ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ADDIS ABABA INSTITUTE OF TECHNOLOGY
School of Multidisciplinary Center of Renewable Energy

ASSESSEMENT OF ENERGY CONSUMPTION IN BREWERY INDUSTRY:

CASE STUDY IN DASHEN BREWERY

A Thesis Submitted to the Graduate studies of Addis Ababa University in Partial Fulfillment of the Requirements for the award of the Degree of Masters of Science in Energy Technology

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Approved by board of examiners

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External Examiner **Signature**

Declaration

I, Zewge Worku Setegn the undersigned, declare that this research thesis entