feasibility analysis of energy conservation opportunities. Chapter 8 Presents the results and discussion of the thesis. Chapter 9 includes the conclusion of the whole work and recommendations for further study and energy action plan.

CHAPTER TWO

LITERATURE REVIEW

Leather factories processes skin and hides using chemical and mechanical processes into a raw leather that is used for different commercial products like shoes, bag, etc. Since skin/hides are waste products from meat processing industries, leather industry the leather industry are considered as ecofriendly [8]. Leather factories consuming electric and fuel energy for various process of the skin/hide into raw leather and they also generate solid and liquid waste. It is categorized as environment polluting factory with several odor and chemical pollution [8].

Despite, Ethiopia Tanneries dispose these waste directly to the environment without any treatment like nearby rivers, the Leather industry generates hard currency to the country next to coffee[9]. Studying the energy performance and environmental impact of tannery wastes in Ethiopian tanneries can be given priority particularly their energy performance for the sectors to be competitive in global market in line with international bench marks and foster hard currency generating capacity of Ethiopia.

2.1 Overview of Ethiopia Tannery S.C

Ethiopia Tannery Share Company is established in 1959 near the town of Mojo, about 90 km from Addis Ababa on a total area of 220,000 sq. The company is established under the cooperation agreement signed between the Ethiopian government and the Chickoslavakia government to enhance the cooperation between the two countries. However as of December 2009, the company operates as a subsidiary of pittards PLC. Pittards is a British company.

The main objective of the establishment was to harness the vast potential of Ethiopia's hide and skin and to enable the country obtain better gains from the processed products of the sector. In addition the company aims to supply semi processed and processed leather for local garment industries. The company is established to process animal hide and skin and to supply the products to local and export markets. 80% of the company products are exported to international markets in the form of both semi-finished and finished products. The remaining 20% is supplied to local markets mainly for shoe factories and garment industries. Since the establishment of the company, Ethiopia tannery has invested in modern machinery, which enables the company to be the leading supplier of finished and semi-finished leather for both domestic and export markets in Ethiopia. The company now can process, 35,000 sq. ft. of hides per day and 25000 Sq. ft. of goat and ship skins per day. However, the company has the capacity of processing 14000 skins and 1500 pcs of hide per day. The main source of the raw material which is skin and hide is sourced from the local market and major other processing chemicals, Machinery and spare parts are imported from abroad. The main products of the factory are;

- Pickle sheep skin
- Wet blue hide and skin
- Crust hide and skin
- Finished garment leather
- Finished glove leather
- Lining leather
- Finished shoe upper smooth, embossed.

2.2 Description of the tanning process in Ethiopia Tannery S.C

Ethiopia tannery S.C collects raw hides and skins from whole sellers. Most of the raw hide and skin is salted. Before the beam house, where soaking and tanning processes are carried out, some preparations like size and quality identification and trimming of unnecessary parts is carried out. In Ethiopia tannery, leather tanning from skins/hides is done by adding various such as trivalent chromium salts which react with the collagen's fibres. The chemical help to stabilize the leather. After tanning, the skins are drained and shaved, obtaining an intermediate product named "Wet-blue" due to the blue-greenish colour of chromium sulphate. If other tanning chemicals are used, like aluminium and vegetable tanning the colour can be wet white or beige then, different operations are conducted to improve its aspect and feel and to give it different textures. These processes are done with chemical processes and Mechanical operations step by step. The process steps to get finished leather skins/hides may be categorized into multiple steps in four stages[10]:

- Beam house operations,
- Tanning,
- Post-tanning
- Finishing.

2.2.1Beam house process

The Beam house operations are described as follows:

2.2.1.1Soaking

The main purpose of soaking is to re-hydrate the hides/ skins ready for subsequent processing, and to remove the salt that is used to preserve the skin prior to the beam house and for storage purpose. Ethiopia tannery uses the soaking process in drums. While, removing the salt and rehydrating the skin/hide, other substances like dirt, blood and dung may also be removed during the soaking process. The soaking can take 18-20 hours. Chemicals that can be used for this process include sodium-hypochlorite and /or wetting agent, emulsifiers, surfactants and enzyme preparations.

2.2.1.2 Unharing

The dehairing process is required to remove hair and epidermis and to make the raw hide or skin ready for further processes. The process can be made manually or by burning with chemicals in drums. The skin is de haired by manual shaving while the hide is by burning.

2.2.1.3Liming

Lime blended with sodium Sulphide is used to loosen or dissolve wool and hair. The duration of the process may reach up to one day. Chemicals include calcium hydroxide (2-10%), lime, sodium sulphide (1-4%), sodium and sulphydriate, caustic soda & Dimenthylamine. The process of liming and the chemicals to be used depends on end use and the nature of material.

2.2.1.4Fleshing

The flesh side of hides /skins can have excess fat, flesh and connective tissue are found attached, which must be removed prior to further processing. The hides/skins are individually fed through a fleshing machine Consisting of a set of revolving cylinders designated to cut and scrape away the unwanted material as the fleshed hides exit the rear of the machine

2.2.1.5Splitting

The objective of this stage of the process is to clean the hide, remove the adipose tissue and

The hair and adapt the thickness of the hide to the desired value.

2.2.2Tanning

The Tanning steps that are carried out process are the following:

2.2.2.2Deliming

The lime in the skins/hide is no longer required in the tanning process and must be removed to avoid interference with subsequent tanning stage, which occurs in acid solution. De liming using ammonium salts carries out-reduction in the pH of the pelts first.

2.2.2.3Bating

Bating is performed in the same de-lime float and uses enzymes to break down the unwanted protein and natural fat.

2.2.2.4Pickling

After beating, pelts are pre-treated by "pickling "in salt and Sulphuric acid to adjust the pH and to prevent precipitation of Chrome salts prior to their addition in the tanning process. Also, for sheepskin there is usually a degreasing step after pickling.

2.2.2.5Tanning

After the pickling process the skin/hide is chrome tanned in drums from 4 to 24 hours. chemicals include: 8-12% pelt weight of chrome tanning salt, and as little as 5-6% for low chrome processes (basic tri-valiant chromium sulphate hydrated complexes) (22-25% Cr_2O_3) 1.0% sodium bicarbonate (basifying agent to adjust pH), 0.1-o.5% masking agent-sodium formate, phthalate or salts of dicarboxylic acids, 0.1 fungicide if product is to be stored/transported in wet blue condition. The objective of this stage of the process is to partially degrade the structure of the skin to facilitate the penetration and the subsequent fixing of chemicals, to adjust the pH to the adequate value for tanning, and to stabilise the structure of the collagen by adding tanning agents (the most common ones are chromium salts or vegetable extracts). After the tanning the skins are stable and in this state they are called 'wet-blue', if tanned with chromium, or 'wet-white', if another tanning agent was used[10].

The Post-tanning steps for a conventional process are the following: shaving, neutralization, re-tanning, dyeing, fat liquoring, summing and drying. The objective of this stage of the process is to adjust the desired thickness for the skin, achieving the characteristics of fullness and colour, and to bring the skin to suitable moisture content. In this stage the skin is called 'crust'.

The Finishing stage for a conventional process consists in diverse mechanical operations and/or the application of various products on the surface to give the leather the final texture and appearance desired. According to the type of starting hide or skin or the final product to be obtained these stages can be carried out in a different way. Consequently, many variations to the conventional process can be found.

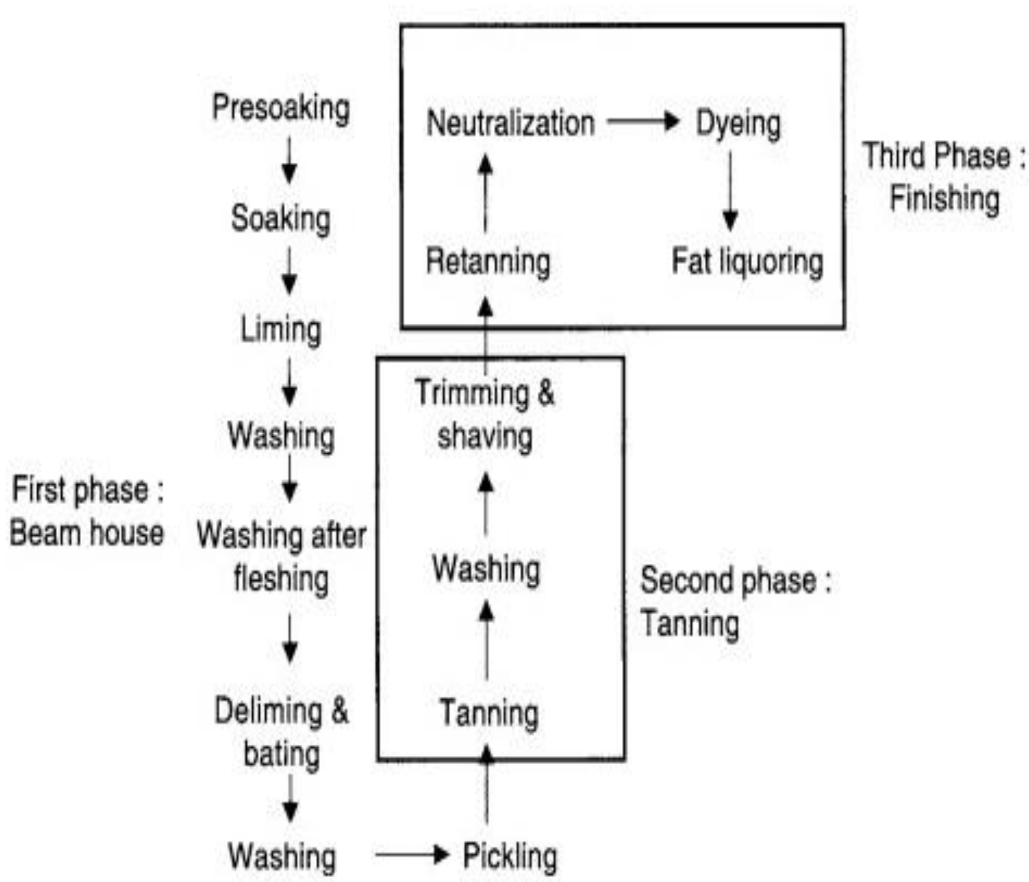


Figure 2. 1: The process to obtain finished leather from fresh hides or skins[10]

2.3 Previously published related works

Evaluating the energy performance of equipment in a factory has several advantages like energy bill monitoring, cost reduction, improve energy efficiency with energy waste minimization and enhance productivity. In this section previous works associated with energy audit /energy performance evaluation system are reviewed.

Energy audits started in the early 1970's when there was the first oil crisis [11]. In fact in 1973, the value of oil prices quadrupled, which increased the financial spending all over the world [12]. Thus energy audits identified simple energy measures which reduced the expenses, which included; switching off of lighting circuits, turning down heating temperatures, turning up air conditioning temperatures and reducing hot water temperatures. Energy audit is one of the major tool to identify the energy performance and thus cut energy wastage and demand of a facility.

[31] summarized the major activities and major roles of energy audit as:

- To identify major energy consuming systems performance and energy & energy bill saving opportunities
- To reduce energy costs
- To increase quality of environment that contributes to increase work productivity
- To minimize costs for repairs and reconstruction
- To rises awareness on energy issues and bill reduction among employee through trainings and notices.

[13] evaluated energy audit of a food, distillation and bottling company. They also stated that energy in an industry has controllable cost if audit is conducted systematically with significant economic benefit to the industry. From their energy audit survey, they come up with the following recommendations:

- Replacing oversized and old motors with proper sized and energy efficient motors help maintain a high power factor
- Connecting capacitor bank to motor load.
- Proper used of daylight when possible with carefully used of energy efficient lamps such as Compact Fluorescent Lamps (CFL's).

[38] defined energy audit as the verification, monitoring and analysis of energy use including submission of technical report containing recommendations for improving energy efficiency with cost analysis and an action plan to reduce consumption. They stated that audit work should be directed to:

- Pinpointing energy wastage systems
- Assessing energy saving potential and
- Suggesting cost-effective energy efficiency measures

[32] evaluated energy audit of Ambo Mineral Water factory. He come up with number of short, medium and long term action plans which are technically and economically feasible energy conservation measure. Some of his recommendations are

- ❖ Replacing old and oversized motors
- ❖ Preparing operational follow up plans for improve the energy performance of water pumps. .
- ❖ Maintaining water treatment plant.
- ❖ Heat insulating of boiler surface.
- ❖ Applying the energy conservation measures identified for steam leakages with regular inspections of the system.

[35] suggested the methods to be followed on determining lists of energy conservation measures as:

- ✓ Make a list of energy conservation measures obtained from audit.
- ✓ Estimate the energy savings for each energy conservation measures compared to the baseline energy use.
- ✓ Estimate the initial costs required to implement the energy conservation measures.
- ✓ Evaluate the cost-effectiveness of each energy conservation measure
- ✓ Analyzed, identified, and rank the cost effective energy the several energy conservation opportunities.

[28] investigated different measures to increase energy efficiency and reduce the primary energy consumption of a tannery located in the region of Catalonia, Spain. In particular, the energy performance of the tannery was assessed based on the protocol and the benchmarks established by the Leather Working Group. Nevertheless, the recommendations given in this paper can be adopted by similar industries with similar energy needs and high thermal energy requirements. The most promising options to increase the sustainability of the tannery were identified by considering the energy savings that can be achieved, the investment costs, and the payback period associated with each solution. The results showed that the energy

consumption of the tannery can be considerably reduced by installing a total surface of 10,000m^2 of solar thermal collectors along with replacing the current old boiler with a more efficient one.

[16] carried out energy survey of in the Sebeta Alcohol and Liquor Factory and found out that boiler, distillery columns, pumps and motors are the major energy consuming systems. Data were gathered

using portable instruments, system nameplates, online instruments installed on systems, log sheets and interview. He highlighted the followings as major energy conservation opportunities:

- The factory employees do not have awareness about energy management,
- The efficiency of furnace and boiler were found to be below the recommended values,
- There is heat loss with the effluent from distillery columns,
- Most motors operate with low load factors
- Using oversized inefficient pumps and
- Using energy consuming equipment beyond their recommended life time even without maintenance.

[37] emphasized that motor-driven systems use more than 66% of the total electrical energy consumption in industries, and electric motor should be considered as a major focus area in energy performance study. According to [33] insulation materials and insulation systems of motors determines its useful lifetime.

[27] analyzed performance of Mugher cement factory on thermal system which consumes large amount of thermal energy for clinker production. In the plant there is area where the waste heat can reduce and recovered. If the waste heat from clinker cooler, waste heat gas from pre- heater and rotary kiln shell is recovered there is a thermal energy saving up to 297.9kJ/kg-clinker. Also thermal efficiency of a plant can improve by 8.4%. Generally, if the plant possible to recover a 44.65kJ/kg-clinker thermal energy lost from kiln shell and generate 40.4 *106kWh/year electric power from hot flue gas exhaust from pre-heater & cooler, it would be possible to save currency about 87,876,143 Birr in annual. further detail work and feasibility study, there is a possible need of complete modification to improve thermal efficiency.

- Internal kiln maintenance should be by designed schedule.
- Pre-heater and tertiary air duct can be reduced by insulating them.
- In addition to the plan of reducing of energy consumption in cement production process, the recovery waste heats can be achieved in order to produce the electrical energy by utilization cogeneration power plant. As indicated above, the plant alone can provide about 5608kw.
- If the plant recover waste heat on rotary kiln shell for the use of pre-heating primary air it can increasing thermal efficiency of a plant.

[15] assessed energy conservation opportunities in cement industry in Iran, based on conducting on-site energy audits of over 30 cement firms in Iran during 2004–2005, discovered the following energy-saving potentials: electricity savings of $223.5*10^6$ KWh equivalent to 11. 3M$, fuel oil savings of $168*10^6$ equivalent to 39.4M$ in prices. They have shown the energy consumption in cement industry in Iran through real auditing and identify technological opportunities in order to decrease energy consumption of the relevant factories, increase the productivity, and improve the production process. Relevant standards planned by government that can provide significant potentials, are discussed too.

[15] Introduced new technologies like;

• Installing air filtration in Oromieh factory will save 8-11 Kcal/Kg thermal energy.

• Installing new design high-efficiency crushing, grinding, and milling equipment cyclones. High efficiency separators will reduce required electricity up to 8 %.

• Replacing high-carbon fuels by low-carbon fuels (e.g. Shifting from fuel oil to natural gas)

• Utilizing the vertical grinding mills on existing ball grinding mills will reduce 30% of energy consumption. Traditional ball mills used for grinding certain raw materials (mainly hard limestone) can be replaced by high-efficiency roller mills, or ball mills combined with high pressure roller presses. The use of these advanced mills saves energy without compromising product quality.

• Applying high efficiency burners and coolers

• Utilizing alternative fuels such as: biomass, solvents, oils, solids…

• Changing cement product formulations, applying a lower clinker to final cement mixture ratio.

They have forwarded the following Energy-efficient opportunities in cement production; Efficient fans, recycle waste heat, replace traditional mills with roller mills and high pressure pressing mills and applying efficient separators, Insulating the hot piping entering mills in order to dry materials and Continuous control of raw material level in mills and adjusting raw material size

[25] have conducted energy audit in Hindustan beverages to excavate the maximal energy-saving potential in production and management process, give proposals on energy-saving management and energy-saving technical renovation, promote the progress of management and energy saving technology, ensure the rapid and healthy development of Hindustan coca cola plant and ultimately realize the objectives. It is expected that after implementation of EMOs, the reduction of energy costs may be more than 10%. It is believed that Energy Audit is one of the most comprehensive methods in

achieving energy savings in industry and thus reducing excessive energy consumption. If the private sector participates in the implementation of the energy audit programmes to their buildings, wasteful consumption of energy will be minimised. Defined Industrial energy audit as an effective tool in defining and pursuing comprehensive energy management programme. As per the Energy Conservation Act, 2001, Energy Audit is defined as “the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption.”

[41] did energy audit of boiler and reported that 13.71 %, i.e., 1439.55 kCal/kg of fuel burnt, input heat energy is carried away with dry flue gasses. they observed that by the direct method, the boiler efficiency drifts by 4.4 % from the best efficiency. Whereas, the indirect method showed a drift of 9.06 %. This abnormal drift was due to the significant input energy loss carried away with the dry flue gasses. The heat loss due to dry flue gasses was 13.71 % of total heat input energy, i.e., 1439.55 kCal/kg of fuel burnt.

[29] investigated the energy consumption performance and possible energy saving potentials of Pasta and Macaroni Factory. The thermal performances of the two boilers are analyzed using an indirect method and the typical boiler efficiency obtained are 81% and 80% respectively. It is found that the major heat loss from the boilers is due to the dry exhaust gas. Similarly, water chiller, air compressor, electrical motors, pumps and lighting system equipment energy utilization have been analyzed. The various energy saving measures are analyzed and it is found that the industry can save 2,301 GJ/year of electrical energy by using high efficient motors instead of the existing normal standard motors, 782.6 GJ/year of heat energy can be recovered from the dry exhaust gas by using air preheater and 1,221 GJ/year of heat energy can be recovered by controlling the air to fuel ratio which is a significant energy saving potential.

[26] studied energy auditing at Arbaminch Textile factory. It was reported by this study that 10 to 20% energy savings can be achieved from equipment such as boilers, compressors, lighting system etc.

[40] addressed the energy inefficiency problems of Walia Steel Industry using production data of 23 months by conducting detailed energy audits. The main energy saving measured he identified were under loaded motors with proper sizes of motors which saves 705,210.25ETB annually and correcting power factor of and reconfiguring electric that decreases energy loss by 69.1% with annual cost saving of 167,690.43ETB.

[39] conducted an energy audit and energy efficiency improvement for Jay Jay textile factory without affecting the quality and the production. For the energy audit and data analysis, As-built drawings, energy bills, years of data records for major energy-intensive equipment, and lighting data are collected. Load flow analysis of the factory distribution network is simulated with MATLAB. Finally, energy efficiency improvement measures are recommended. Accordingly, the thesis finding shows that, the possibility of an annual energy saving of 380 MWh, which is around 10.28% of the total annual energy consumption. Energy intensity analysis is done in comparison with the benchmark showing there is an opportunity of saving 2,237,059.09 ETB/year by implementing energy efficiency improvement practices. By minimizing air leakage of the compressor and using an outside air system, the factory can save 45,403.86 kWh/year of energy or a cost saving of 47,873.84 ETB/year. Improving the factory lighting as per the required for the specific work station results in an energy saving of 113,880.00 kWh/year. However, by using energy efficient lighting 311,433.60 kWh/year of energy or 328,687.02 ETB/year can be saved. MATLAB simulation result shows that the distribution network active power loss reduced from 68.43 kW to 39.77 kW. PF correction, using energy efficient lighting technologies, and air compressor leakage prevention found the main mitigating methods to save energy.

[7] presented the results of the energy audit conducted to investigate the energy consumption pattern of company from its record of fuel expenditure and electricity bills for a period of 5 years (2012 - 2016). Also, the use of energy models system, Energy Quick Energy Simulation Tool to evaluate the consumption of the energy end users and performance of the company. Results shows peak electricity demand during the hot months from April to August due to high cooling or significant Air condition requirement. The annual average consumption demand of electricity and diesel (kWh equivalent) of the company were 118960.72 kWh and 2881.17 kWh respectively. The energy modeling and simulation results shows that the sum total of the total monthly energy consumption by the end users is 138164 kWh representing the total average value of the annual energy use in air-conditioning (space cooling) was 27%, ventilation fan 2%, factory machineries 39%, heat rejection is 4%, pump and auxiliary is 2% and area lighting 26%

2.4 Summary of Literature Survey

These different pervious works are summarized as follows;

- Defined energy audit as the verification, monitoring and analysis of energy use including submission of technical report containing recommendations for improving energy efficiency with cost analysis and an action plan to reduce consumption [38].
- To identify where energy is being consumed, assesses energy saving opportunities and to minimize cost energy is role of an energy audit [31].
- Changing oversized and old motors, repairing of water treatment plant, insulating of boiler surface and replacement of low operating water pumps are basic recommendations to decrease the cost of energy in factory [32].
- The possibility of an annual energy saving of 380 MWh, which is around 10.28% of the total annual energy consumption can achieved by PF correction, using energy efficient lighting technologies, and air compressor leakage prevention methods [29]
- The major heat loss from boilers is due to the dry exhaust gas and can be recovered by using air preheater industry can save 782.6 GJ/year of heat energy [39].

2.5 Research gap

The following research gaps are identified at the Ethiopia Tannery S.C.

- No energy consumption and performance analysis was conducted.
- Major energy consuming systems and their existing efficiency is not known.

CHAPTER THREE

3 MATERIALS AND METHODS

3.1 Introduction

This chapter introduces overall design of the study, which includes the methodology adopted for carrying out the work and various phases of this research. Details of the work done in each phase along with the tools and techniques used have also been covered in detail here.

3.2 Method

The methods employed to achieve the objectives of the research are

1. Literature Review: Previous research case studies, related books, journals & guidelines related to the subject matter have been reviewed in order to have a clear understanding of the subject matter.
2. Data collection

   The necessary data for the thesis are collected through interviews, measurements, Factory visit and also from different sources. The necessary's data like

   - The energy consumptions and production capacity of the factory for the last three years.
   - Operating hour of the factory
   - Types of fuels used
   - Cost of electricity and fuel of the factory, energy bill.
3. Analysis; Energy/mass balance and energy loss/waste analysis.
4. Identification and development of energy conservation opportunities (ECO$_S$)
5. Conduct cost benefit analysis: Technical and economic feasibility
6. Write the energy action plan with the possible energy conserving potential recommendations.

3.3 Data collection

The data collected during the initial phase of the thesis include plant lay out, operational hours, bench mark data that is used to compare energy consumption of the factory is also prepared. Three years' worth of energy and leather production data were gathered from the factory's production manager office in order to examine Ethiopia Tannery Share Company's energy use.

3.3.1 Factory energy bills data collection

The total energy consumption of the factory is the sum of the electrical and thermal energy consumption, however the fuel is measured and tabulated in terms of liters, in order to change the liter in the equivalent heating the fuel consumption is multiplied with heating value of the fuel used. The factory used Furnace oil, Diesel oil and Gasoline Simultaneously and their heating value are 40 MJ/L, 38.8 MJ/L and 35 MJ/L respectively. Accordingly, the thermal energy used in each month is calculated in kWh and tabulated in table 3.1.

Table 3. 1: Ethiopia Tannery S.C, Monthly consumption of all types of energy resources

Billing Period (G.C)	Energy Resources					
	Electric Energy	Furnace Oil	Diesel oil	Gasoline	Thermal Energy	Total Energy
	kWh	Liters	Liters	Liters	kWh	Kwh
2019						
January	288000	81700	11999.5	1103.8	1047837.9	1335837.9
February	222000	76177	10919.0	1225.8	976011.5	1198011.5
March	216000	58993	9161.0	0	754213.0	970213.0
April	216000	63665	9494.0	140	811074.2	1027074.2
May	174000	50000	16665.0	280	737889.4	911889.4
June	132000	50754	31339.5	204.1	903687.1	1035687.1
July	192000	59655	13391.1	610.6	813095.8	1005095.8
August	246000	66549	11467.6	576	868628.4	1114628.4
September	333000	54418	6360.0	284.6	675958.1	1008958.1
October	420000	56402	7657.1	0	709215.6	1129215.6
November	186000	68228	7564.0	280	842334.2	1028334.2
December	138000	84482	10930.0	333.6	1059733.0	1197733.0
Total	2763000	771023	146947.8	5038.5	10199678.4	12962678.4
2020						
January	318000	61545	7203	307.8	764454.2	764454.2
February	132000	48761	5456	522.4	605671.2	605671.2
March	114000	41286	11161	70	579704.7	579704.7
April	108000	23240	4191	0	303396.2	303396.2
May	72000	8220	5958	465.4	160071.6	160071.6
June	132000	15480	6959	799.7	254777.4	254777.4
July	72000	18160	11493	822.3	333639.8	333639.8
August	126000	24472	7184	898.9	358077.8	358077.8
September	192000	34040	5345	847.4	444068.4	444068.4
October	162000	37147	4964	583.5	471918.1	471918.1
November	132000	20640	6813	522.8	307845.0	307845.0
December	108000	19150	7325	655.4	298091.9	298091.9

Total	1506000	352141	84051	6495.6	4881716.3	4881716.3
2021						
January	108000	17006	5477	228.6	250208.1	358208.1
February	144000	20060	7792	63.7	307488.7	451488.7
March	132000	20531	5421	291.4	289381.1	421381.1
April	84000	13480	10503	289.5	265791.5	349791.5
May	120000	14900	6302	440.7	237761.9	357761.9
June	108000	12900	5421	374.2	205398.0	313398.0
July	90000	6140	7510	394.7	153000.0	243000.0
August	78000	20640	10926	37.5	347457.3	425457.3
September	150000	15560	5608.4	25.6	233583.9	383583.9
October	102000	8166	8277.5	233.1	182212.2	284212.2
November	102000	15660	7577	131.0	256936.8	358936.8
December	84000	18850	6401.7	0	278440.5	362440.5
Total	1302000	183893.0	87216.7	2509.9	3007660.2	4309660.2

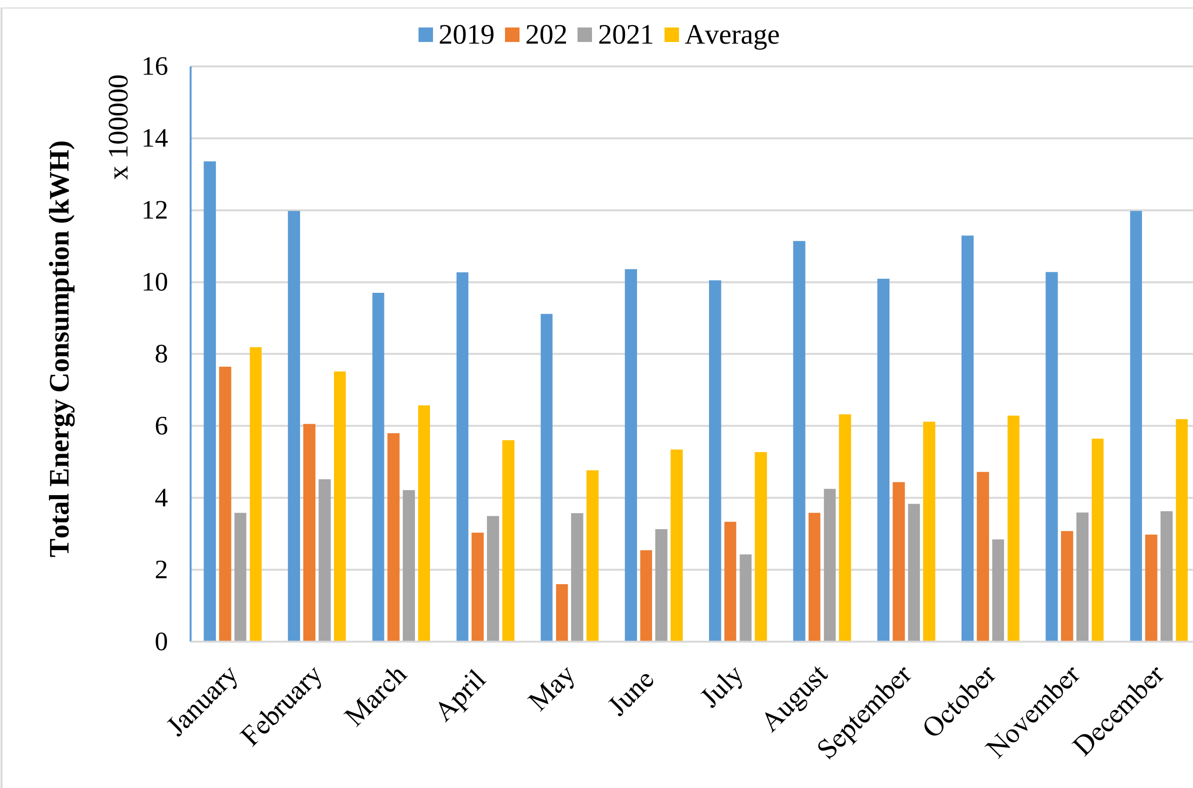


Figure 3. 1: Monthly Thermal energy and Electrical Energy Consumption of Factory

3.3.2 Factory's "Leather" production data collected

Table 3. 2: Production data collected

Months	Year			
	2019	2020	2021	Average
	Produced leather (m^2)	Produced leather (m^2)	Produced leather (m^2)	
January	98285	81410	19025	66240.2
February	106962	44583	11985	54510.2
March	88771	35069	18759	47533.2
April	88610	23316	10601	40842.3
May	89891	11443	11582	37638.9
June	68779	15170	17033	33660.8
July	90111	18862	22722	43898.5
August	86781	15293	8633	36902.3
September	114368	18243	13253	48621.1
October	141955	19952	7083	56330.4
November	58755	21662	11040	30485.7
December	64068	18850	10201	31039.4

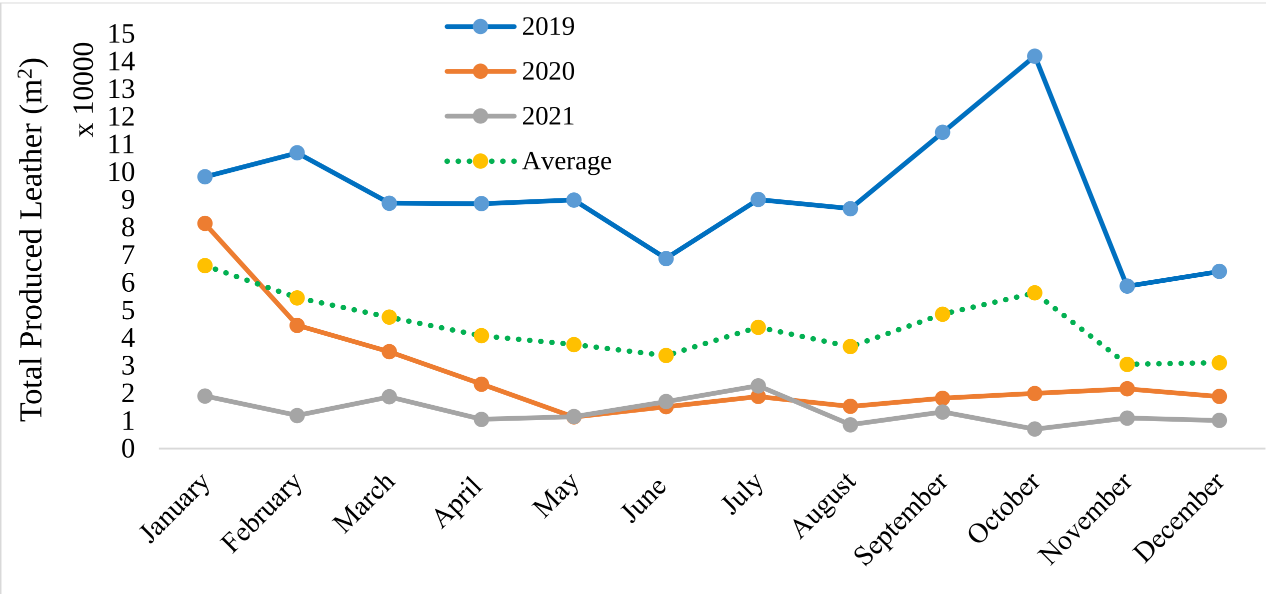


Figure 3.2: Dynamics of monthly production volume of total leather

3.3.3 Specific energy of the factory

Monthly specific energy consumption is defined as an average energy monthly needed to produce one meter square of finished leather.

Table 3. 3 The monthly Specific Energy Consumption of the factory

Production period in G.C	Specific Energy Consumption of Electricity	Specific Energy consumption of Fuels	Total Specific Energy consumption
	kWH/m^2	kWH/m^2	kWH/m^2
2019			
January	2.9	10.7	13.6
February	2.1	9.1	11.2
March	2.4	8.5	10.9
April	2.4	9.2	11.6
May	1.9	8.2	10.1
June	1.9	13.1	15.1
July	2.1	9.0	11.2
August	2.8	10.0	12.8
September	2.9	5.9	8.8
October	3.0	5.0	8.0
November	3.2	14.3	17.5
December	2.2	16.5	18.7
Total	2.8	10.4	13.2
2020			

January	3.9	9.4	13.3
February	3.0	13.6	16.5
March	3.3	16.5	19.8
April	4.6	13.0	17.6
May	6.3	14.0	20.3
June	8.7	16.8	25.5
July	3.8	17.7	21.5
August	8.2	23.4	31.7
September	10.5	24.3	34.9
October	8.1	23.7	31.8
November	6.1	14.2	20.3
December	5.7	15.8	21.5
Total	5.0	16.1	21.0
2021			
January	5.7	13.2	18.8
February	12.0	25.7	37.7
March	7.0	15.4	22.5
April	7.9	25.1	33.0
May	10.4	20.5	30.9
June	6.3	12.1	18.4
July	4.0	6.7	10.7
August	9.0	40.2	49.3
September	11.3	17.6	28.9
October	14.4	25.7	40.1
November	9.2	23.3	32.5
December	8.2	27.3	35.5
Total	8.5	19.7	28.2

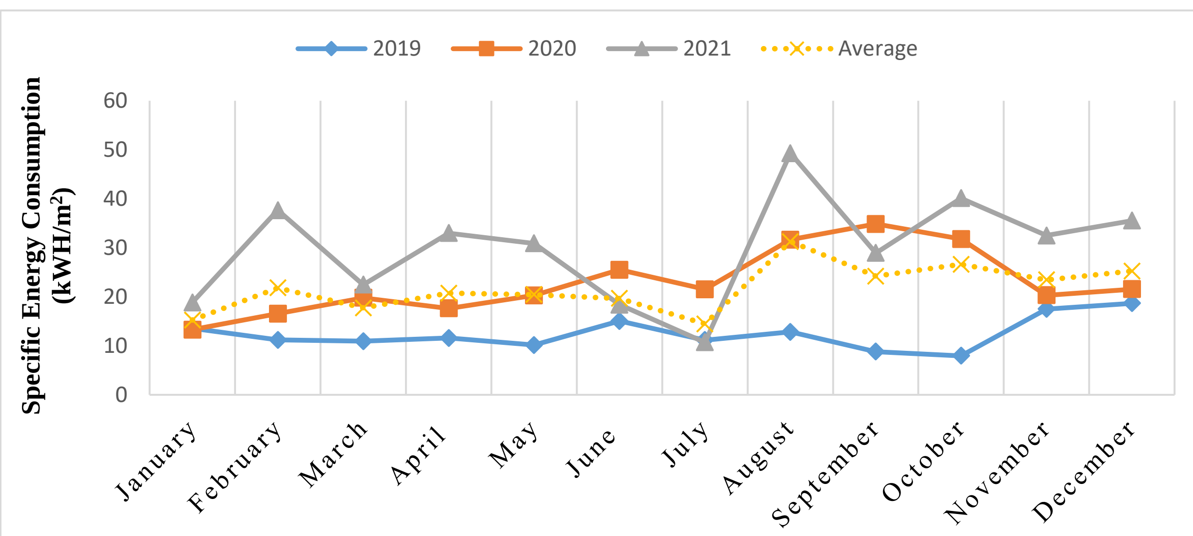


Figure 3. 3 Monthly specific Energy Consumption of Ethiopia tannery S.C

3.3.4 Data analysis of factor's energy consumption and production

Using the average total production of 36 months and the total energy consumed in 36 months. The specific energy consumption of the Ethiopia Tanner S.C is shown on table 3.4.

Table 3.4 Total energy consumed and total leather produced in three years

Year	2019	2020	2021	Total
Total Energy Consumed (kWH)	12962678.4	6387716.3	4309660.2	23660054.9
Volume of Leather Produced (m^2)	982969.7	303901.7	152748.6	1439620.0
SEC (Kwh/m2)				16.4

$$\text{SEC} = \frac{Total\ energy\ consuption\ in\ 36\ months}{Total\ Volume\ of\ leather\ produced\ in\ 36\ months} \tag{3.1}$$

The weighted average energy consumption per meter square is 7.3KWh/m^2, and it ranges from 5.1-9.4KWh/m^2 depending on the site condition and the production process. The calculated energy consumption per meter square of Ethiopia tannery S.C is 16.4kWH/m^2. It is very far from the weighted average of European tanneries. Thus, from further analysis in subsequent chapters the factory can achieve close figure to the minimum value in the range if the recommendations are implemented.[7]

3.4 Materials used

1.Combustion Analyzer: - Used to measure flue gas concentrations

2.Infrared Thermometer: -

3.Ultrasonic Leak detector: - to identify where the compressed air leak is, and some small steam leaks,

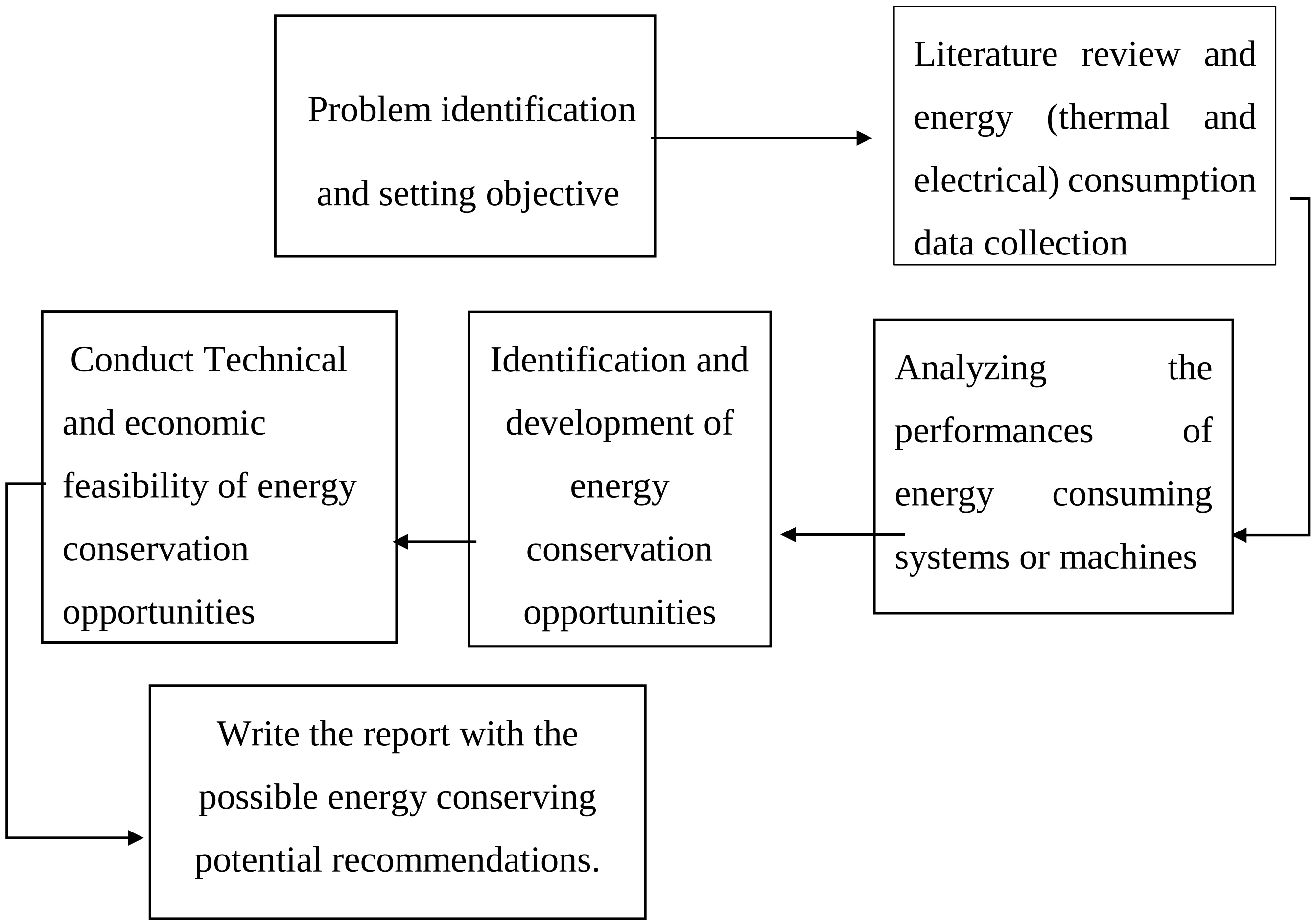
4. Thermocouple**:** Measures surface temperatures.

5.Power factor meter: - A portable hand-held wattmeter and power factor meter is very handy for determining the power consumption and power factor of individual motors

6.Non-contact type Tacho meter: - used for measurement of motor speed

In addition to the above tools, some equipment and technical has been used. In addition, some information like fuel consumption and daily working hours of the boilers is obtained by using the operator's deep stick.

The overall progress of this study implemented was presented in flow chart. The following methodology was followed to achieve the objectives of the study.



CHAPTER FOUR

ENERGY PERFORMANCE ANALYSIS OF BOILER AND STEAM DISTRIBUTION SYSTEM

4.1 Introduction to Boiler:

The energy performance analysis methods: direct and indirect (heat loss methods) are discussed in this section that are used for analyzing the energy performance of the tanner boiler. In addition, this chapter contains the energy performance analysis for steam distribution system.

Figure 4.1: Boiler of Ethiopia Tannery S.C

4.2 Boiler inspection and data collection

A variety of devices, including a combustion analyzer, IR thermometer, tape rule, thermocouple and visual inspection, were used to gather data for the boiler.

4.2.1 Data collected by visual inspection and interviews

Data gathered include, mass flow rate of blow down water, age of boiler, insulation material costs for boiler, water treatment, boiler operation hours, and other information were gathered through walk through visit and oral questioning of employee.

4.2.2 Data collected by measurement

The following important data are needed for analyzing the boiler energy performance:

4.2.2.1 Flue gases data

The portable combustion analyzer was utilized to measure the flue gas data. Using a vacuum pump, a sample is extracted from the stack or flue, and electrochemical gas sensors are used for analysis.

Figure 4.2: Stack of Ethiopia Tannery S.C

Table 4.1: Boiler flue gas data

Measurements	O_2	CO	CO_2	T-Air	T-Stack	Excess Air
	%	**ppm**	**%**		**C**	**%**
Run -1	6.7	7	15	29.8	220	14
Run-2	7.1	8.5	13.5	27.6	216	10.7
Run-3	6.4	6	14.3	25.2	226	12.6
Average	**6.7**	**7.16**	**14.26**	**27.53**	**220.6**	**12.4**

4.2.2.2 Boiler surface, blowdown and feed water temperature data

An infrared thermometer is used to detect the boiler surface temperatures (the circumference and base areas), feed water, and blowdown in order to determine the energy lost from the boiler surfaces.

Table 4.2: Boiler Surface, Blowdown and Feed Water Temperature and Ambient Temperature Data

S/N	Item	Temperature measured (^oC)	Ambient Temperature (^oC)
1	Boiler circumference	44.6	27
2	Boiler front surface	91.8	30
3	Boiler back surface	38.4	26
4	Feed water temperature	55	25
5	Blowdown temperature	115	26

4.2.2.3 Boiler dimension data

The dimension of were measured with a metre.

Table 4. 3: Boiler dimensions data

S/N	Boiler dimensions	Measured data (m)
1	boiler length	5.1
2	Diameter of front surface	2.46
3	Diameter of back surface	2.46

4.2.2.4 Volume flow rates of fluids

The following volume flow rate of fluids entering and leaving the boiler and furnace were measured as summarized in Table 4.4.

Table 4. 4: Volume flow rate of fluid

S/N	**Fluid**	**Volume flow rate (m^3/s)**
1	Feed water to boiler	7.8×10^{-4}
2	Feed fuel oil to boiler	5.9×10^{-5}
3	Blowdown	2.5×10^{-4}
4	**Steam mass flow rate = 0.759kg/s**	

4.3 Mass Balance of the Combustion System

4.3.1 Mass Flow Rate of Fuel

To analyze the energy supplied by the furnace oil, the furnace oil mass s flow rate was estimated from:

$$\text{Mass flow rate of fuel } (\dot{m}_{fuel}) = \dot{V}_{fuel\ oil} \times Density\ of\ fuel\ oil \qquad (4.1)$$

Density of Furnace oil = 960kg/m^3

4.3.1.1 Mass Balance of Fuel Combustion

Crucial factors needed to analyze the fuel energy content after and before combustion are discussed below.

a)Air Fuel Ratio of Fuel Combustion

To determine the mass flow rate of flue gases, the actual mass of air supplied per kilogram of fuel (AAS), theoretical air fuel ratio, and excess air of fuel oil are estimated.

Air supply actual mass per kilogram of fuel (AAS) = {1 + Excess Air/100} x Theoretical air 4.2a

On the other hand, theoretical air = [(11.6 x C) + {34.8 x (H 2 - O2 /8)} + (4.35 x S)]/100 kg of air and kg of oil. The ultimate analysis (%) and furnace oil composition, as shown in Table 4.5, are utilized to compute the theoretical air.

Table 4. 5: Composition of Furnace oil and Ultimate Analysis (%) [16]

No	**Component**	**% by weight**
1	Carbon	84
2	Sulphur	3
3	Hydrogen	12
4	Oxygen	1
5	Nitrogen	0.5
6	Moisture	0.5
GCV = 40 MJ/L		

$$\text{Theoretical Air} = [(11.6 \times C) + \{34.8 \times (H_2 - O_2/8)\} + (4.35 \times S)]/100 \text{ kg of air/kg of oil} \quad (4.2)$$

$$Excess\ Air\ Supplied(EA) = \frac{O_2\%}{21 - O_2\%} \times 100 \quad (4.3)$$

The flue gas measurements provided in Table 4.1 by the Combustion Analyzer are used to determine the excess air. Actual mass of air supplied per unit mass of fuel (AAS) is analyzed by

AAS = [1 + Excess Air/100] x theoretical air (4. 4)

4.4.2 Mass of Dry Flue Gases

Energy losses from flue gases must be factored into the mass flow rate of the gases. In order to accomplish this, the molecular weight of the fuel's component parts, the fuel oil's composition, and the final analysis of these are essential for the actual chemical reaction (carbon, hydrogen, and sulfur are the combustible ingredients in furnace oil) in the boiler.

Table 4. 6 : Molecular weight of the constituents of the fuel oil

Element or Compound	C	O_2	H_2	S	N_2	CO_2	SO_2	H_2O
Molecular Weight	12	32	2	32	28	44	64	18

Theoretical burning of a unit mass of fuel releases the gases shown in equation 5.5.

$$1Kg\ of\ fuel + Dry\ air \rightarrow CO_2 + H_2O + SO_2 + N_2 \qquad (4.5)$$

i) Mass of Carbon dioxide (kg) per 1kg of fuel

$C + O_2 \rightarrow CO_2$

12 + 32 → 44 ; From,12 kg of C requires 32 kg of O_2 to form 44 kg of CO_2 Therefore 1 kg of C requires (32/12 kg = 2.67 kg) of O_2. Taking ultimate analysis of C

percentage in Furnace oil (Table 4.5 :84 %)

$0.84xC + 0.84x2.67O_2 \rightarrow 3.08CO_2$

ii) Mass of Sulphur dioxide (kg) per 1kg of Oil

$S + O_2 + \rightarrow SO_2$

32 + 32 → 64

From the above 32 kg of S requires 32 kg of O_2 to form 64 kg of SO_2, therefore 1 kg of S requires (32/32 kg = 1 kg)of oxygen. Taking ultimate analysis of S percentage in Furnace oil,(table 4.5).

$0.03\ S + 0.03x1\ O_2 \rightarrow 0.06\ SO_2$

iii) Mass of Water (kg) per 1kg of oil

$2H_2 + O_2 \rightarrow 2H_2O$

4 kg + 32kg → 36kg

From the above 4 kg of hydrogen requires 32 kg of Oxygen to form 36 kg of water vapor (H_2O), therefore 1 kg of H_2 requires 8 kg of O_2. Taking ultimate analysis of H_2 percentage in oil(table 4.5).

$0.12\ H_2 + 0.12x8\ O_2 \rightarrow 1.08\ H_2O$

To determine the mass flow rate of dry flue gases we have to add up the mass of each flue gases except the water vapor. i.e.

Mass of flue gases (m) = mass of CO_2 + mass of SO_2 + mass of N_2 + mass of O_2

$$m = {}^{(0.84 \times 44)}/_{12} + {}^{(0.03 \times 64)}/_{32} + AAS \times {}^{77}/_{100} + EA \times {}^{23}/_{100}$$

But, EA=AAS-TA

Mass flow rate of dry flue gas ($\dot{m}_{flue\ gases}$) = m x mass flow rate of Furnace oil = m x $\dot{m}_{fuel}$ (4.6)

4.5 Mass Balance of Steam System

4.5.1 Feed Water Mass Flow Rate

The mass flow rate of feed water, which is determined by raising the ambient temperature to the temperature of the feed water, is crucial for calculating the input energy of the feed water. This energy can be found via:

$$\dot{m}_{feed\ water} = \dot{V}_{feed\ water} \times \rho_w \qquad (4.7)$$

Where

$\dot{m}_{feed\ water}$- Mass flow rate of feed water

ρ_w _ Density of feed water(kg/m^3)=985 kg/m^3 at 55°C

$\dot{V}_{feed\ water}$ _ Volume flow rate of feed water

Using Table 4.4 for Volume flow rate of feed water and steam table for density of water at 55 ^oC ,mass flow rate of feed water can be determined using equation 5.7.

4.5.2 Mass Flow Rate of Blowdown

The mass flow rate of blowdown is crucial to calculate the energy lost as a result of blowdown. There are two shifts in a day at the factory according to interviews and factory observations, the factory releases (blows down) twice a shift for roughly 20 seconds each time. Therefore, the total time blowdown per day is equal to 2 shifts x 2 blowdown/shift x 20 seconds/blowdown = 80 seconds. It took 12 seconds to fill a container with 3 liters during blowdown using a stopwatch and a 2-liter container because there was no flow meter. From this:

$$\dot{V}_{blowdown} = \frac{3L}{12s}$$

And from the blowdown temperature (table 4.2, 115 ^{0}C)

$$\dot{\mathrm{m}}_{\mathrm{b}} = \dot{V}_{blow\ down} \times \rho_{water\ at\ 115\ ^oC} \quad (4.8)$$

Using steam table

$\rho_{water\ at\ 115\ ^oC} = 1/Specific\ volume\ at\ 115\ °c$

$\dot{\mathrm{m}}_{\mathrm{b}}$= mass flow rate of blowdown

4.5.3Mass Flow Rate of Steam

The boiler energy output is calculated using the mass flow rate of steam. The steam mass flow rate can be calculated as follows. The feed water, or input mass for the specific boiler in the factory; the output masses are steam and blowdown. The mass flow rate of steam can be analyzed from:

$$\dot{m}_{steam} = \dot{m}_w - \dot{m}_{blowdown} \quad (4.9)$$

4.6 Energy input to the boiler

The following formulas are used to compute the boiler's input energy, which includes combustion air, furnace oil, and feed water.

4.6.1 Energy of Feed Water Supply

The enthalpy of feed water due to sensible rise in temperature from 25°C room temperature to 55°C can be estimated from [16]:

$$Q_w = \dot{m}_w \times C_{Pw} \times (T_w - T_a) \tag{4.10}$$

Where, $T_W = (55℃)$

$T_a = (25℃)$

$\dot{m}_w = 0.76\ Kg/s$

$C_{Pw} = 4.18 kJ/Kg\ ℃$

$Q_w = 95.3 kW$

4.6.2Energy of Furnace Oil Supply

Fuel chemical energy is equal to its mass flow rate times its gross calorific value [16].

$$Q_{Furnace\ oil\ chemical\ energy} = \dot{m}_{fuel} \times GCV_{Furnace\ oil} \tag{4.11}$$

To calculate sensible heat energy in due to pre heating of Furnace oil [16].

$$Q_{\ Furnace\ Oil\ Sensible} = \dot{m}_{fuel} \times C_{PFurnace\ oil} \times (T_{inlet\ oil} - T_a) \tag{4.12}$$

Where

C_f - Specific heat of fuel = 2.35kJ/kg° K [42]

T_i -Fuel inlet temp. =120 ℃

Ta -Ambient temp. = 25 ℃

$$Q_{Fuel\ total} = Q_{Furnace\ Oil\ Sensible} + Q_{Furnace\ oil\ chemical\ energy} \tag{4.13}$$

4.6.3Energy of Combustion Air

The enthalpy of combustion air at inlet to the furnace is taken as zero.

4.7 Energy output of boiler

Boiler converts water into steam, which releases a significant quantity of output energy in the form of heat. This can be computed as follows.

$$Q_{Heat\ of\ steam} = \dot{m}_{steam} \times h_g \quad (4.14)$$

4.8 Energy Losses of the Boiler

The boiler energy losses discussed in the analysis below are used for estimating the energy performance of the boiler by indirect method.

4.8.1 Heat Loss Due to Dry Flue Gas

The energy loss resulting from dry flue gas exiting the boiler is estimated from [42].

Heat loss due to dry flue gas (Q_{flue})

$$Q_{flue} = \dot{m}_{Dry\ flue\ gases} \times C_{pfluegas} \times (T_{flue} - T_a) \quad (4.15)$$

$\dot{m}_{Dry\ flue\ gases} = 1.17$kg/s

$T_{flue} = 220°C$

$T_a = 25°C$

$C_{pfluegas}$ is $\frac{0.963kJ}{Kg}$°C then, Q_{flue} can be determined.

4.8.2 Heat Loss due to the Presence of H_2 in Fuel

Water is known to contain both oxygen and hydrogen. Water is created when the hydrogen in the fuel oil combines with oxygen during combustion. A portion of the energy released during combustion is lost as water forms. This energy loss is seen below [42].

$$Q_{\mathbf{H_2}\text{infuel}} = m_{wv} \times \left[Latent\ heat\ of\ vapor\ at\ 25°C + C_P\left(T_{flue} - T_a\right)\right] \times \dot{m}_{fuel} \quad (4.16)$$

M_{H_2O}-Mass of water per kg of fuel = 1.08(from section 4.4.2)

$h_{fg@25°C}$ –Enthalpy of water = 2441.12 kJ/kg

Mass flow rate of furnace oil = 0.0574kg/s (from equation 4.1)

Enthalpy of water at 25^0C = h_{fg} = 2441.12KJ/kg

C_p =Specific heat capacity =1.88KJ/kg °C = 0.45kCal/kg °C [42]

Temperature of flue gas =$T_{flue\ gas}$ = 220^0C (table 4.1)

Ambient temperature = T_a = 25^0C (table 4.1)

4.8.3 Heat Loss due to Moisture Content of Fuel

A portion of the energy released during combustion is lost because most fuels contain moisture, which causes water to develop during the combustion process. This fuel's moisture-related energy loss is calculated using [42].

$$Q_{moisture\ in\ fuel} = moisture\ in\ fuel \times \left[h_{fg} + C_p\left(T_{flue\ gas} - T_a\right)\right] \times \dot{m}_{fuel} \qquad (4..17)$$

Using, Moisture in fuel = 0.5 from (Table 4.5)
C_p= 0.45kcal/kg ^oC = 1.88kJ/kg ^oC

4.8.4 Heat Loss due to Moisture Content of Combustion *Air*

Under normal circumstances, there is moisture in the combustion air. The energy lost as a result of this moisture is as follows [42].

$$\mathrm{Q}_{\text{due to humidity of comb. Air}(\omega_{\text{air}})} = \mathrm{AAS} \times \dot{\mathrm{m}}_{\text{fuel}} \times \omega_{\text{air}} \times \mathrm{C_p}\left(\mathrm{T}_{\text{flue gas}} - \mathrm{T_a}\right) \qquad (4.18)$$

Where,

AAS = 20.6kg of air/kg of oil(From section 4.4.2) and Mass flow rate of fuel= 0.057kg/s

Cp = 1.88KJ/kg.^{o}C K=0.45kCal/kg. ^{o}C

Relative humidity ratio of the air φ = 53.25% [5] and air moisture content factor (ω_{air}) =0.01211 kg of H_2O/ kg of dry air [17].

4.8.5 Heat loss due to Radiation and Convection from the Boiler Surface

The combined convection and radiation heat losses from the boiler surface is analyzed by [42].

$$Q_{Surface} = \left[0.548\left(\left[\left[\frac{T_s}{56.55}\right]^4\right] - \left[\left[\frac{T_a}{56.55}\right]^4\right]\right) + 1.957\left[[T_S - T_a]^{1.25}\sqrt{\frac{196.85V_{wind} + 68.9}{68.9}}\right]\right]\frac{w}{m^2} \times S_{area} \qquad (4.19)$$

Where ,

T_s= Surface temperature:

T_{front} = 364.8K, T_{back} = 311.4K and $T_{cylindrical}$ =317.6K

T_a: Ambient temperature(local):

$T_{front\ local\ ambient}$ =298.35K, $T_{back\ local\ ambient}$ = 302.95K and $T_{cylindrical\ Local\ ambient}$ =300.75K

V=Wind velocity measured. Using the dimensions of boiler given in Table 4.3,

The front, cylindrical and back Surface area (SA) is 2.41m^2, 24.74 m^2 and 2.41 m^2 ,respectively.

4.8.6 Heat Loss Due to Blowdown Water from the Boiler

When water boils and steam is produced, the dissolved particles in the water stay in the boiler. These solids promote foaming and introduce water into the steam over a specific concentration. Additionally, the deposits cause the boiler's interior to become scaled that cause heat transfer resistance. Thus, blow down is important for clearing deposits, but if done incorrectly, it can also be a source of heat loss. This is provided by [42].

$$Q_b = \dot{m}_b * h_f \ @115°\mathrm{C}$$

$\dot{m}_b$ = Mass flow rate of blowdown

Enthalpy of blowdown at 115^{0}C=h_f @115°C= $\frac{482.59kJ}{Kg}$

When $\dot{m}_{blowdown} = 0.00033\ Kg/s$,

$Q_{blowdown}$ =Q_b

To analyzed, the fraction of energy losses from the boiler relative to each other, the following analysis steps were used [42].

i. Percentage heat loss due to dry flue gas =$\left[\frac{m_{flue\ gas} \times C_{P\ Flue\ gas} \times (T_f - T_a)}{GCV\ of\ fuel}\right] \times 100$

   m = mass of dry flue gas in kg/kg of fuel
   Cp – Specific heat of flue gas

ii. Percentage heat loss due to H_2 in fuel = $\left[\frac{9 \times H_2 \times (584 + C_P \times (T_f - T_a))}{GCV\ of\ fuel}\right] \times 100$

   Where, H_2 – kg of H_2 in 1 kg of fuel
   C_p – Specific heat of superheated steam

584 is the latent heat corresponding to the partial pressure of water vapor

iii. Percentage heat loss due to moisture present in fuel = $\left[\frac{M(584+C_P\times(T_f-T_a))}{GCV\ of\ fuel}\right]\times 100$

Where, M – kg of moisture in 1kg of fuel

iv. Percentage heat loss due to moisture present in air = $\left[\frac{\mathrm{AAS}\times\omega_{\mathrm{air}}\times\mathrm{C_P}\times(\mathrm{T_f}-\mathrm{T_a})}{\mathrm{GCV\ of\ fuel}}\right]\times 100$

v. Radiation, convection and blowdown losses are approximated to be 2 %.

4.9 Efficiency of the Boiler

As prescribed by the ASME Power Test Code, PTC 4.1, the fuel-to-steam efficiency of a boiler can be determined by two methods; the Input-Output Method and the Heat Loss Method. In this paper heat loss method was discussed since it shows the actual operating efficiency by considering different losses [42].

i. Combustion Chamber Efficiency

$$\eta_{comb} = 1 - \frac{\sum_1^4 Losses}{Total\ Energy\ Input} \tag{4.20}$$

ii. Thermal Efficiency of the Boiler

$$\eta_{\mathrm{th}} = 1 - \frac{\sum_1^6 Losses}{Total\ Energy\ Input} \tag{4.21}$$

By substituting the energy inputs and losses thermal efficiency can be calculated.

The overall efficiency of the boiler was analyzed by [42].

$$\eta_{\mathrm{overall}} = \left[1 - \frac{[\sum_1^6 Energy\ Losses + Boiler\ Shell\ Loss]}{Total\ Energy\ Inputs}\right]\times 100 \tag{4.22}$$

OR

$$\eta_{\text{overall}} = 100 - (\text{i} + \text{ii} + \text{iii} + \text{iv} + \text{v}) \quad (4.22a)$$

Heat loss from boiler shell is estimated from [42].

$$Q_{\text{shell}} = \text{thermal efficiency} \times \left[[\textstyle\sum_1^6 En.Losses + Q_{steam}] - [\sum_1^4 Input\ Energy] \right] \quad (4.23)$$

4.10 Energy Performance Analysis of Steam Distribution System

4.10.1Steam Distribution System

Condensate return lines, pipe systems, steam traps from a boiler to usage locations, and other equipment, such as pumps, are all part of a steam distribution system. Energy waste might result from these devices' aging and wear. Vitality by enhancing the insulation, finding and fixing leaks in the steam and condensate, keeping up with the steam traps and condensate pumps, and treating the water, management may have an impact on this system. Energy can be saved by insulating the pipes that carry steam or condensate. The energy performance assessment of steam distribution lines was carried out by gathering data with portable devices such as an infrared thermometer, a meter, and by inspection. This section discusses energy performance evaluations of steam distribution lines.

4.10.2Data collection

4.10.2.1 Steam line surface's data collected

The goal of the steam pipeline is to deliver steam to the place of application at the proper temperature and pressure. However, because uninsulated steam tubes are exposed to the environment, they can result in a large waste of heat energy. Therefore, insulation is required to prevent heat loss from steam pipes by convection and radiation. To undertake the energy performance evaluation of steam line surfaces, data were gathered by examination and the use of portable tools such as an infrared thermometer and a meter.

Table 4. 7Steam line surface measured data

S/N	Physical quantity measured	Value obtained
1	Ambient Temperature	26.5 ^{o}C
2	Insulated surface Temperature	40 ^{o}C
3	uninsulated surface Temperature	140 ^{o}C

Table 4. 8: Steam pipe measured data

S/N	Diameter (mm)	Length of insulated pipe (m)	Length of uninsulated pipe (m)
1	63.5	109.7	45
2	50.8	43	18
3	38.1	247.7	48

4.10.1.2 Steam leakage data collected

Large-scale steam leaks can be costly and a cause of energy waste, thus they should be prevented. Six locations at the Ethiopia Tannery S.C Factory, each with a plume length listed in table below have been found to be leaking steam at a temperature of 150 ^{o}C. on average.

Table 4.9: Steam leakage measured data

S/N	Leakage location	Plume length (mm)	Steam leakage (kg/hr)
1	Boiler Header	400	5
2	Boiler Surface	200	2.5
3	Toggle Area	300	2.75
4	Inlet to production room	250	2.6
5	Near Coater machine	300	2.75
6	In vicinity of Vacuum dryer	200	2.5

4.10.3 Heat loss from insulated and un-insulated steam line surfaces

According to the information in tables 4.7 and 4.8 above, there are insulated and uninsulated sections of the steam pipeline at Ethiopia Tannery S.C. that are connected to various industrial machinery that use steam. The following formulas can be used to determine the heat loss from it [6]:

$$S = [10 + (T_s - T_a)/20](T_s - T_a) \quad (4.24)$$

Where:

S = Surface heat loss in kcal/hr m^2

A = Surface area in m^2

T_s = Hot surface temperature in ^oC

T_a = Ambient temperature in ^oC

$$Total\ surface\ heat\ loss(H_s) = S \times A \tag{4.25}$$

Surface area of insulated pipeline = A= πDL

Using equation 24 and 25 the surface heat loss of each pipe is calculated as follows:

1.Pipe with diameter of 63.5 mm

Hot surface (Insulated surface) temperature = T_s = 40 ^0C

Ambient Temperature = T_a = 26.5 ^0C

Surface area of insulated pipeline = A= πDL = 21.87m^2

Where L is length =109.7m and D is diameter=0.0635 m of the insulated pipe respectively. Factors like wind velocity, and conductivity of insulating material have been neglected Similarly, for rest of two pipes surface heat loss can be calculated.

$$Equivalent\ fuel\ loss(H_{LOSS})(\frac{Kg}{Year}) = \frac{H_{loss} \times Yearly\ hour\ of\ operation}{GCV\ of\ Fuel\ (\frac{kCal}{Kg}) \times \eta_{boiler}} \tag{4.26}$$

4.10.3 Heat Losses Due to Steam Leakages

The kilogram of steam lost can calculated by adding up all the lost given in table 4.9, accordingly we get the total lost steam due to leakage is 18.1Kg/hr. Hence the steam is leaving at average temperature of 150 ^oC, taking the h_g (saturated vapor enthalpy at 150 ^oC) equal to 2745.9kJ/Kg we get heat lost due to leaking steam as follows:

$$Q_{leak} = \dot{m}_{leak} \times h_g \tag{4.27}$$

CHAPTER FIVE

ENERGY PERFORMANCE ANALYSIS OF ELECTRICAL MOTORS AND LIGHTING SYSTEM

5.1 Introduction to Motor

An electric motor's purpose is to transform electrical energy into mechanical energy. Motors are utilized in Ethiopia Tannery S.C. to power various parts such as: drums, fans, pumps, conveyors, air compressors, and more. A variety of data were gathered via motor nameplates, voltmeters, control board displays, meters, time watches, and by direct observation to examine motors' energy performance. It has been discovered that many motors have a loading factor of less than 40%. The energy consumption results of motors are covered in this part, along with options and strategies for energy saving.

Electric motors in the industry are powered by more than 85% of the electricity used. Nevertheless, since the motor shaft power is utilized to drive equipment, whose efficiency is likewise essential for optimizing overall electricity usage, motors only represent a stopgap in the energy conversion process. Energy-efficient motors can be preferable from outdated, rewound ones, especially if the motors run for extended periods of time, given the rising cost of electricity. The following formula [28] provides the margins for kw savings.

$$\%\ \mathrm{K}w\ Savings = \frac{(\text{new efficiency} - \text{old efficiency}) * 100}{\text{New efficiency}} \tag{5.1}$$

In the factory, there is a centralized power factor corrector and on minimum loading condition the power factor is 0.96 but when the load increases, the power factor depreciates and at peak load the power factor becomes 0.75.

5.2 Factors Affecting the Induction Motor performance

5.2.1 Unbalanced voltage and frequency

Operating a motor at other than rated voltage and frequency can result in reduced efficiency and effects on power factor break-away torque, starting current, running speed etc. All the electrical motors in the factory are as per the standard of the utility company which is 380V and 50 Hz. so this issue is not a problem in the factory.

Even a small degree of unbalance at the motor terminal voltage can result in large negative sequence current in the motor. Thus, small unbalance in voltage will cause large increase in motor loss and heating. Careful balancing of voltage everywhere is imperative from this point of view.

We have measured motor terminal voltages of several motors in the factory and the voltages are balanced. So the loss due to voltage unbalance is very minimum.

Table 5. 1: Voltage distribution on RST phases

Serial number	R phase to neutral	S phase to neutral	T phase to neutral
05-47-1	229.9	229.4	228.3
05-47-2	226.3	224.6	225.3
05-44-2	225	226.8	226
06-57-3	224.5	227	225.6
05-45-2	232	232.4	232

5.2.2 Loading level

Motors are made to run as efficiently as possible when they are fully loaded. Power factor decreases at part load efficiency. Therefore, when using an oversized motor for the same power output, the motor's active and reactive power inputs will be higher than when using a properly designed motor. As a result, part loading induction motors will raise losses and the plant's maximum KVA demand, particularly when done on a continuous duty basis.

Motors operate efficiently between 60% and 100% of their rated output. Typically, maximum efficiency is close to 75% of the rated load. Significant losses in active and reactive power occur when the load is less than 50% of the rated load. When part loading of motors is noticed, the large motor must be replaced [19]. Therefore, when evaluating a motor's performance, knowledge of load and efficiency are needed. However, because motor nameplates are frequently lost or painted over, it is frequently impossible to establish a motor's effectiveness after a lengthy period of service. Therefore, motor loading can be utilized to assess a motor's performance [19].

5.3 Electrical motor minimal nominal efficiency

Table 5. 2: electrical motor minimal nominal efficiency

Power (KW)		Minimum Nominal Efficiency (%)
From	to	
1	3	78.8
4	7	84
7	14	85.5
15	37	88.5
37	74	90.2
75	92	91.7
93	More	92.4

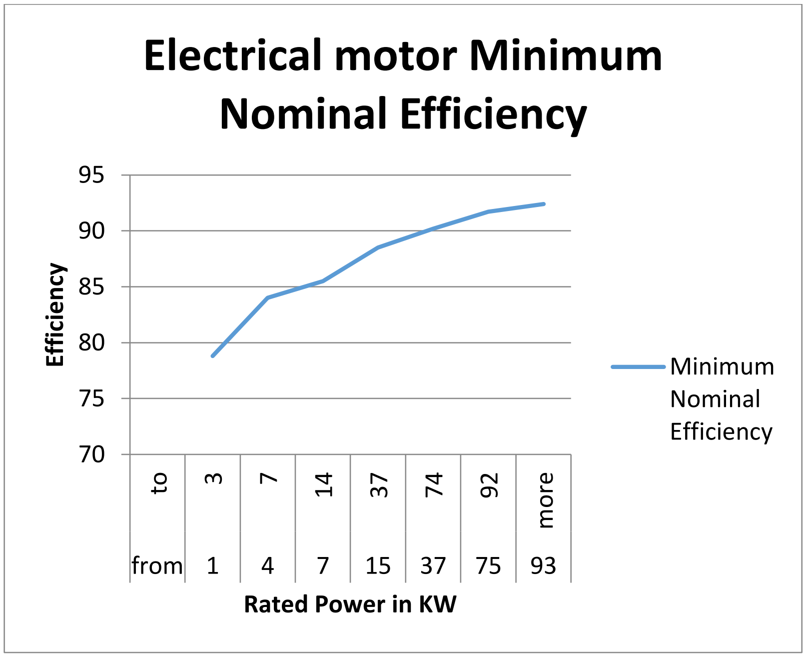


Figure 5. 1: Electrical motor minimum nominal efficiency versus to rated power

From the above figure we can understand that as rated power increased minimum nominal efficiency also increased.

5.4 Electrical motor data collected and percent of load calculation

During the survey of electrical motors, the following difficulties has been faced

1. Since machines have served for long time in harsh environment, the plate data for some machines was not visible
2. the shaft is not accessible for motor speed measurement
3. the machine is not operational due to some fault
4. the machine is not working due to shortage of chemicals

However, we have managed to collect the following data.

Table 5. 3: Efficiency and load on different motors

Information		Power (KW)		RPM			Calculated		
id number	process	plate	measured power input	plate	measured	synchronous speed	Power output (KW)	% load	Efficiency
03-48-02	Drum	15	10.2	1460	1480	1500	7.50	50%	74%
03-48-04	Drum	15	8.3	1460	1484	1500	6.00	40%	72%
04-48-3	Drum	11	6.6	2940	2974.7	3000	4.64	42%	70%
04-48-4	Drum	11	7.3	2940	2975	3000	4.58	42%	63%
18-63-8	water pump	11	5.6	2880	2954	3000	4.22	38%	75%
06-57-2	Mustard	18	15	970	991	1000	5.60	30%	37%
06-46-3	dedaster	22	17	1470	1491	1500	6.60	30%	39%
	dedaster	15	7.5	1470	1487.8	1500	6.10	41%	81%
05-45-2	Buffing	37	18.6	1471	1493	1500	8.93	24%	48%

From the collected data the efficiency of the motors is in the range of 37% to 81%. But under normal condition the efficiency is expected to be more than 80% that means the efficiency of the electrical motors is in a bad condition.

There are several factors which affect efficiency of electrical motors which are explained above but in this case the major reason is extent of loading. The percentage loading calculated from the collected data is in the range of 24% to 50% with average loading of 37%. The acceptable range for electrical motor loading is from 50% to 100% and the optimum range is 60% to 80 %. From this, we can conclude that the machines are under loaded and this contributes greatly for the machines poor efficiency.

Our recommendation for this issue is first to experiment the machines by increasing the loading to see if the efficiency will improve. For example, if a drum is loaded with 1000Kg of skin before then increase the load 10%, 20% etc. until you get acceptable efficiency and optimum percentage of loading. With this experiment, if it is not possible to increase the efficiency, then it is better to replace the electrical motor with good efficiency motor.

5.4.1Effect of speed on motor efficiency

For same HP rating of a motor, higher speed results in higher efficiency at the rated loads.

5.4.2 Effect of Duty cycle on motor efficiency

The losses in the induction motors depend on the type of duty. The duty cycle of the motor has to be obtained and suitability of the motor for the duty must be examined. For example, a continuous duty rated motor should not be used for an intermittent duty.

5.4.3 Operational management

Motors maintain good efficiency in the range of 60% to 100% loading of rated output. Maximum efficiency is usually near 75% of rated load. So especially for the drums it is very important to follow up and load the drum with full capacity. A good potential saving on operational management is possible without the need of any additional investment.

5.5 Energy Performance Evaluation the Lighting System

A lighting system comprises all of the components necessary to deliver a desired level of space illumination. It includes components such as switch to control power, wiring, lighting luminaries, fixtures etc. The previous lighting bulbs are 250 W mercury bulbs. This bulb was best solution at the time when the factory was established. LED lighting uses more than 75% less electricity with lifespan between 30 to 50 times longer than incandescent light bulbs [44].

Based on our survey findings, fluorescent bulbs and high-pressure sodium bulbs dominate the lighting systems in our facility. Therefore, transitioning to LED bulbs is imperative to mitigate energy loss associated with inefficient bulbs, thereby promoting energy efficiency

Table 5.4 comparison of lumen output and power input [43]

LIGHT OUTPUT	POWER REQUIREMENTS	
	INCANDESCENT	LED
450 lumens	40 watts	4.5 to 7 watts
800 lumens	60 watts	6.5 to 11 watts
1,100 lumens	75 watts	10 to 15 watts
1,600 lumens	100 watts	14 to 18.5 watts

CHAPTER SIX

ENERGY PERFORMANCE ANALYSIS OF WATER PUMPS AND AIR COMPRESSOR

6.1 Introduction to Water pump

In the factory, there are various water pumps with various characteristics. Pump-to-piping system matching is the most important factor in energy efficiency in a pumping system. Therefore, even if an efficient pump is chosen, its efficiency will be very low if it is not compatible with the system. Furthermore, a gradual decrease in efficiency is also anticipated as a result of deposits in the piping system and impellers. Considering the substantial quantity of electricity linked to pumping systems, even little enhancements in pumping efficiency have the potential to result in substantial electricity savings. In this chapter, the energy use performances of water pumps and compressors are discussed.

6.2 Water pump inspection and data collection

Inspection and measuring methods were used to gather various data on water pumps from the firm in order to calculate their energy performance.

6.2.1 Data Collected by Measurements

Instruments such as mechanical water flow meters, pressure gauges, local control panels, and control boards were used to measure volume flow rate, pressure (head), input power to motors, current, and voltages in order to gather the data required for the computation of water pumps energy performance analysis.

Five pumps have pressure gauges on pumps were considered for investigation. The data log and the pump nameplates itself provided the rated head information for the water pumps. The pressure gauges that are mounted on the pumps were utilized to determine head data of the water pumps. This involved reading the pressure levels on the suction and discharge sides, taking the difference, and converting it to system international units (meter).

$$\Delta P = \text{Discharge side Pressure} - \text{Suction side pressure} \qquad (6.1)$$

Where, ΔP= Pressure difference

1bar = 10 meters (For water)

Table 6. 1: Pump head measurement

Pumps	Discharge side pressure(Bar)	Suction side Pressure(Bar)	Pressure Difference = ΔP	Head(m) =10xΔP
Soaking pump	3	2.65	0.35	3.5
Liming pump	3.5	2.7	0.8	8
Deliming Pump	2.8	2.45	0.35	3.5
pickling pump	3.5	2.3	1.2	`12
Neutralization pump	2.0	1.75	0.25	2.5

Table 6. 2: Measured and nameplate data of water pumps

Pump Location	Name plate data				Service Year	Measured data		
	ΔH (m)	Qrated (m^3/s)	Eff. η_{motor}	Elec.Motor Power (kW)	Year	ΔH (m)	Pm $P_{elect.input}$ (kW)	Q(m^3/s)
Soaking pump	30	0.01	88	11	15	3.5	12.3	0.02
Liming pump	30	0.02	87	12	17	8	8	0.023
Deliming Pump	30	0.01	91	10	13	3.5	7	0.0132
pickling pump	40	0.016	88	16	9	12	10	0.013
Neutralization pump	10	0.0008	75	5	10	2.5	2	0.0035

6.3 Pump efficiency

6.3.1 Motor input power

The motor input power, Pm had been measured and tabulated in (table 6.2) above.

6.3.2 Pump shaft power

The motor input power and motor efficiency are multiplied to determine the pump shaft power (P_{sh}). It is preferable to utilize the motor efficiency, which can be found in figure 6.3 along with the matching motor loading percentage and motor loading, to determine the shaft power. However, the figure is not very apparent, so the motor's rated efficiency is utilized instead [32]

$$P_{sh} = P_m \times \eta_{motor} \tag{6.2}$$

Where, P_{sh}= Pump shaft power

P_m= motor input power

η_{motor}= motor efficiency

6.3.3 Hydraulic power of pumps (P_h) [32]

$$P_h = \frac{Q(m^3/s) \times H(m) \times \rho(Kg/m^3) \times g(m/s^2)}{1000} \tag{6.3}$$

Where, P_h= Hydraulic power of pumps

Q=volume flow rate(m^3/s)

H=head(m)

ρ- density of water=1000kg/m^3)

g=gravity(m/s^2)

6.3.4 Flow Measurement Using Volume Time Ratio(Q)

This approach measures the amount of time it takes for the water volume to change by one m^3 using a flow meter installed on water lines. The volume flow rate ($Q[m^3/s]$) of pumps is then determined by dividing the volume by the whole time.

$$Q = V/t \tag{6.4}$$

6.4 Water pump efficiency (η_p)

$$\eta_p = \frac{P_h(kW)}{P_{sh}(kW)} \quad (6.5)$$

6.5 Pump curves, system curves and pump operating point

A pump's pump performance curve displays the head-to-flow rate relationship. The flow rate in the pump rises as the head decreases. A system curve is essentially a depiction of the system resistance, or the head that the pump must overcome at different flow rates. It varies depending on the system's physical configuration, including the piping's diameter, length, and elevation. Pump and system curves can be superimposed to visually represent the impact of a pump installation. The intersection of the two curves is always the operational point.

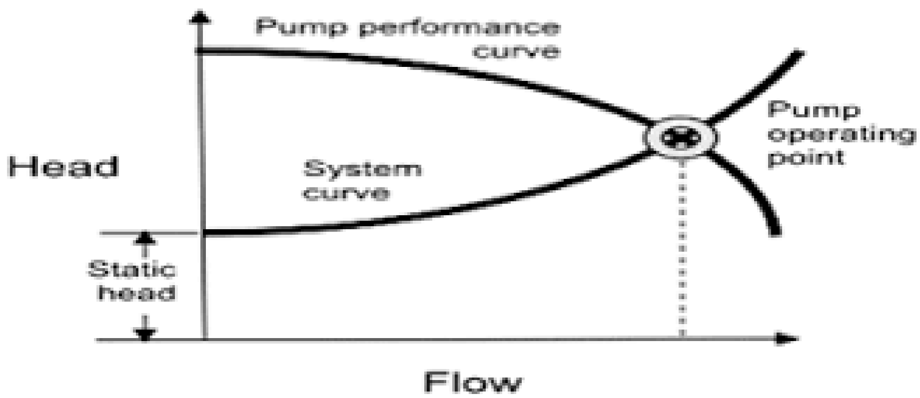


Figure 6. 1Head- Flow Curve, System curve and Pump operating point

Pump efficiency changes with head (pressure) and flow, peaking at a specific flow rate. The pump used for a particular application is mostly determined by how well the pump's head-flow characteristics match the needs of the system located downstream of the pump.

All of the evaluated water pumps in this section have rated heads that are significantly different from their operational heads, or low heads. According to the above talks, poor efficiencies are not the result of defective or inefficient pumps, but rather of a mismatch between the good and efficient pumps and the issues with the pump's motor sizing and the piping system. This suggests that the pumps are not functioning near their optimal efficiency point (BEP).

6.7 Inspection of the Compressed Air Distribution System

The factory has new a screw type air compressor with the capacity of 10 bar and compressed air distribution systems that is used for supply of air for chemical mixing, in vacuum dryer room to move piston up and down, in buffing room for cleaning, supply compressed air to factors work shop for different purposes and etc. The compressed air distribution system has no leak and the compressor is placed properly and no ECO is obtained.

CHAPTER SEVEN

RESULT AND DISCUSSION

7.1 Energy performance of boiler

The plant uses fire- tube boiler with capacity of 4000 kg/ h at 14.7 bar and 210 ^{0}C. It uses Furnace oil for thermal energy generation. The boiler has feed water system, energy system, air system and brume system. The boiler is used to develop brume which is directed through pipeline system to different points of use similar as Vacuum dryer, Toggles machines, Spray machines, and etc. It produces brume at average temperature of 152^{0}C and 5 bar. The boiler is spherical in shape and its three shells are exposed to the ambient air. The ideal of this section is to estimate the energy performance of the boiler in the plant. In order to do this, different instruments such as combustion analyzer, mechanical in flow meter, infrared thermometer, cadence, Vernier caliper and inspection has been used to collect data. From the data collected, the input and out mass of combustion system of the boiler were calculated. The heat input, heat affair and loss heat of the boiler calculated were 2519.1 kW, 2500kW and 414.3 kW independently. The possible reasons linked for effectiveness drop of the boiler were loss due to the presence of hydrogen in energy, loss due to dry flue gas, loss due to the humidity content of combustion air, boiler shell loss. And possible energy conservation openings linked from detail energy inspection were repairing feed water treatment factory cost of energy saved will be about 569332.8 Birr and separating boiler face cost of energy saved will be around 70,405.2 Birr. In this section; data collection, determination of the factual operating effectiveness of boiler, energy conservation openings, specialized evaluation of ECOs, and provident evaluation of ECOs and summary of energy conservation measures are bandied.

7.2 Heat energy balance of the Boiler

Sankey diagram is a very useful to represent whole input and output energy flows in any energy end use after carrying out energy balance calculations of the boiler.

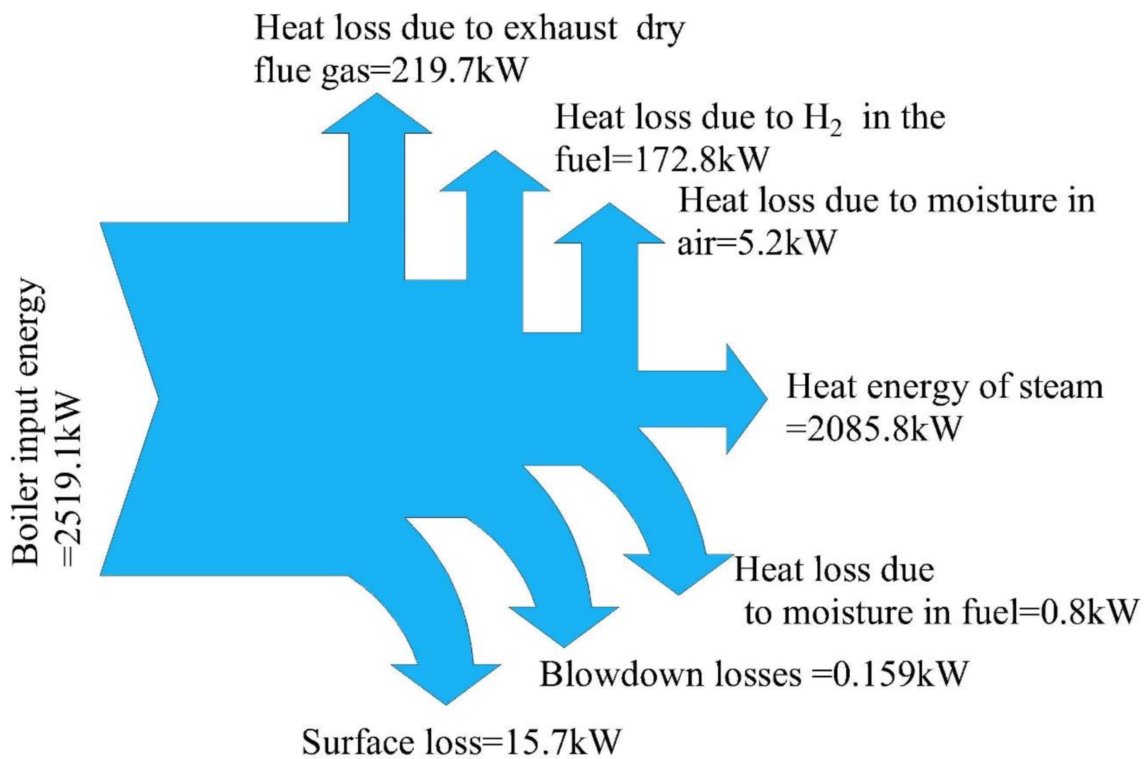


Figure 7.1. Energy Sankey diagram of boiler

As it can seen from the Sankey diagram (Figure 7.1) about 414.359kW of energy loss is observed in boiler. The highest loss is loss due to dry flue gas loss and loss due to hydrogen in the fuel respectively. The average total heat input delivered to the boiler is 2519.1Kw and output and losses are 2500.16kW, with difference of 0.044%.

For oil fired boiler the recommended percent of excess air is 15 % with the volume percent of CO_2 15% [5] while the calculated average excess air supplied to the furnace of the Ethiopia Tannery S.C boiler is 46.8 % (12.6 % from flue gas analyzer) with the volume percent of CO_2 being 14.2%. This high excess air affects energy loss due to dry flue gas.

From this discussion, the volume percent of CO_2 is in required range and the excess air can be controlled by reducing motor capacity of air blower of the boiler. To control the excess air one can use portable oxygen analyzers and draft gauges can be used to make periodic readings to guide the operator to manually adjust the flow of air for optimum operation. Excess air reduction up to 20% is feasible [42].

The boiler's combustion chamber efficiency yields an efficiency of 84.2%. The boiler has an overall efficiency of 77.56% and a thermal efficiency of 83.6%. The manufacturing boiler's efficiency is good, even if it falls short of the furnace oil fuelled boiler recommended design performance of 85% [5], [17].

The following ECOs listed below are discussed in detail chapter 8 of this document.

a) Repairing boiler feed water treatment plant
b) Insulated boiler surface
c) Installing an economizer

From the energy performance assessment of steam distribution system, the annual energy savings from insulating steam lines are about 273,450 Birr, with a simple payback period of 0.296 years, and the annual energy savings from steam leaks are approximately 160,068.75 Birr, with a simple repayment period of 0.13 years. Heat loss from insulated and un-insulated steam line surfaces is the sum of heat loss in each pipe as calculated $10{,}938 Kg/year$ or 273,450 Birr/year. Generally, to decrease energy loss of factory can replace, insulate old the steam distribution pipes.

The following result and discussion are obtained from the energy performance assessment of lighting system and motor.

- Regular maintenance and old lighting system installed in a workplace significantly influences energy consumption. Fixtures can accumulate dust over time, acting as dust traps. Failure to clean them periodically results in increased dust accumulation, leading to decreased illumination levels. Therefore, transitioning to LED bulbs is imperative to mitigate energy loss associated with inefficient bulbs, thereby promoting energy efficiency.
- From the collected data the efficiency of the motors is in the range of 37% to 81% . But under normal condition the efficiency is expected to be more than 80% that means the efficiency of the electrical motors is in a bad condition.

- There are several factors which affect efficiency of electrical motors which are explained above but in this case the major reason is extent of loading. The percentage loading calculated from the collected data is in the range of 24% to 50% with average loading of 37%. The acceptable range for electrical motor loading is from 50% to 100% and the optimum range is 6,0% to 80%.

The following result and discussion are obtained from the energy performance assessment water pumps.

Table 7.1: Calculated parameters of pumps

Pump Location	Operating parameters			Service Year	P_{sh}	P_h	η_p
	ΔH (m)	P_m (kW)	$Q(m^3/s)$	Year	(kW)	(kW)	%
Soaking pump	3.5	12.3	0.02	15	10.824	0.6867	6.3
Liming pump	8	8	0.023	17	6.96	1.80504	25.9
Deliming Pump	3.5	7	0.0132	13	6.37	0.45322	7.1
pickling pump	12	10	0.013	9	8.8	1.53036	17.4
Neutralization pump	2.5	2	0.0035	10	1.5	0.08584	5.7

The water pumps' efficiency is shown in the final column of the table, as computed and reported in table above. We can see from these efficiency statistics that all of the evaluated pumps were operating at extremely low efficiency. The inefficient pump (bad pump), the mismatch between the good and pipe systems, or an issue with the pump's motor sizing could all be the cause of the low efficiency.

CHAPTER EIGHT

ECONOMIC AND TECHNICAL FEASIBILITY ANALYSIS OF ENERGY CONSERVATION OPPORTUNITIES

8.1Introducation

There are various energy efficiency practices that are proven, cost-effective, and available for implementation today. These opportunities are applicable at the component, process, facility, and factory levels. The following major energy saving potentials are analyzed.

1.Repairing boiler feed water treatment plant
2.Insulated boiler surface
3. Installing an economizer
4.Insulating steam lines

Energy Conservation Opportunities for steam leakage are: Replacing old steam distribution pipes lines, insulationsteam distribution pipes, distribution line node and valve point must be fitted correctl y and periodic checkup of steam pipelines must be carried out.

8.1.1Technical Evaluation of Repairing Water Treatment Plant

Boiler shell loss can occur from scale deposits on boiler tubes caused by excessive hardness contamination from inefficient water treatment plants. This reduces heat transfer to the feed water. Boiler shell loss thus results in a reduction in boiler efficiency. 19.1 kw is the shell energy loss, as determined previously. Repairing the factory's water treatment facility will lessen this loss. Technically, it is possible to replace the water treatment plant in the factory because it has sufficient space and skilled labor.

8.1.2 Technical Evaluation of Boiler Surface Insulation

The boiler of the factory is cylindrical in shape and it has length of 5.1 m and diameter of 2.46m for both front and back surfaces (measured by meter).Three surfaces of boiler exposed to the ambient air with their respective average temperature are: front surface temperature of 91.8^{0}C back surface temperature of 38.4^{0}C and cylindrical surface temperature of 44.6^{0}C Front area of $4.75m^2$ and loss of 5.13kw, back area of $4.754m^2$ and loss of 1.22kw, and cylindrical area of $39.4m^2$ with loss of

9.37kW having total boiler surface loss of 15.7kw. To avoid this lose, insulating boiler surface is taken as one of ECOs and it is technically feasible.

8.1.3 Technical Evaluation of Installing Economizer

Installation of economizer in a given factory is used for preheating the feed water which offers an increase in overall thermal efficiency of the boiler by reducing the flue gas exit temperature. For the furnace oil fired boiler, the flue gas exit temperature from a boiler is usually maintained at approximately 200^0C [17]. Its average flue gas temperature is 220^0C which is higher than the recommendable range. Thus installing an economizer for the factory is technically feasible.

8.1.4 Technical evaluation of insulating steam lines

Among the energy-saving measures found for steam distribution system, routine steam line inspections may be carried out by manufacturing workers at no expense but with great significance. However, as it can lower losses, even if insulating steam lines requires a substantial financial investment and increase productivity, it is technically possible.

8.1.5 Technical Evaluation of Energy Conservation Opportunity of Steam Leakage

The plant personnel may perform cost-free nodal point fitting and routine steam line inspections by utilizing the energy reduction options that have been found. Regular maintenance, including replacing and insulating steam pipes, can assist in lowering energy losses from steam leaks and increasing component efficiency. It is therefore technically possible.

8.2 Economical Evaluation of the ECOs

In this section energy saving analysis, implementation cost and simple payback period of energy conservation opportunities are discussed.

8.2.1 Economic Evaluation of Repairing Water Treatment Plant

In order to conduct economic evaluation of repairing water treatment plant energy saved from thermal and overall efficiency, gross calorific value of fuel and mass flow rate of fuel are used. Also implementation costs and simple payback period are conducted here.
i) Energy Saving:-Assuming electrical energy to the air blower motor of the boiler is negligible when compared to fuel energy to the boiler and the energy of fuel that can be saved by repairing the water treatment plant is 19.1kw (Equation 7.1). The total amount of cost of energy

saved by repairing the water treatment plant is about 569,332.8 Birr or 8251.2 liters of fuel oil.

ii) Implementation Cost: For cleaning equipment (fire tube, about 147,000 birr), filtering materials (13,000birr), and chemicals and for other expenses (12,500Birr), the roughly estimated cost for repairing water treatment plant is 172,500birr (Factory water treatment plant head interview).

iii) Payback Period: The simple payback period can be computed by taking the ratio of the cost of implementing the repairing water treatment plant to cost of energy saved.

Simple Payback period (SPP) = Implementation cost/cost of energy saved (8.1)

SPP = 0.3year or 4 month

Since the simple payback period is about 4 month, the repairing of water treatment plant is economically feasible.

8.2.2 Economic Evaluation of Boiler Surface Insulation

1. Saving Analysis : As mentioned in technical analysis boiler has surface loss of 15.7kw.Assuming that the factory will accomplish the task of insulation by recovering surface loss of 70%(operator interview),7.95kw energy will be saved or about 70,405.2 birr(2.46birr/kWh taken ,EEU) which saves about 2816.2 liters of fuel oil.

2. Implementation Cost: The surface insulation of the boiler consists: Cost of insulating materials for total area of boiler 48.9m^2 with 40mm thickness of insulation is assumed to be 21,500birr (purchasing department interview) and other miscellaneous costs of 11,500 birr (total of 32,000birr).

3.Payback Period: The simple payback period can be computed by taking the ratio of implementation cost to cost of energy saved annually.

Simple payback period (SPP) = 0.46 year or 6 months using (equation 8.1) which is economically feasible for the factory.

8.2.3 Economical evaluation of insulating steam lines

This part covers energy analysis, labor and material expenses associated with putting the measures in place, and simplified payback time computation.

1. Saving Analysis

Annual costs of heat loss (Birr) = H_{loss} x Fuel cost (Birr/kg)

Where,

Furnace oil cost = 67 ETB/L (From Ethiopia Tannery S.C fuel cost sheet)

H_{loss} is the sum of heat loss in each pipe (equation 26).

Thus ,$H_{loss} = 10{,}938 Kg/year$

Annual costs of heat loss (Birr) = $10{,}938 Kg/year$ x 25 ETB/Kg = 273,450 Birr/year

2.Cost of Implementation

A medium temperature insulator, consisting of 85 percent magnesia, asbestos, calcium silicate, and mineral fibers with a temperature range of 90 to 325 degrees Celsius, will be built in order to insulate the steam lines. Based on past manufacturing experience, insulating a steam line with a 40mm thickness will cost around 730birr per meter. The overall average cost of insulation will be 81,030 birr for total insulation length of 111 m.

3.Simple Payback Period

Simple Payback Period using (8.1) = 0.296 year. It takes around 4 months for a return to be required.

8.2.4 Economic Evaluation of Energy Conservation Opportunity of Steam Leakage

1. Energy saving analysis

The following formula can be used to determine the energy expenses associated with the steam leaks. Annually Heat loss due to steam leak(Q_{loss}) is $14{,}015.6 MJ$ /year (equation 8.2).

$$\text{Equivalent Fuel loss}(Q_{LOSS})\left(\frac{Kg}{Year}\right) = \frac{Q_{loss} \times \text{Yearly hour of operation}}{\text{GCV of Fuel }\left(\frac{kCal}{Kg}\right) \times \eta_{boiler}} \quad (8.2)$$

$$Equivalent\ Fuel\ loss(Q_{LOSS})\left(\frac{Kg}{Year}\right) = \frac{224{,}249.96 MJ/year}{44 MJ/Kg \times 0.796} = 6{,}402.75 Kg/year$$

Annual costs of heat loss (Birr) = $6{,}402.75 Kg/year$ x 67 ETB/Kg = 160,068.78 Birr/year

2.Implementation Costs

It is largely predicted that the implementation of line and nodal point insulation, replacement old line and component parts, and other associated operations will cost around 21,400 birr. (Interview with technical people)

3. Simple Payback Period (SPP)

SPP = 0.133 year, which about two months using (equation 8.1).

8.3 Economic and technical feasibility of ECOs factory lighting system

The following ECOs are obtained from the visual inspection of the factory lighting system are technically feasible.

1. Some of the factory bulbs are hanged high

2. Most of the lamps of the factory are old and dirty

Economic Feasibility ECOs of lighting system

From energy conservation as well as providing adequate light that suffices to pursue the production it is worth to replace the lamps with LED which have low power requirements.

8.4 Energy conservation opportunities for water pumps

- Mismatch between the efficient (good pump) and the piping system
- Housekeeping measures

8.4.1Technical evaluation of energy conservation opportunities

Mismatches between the efficient (excellent) pump and the housekeeping and pipe systems are chances for energy reduction. Energy conservation opportunity number two's technical feasibility analysis, which involves a filter pump leak, is low-cost or free to fix with a regular maintenance schedule. The technical examination of upgrading low-efficiency pumps is preferable for the proper operation of the plant by replacing the pumps that fit the necessary operational values for energy saving opportunity number 1.

8.4.1.2 Technical evaluation of replacing pump operating with low efficiency

A pump that operates at a distance from its most efficient point wastes energy and incurs considerable maintenance costs (seals, bearings). This may be the result of a pump that is not the right size for the system, in which case it is best to replace it with one that is [21] for optimal performance. In this specific study, the five low-efficiency pumps listed in (table 6.3) are swapped out with appropriately sized pumps.

Estimation of the parameters of the pumps to be used

In this, the heads are increased by 20% assuming that there are losses.

- Motor Efficiency is taken from the actual motor efficiency being used in the factory.
- Pump efficiency of 60% is used [11], which is an average pump efficiency.
- Input Power of the Motor are calculated with estimated parameters**.**

Input power of the motor

$P_{motor} = (\rho_{water} * H * g * Q)/(\eta_{motor} \times \eta_{pump}$ (8.3)

Table 8.1: Estimated parameters

Pump Location	Parameter to be used				
	ΔH (m)	Qrated (m^3/hr)	Pump efficiency	Motor efficiency	Input power of motor (kW)
Soaking pump	4.5	75	60	92	1.67
Liming pump	9.5	84	60	91	3.94
Deliming Pump	4.5	49	60	90	1.09
pickling pump	13.5	49	60	93	3.27
Neutralization pump	3.5	13	60	92	0.22

This implies replacing the pumps are technically feasible.

8.4.2Economical evaluation of replacing pumps operating with low efficiency

When performing an economic analysis of replacing low-efficiency pumps, the energy saved from the pumps' different motor input powers, the implementation cost of the replacement pumps, and their corresponding simple payback are computed.

a. **Energy saving analysis**

The energy saved was computed from the difference of motors‘ input power given to pumps.

Annually Energy Saved =[$P_{motor\ Old\ Pump}$-$P_{motor\ New\ Pump}$]×Hours operated Annually .

According to operators of the factory (Electricians), the motors connected on operation line run about 16 hours per day and in average the factory runs for 25 days per month throughout the year.

Then; Hours operated Annually = 5400 hrs

Annually Energy Saved (kWh)= [$P_{motor\ Old\ Pump}$-$P_{motor\ New\ Pump}$]×5400 or using electric energy flat rate medium industries 0.607Birr/kWh (EEU);

Annually Energy Saved(ETB)= [$P_{motor\ Old\ Pump}$-$P_{motor\ New\ Pump}$]×5400 x0.607Birr/kWh

Table 8.2 Annual energy saving of pumps

Pump and its location	Old Input Power of Motor ($P_{motor\ old}$) Kw	New Input Power of Motor($P_{motor\ new}$) kW	Annually Energy Saved (ETB)
Soaking pump	12.3	1.67	34843.014
Liming pump	8	3.94	13307.868
Deliming Pump	7	1.09	19371.798
pickling pump	10	3.27	22059.594
Neutralization pump	2	0.22	5834.484

b. Implementation cost of the pumps

Cost of soaking pump is estimated as 30500 ETB and for liming pump 35000 ETB, for deliming pump 30500ETB, for pickling Pump 40,000 ETB and neutralization pump 25000(factory purchasing team Interview).

Assuming 10 % additional cost (transportation, installation and other costs) for each pumps and the total implementation cost is;

- Implementation cost for soaking pump = 30500ETB + 0.1x30500ETB = 33550ETB
- Implementation cost for liming pump = 35000ETB + 0.1x35000ETB = 38500ETB
- Implementation cost for deliming pump = 30500ETB + 0.1x30500ETB = 33550ETB
- Implementation cost for pickling Pump = 40000ETB + 0.1x40000ETB = 44000ETB.

- Implementation cost for neutralization pump = 25000ETB + 0.1x25000ETB = 27500ETB

c. Simple payback period (SPP)

Can be calculated using (equation 28)

Table 7.3: Simple payback period of pumps

Pump and its location	Implementation cost(ETB)	Annually Energy Saved (ETB)	SPP (Year)	Rank
Soaking pump	33550	34843.014	0.96	1
Liming pump	38500	13307.868	2.89	4
Deliming Pump	33550	19371.798	1.73	2
pickling pump	44000	22059.594	1.99	3
Neutralization pump	27500	5834.484	4.71	5

Factory must follow all operational guidelines and replace the water pumps according to their rank of recovery period in order to improve its systems.

CHAPTER NINE

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusion

Adopting energy saving opportunities in industries is needed for ensuring a sustainable industrial development. Thus, Ethiopia Tannery S.C.'s energy performance analysis has been the subject of this thesis. The factory's antiquated, energy-intensive, and inefficient systems, including the electric motors, boiler, water pumps, and steam distribution lines, were investigated for their energy efficiency, energy conservation strategies, and energy performance were determined. Benchmark data and 36 months of data (January 1, 2019 – December 30, 2021) on energy (Furnace oil, diesel oil, and gasoline in liters and electricity in kWh) were gathered and utilized in order to examine the factory's energy consumption and specific energy and provide a conclusion.

The analysis indicates that fewer than 50% of factory-installed motors have motor loading. Replacing water pumps can result in an annual energy cost savings of around 95416ETB. According to the boiler's detailed energy audit, the combustion system's input and output masses were determined to be 21.66 kg and 21.6 kg, respectively. The boiler's computed heat intake, heat output, and heat loss were 2,519.1 kW, 2085.8 kW, and 414.35 kW, respectively. The boiler's estimated combustion chamber efficiency was 84.3%. However, the boiler had an overall efficiency of 79.5% and a thermal efficiency of 83.6%. The detailed energy audit revealed the following potential energy-saving measures: fixing the feed water treatment plant (the energy saved will cost around 569332.8ETB), and insulating boiler surface (cost of energy saved will be around 70405.2ETB).

Finally, the steam distribution lines energy audit revealed the potential for yearly savings of around 160068.6ETB. In this specific industry, the boiler feed water tank receives condensate from the point of use, which raises the temperature of the feed water to 55 degrees Celsius. In Ethiopia Tannery S.C., some steam trap points(points on the heat exchanger around the bottle washer)have issues and must be taken into account in order to enhance the steam strap's overall working efficiency. Overall, this thesis evaluated Ethiopia Tannery S.C.'s energy usage and, found and suggested energy-saving possibilities and practices.

9.2 Recommendation

The following suggestions are crucial and must be implemented if an Ethiopian Tannery S.C. wants to increase the efficiency of its energy use.

- Replacing the factory's outdated and large motors
- The firm must replace low-operating water pumps and adhere to all operational guidelines in order to enhance the energy efficiency of water pumps and their systems.
- Maintaining the water treatment facility and insulating the boiler's surface.
- The plant must implement energy-saving solutions for surfaces and steam leaks that have been found, as well as perform routine inspections.
- The financial feasibility and material selection of all energy conservation opportunities discussed above were based on information gathered from technical personnel of the company and previous cost of similar commodities in the company, so further study is required to deal with the implementation of recommended measures.

9.3 Energy action plan

Table 9.1: Summary of Thermal Energy Saving

S/N	**Measure**	**Annual cost Saving**	**Investment cost**	**Pay-back period**	**Recommendation**
		ETB	**ETB**	Year	
2	feed water treatment	569332.8	172,500	0.3	Short terms target
3	saving from using steam leakage	160,068.6	21,400	0.13	Short term target
4	Saving from boiler surface insulation	70,405.2	32,000	0.46	Medium term target
	Total	799,806.6	225900		

Table 9.2: Summary of electrical energy saving with initial investment required and payback period

S/N	Measure	Annual Energy Saving	Annual cost Saving	Investment cost	Pay-back period	Recommendation
		kWh	**ETB**	**ETB**	**years**	
1	Saving from replacing less efficient electrical motors	12,387.20	86,214.96	1846165.72	21.41	not feasible
	Total	12,387.20	86,214.96	1846165.72		

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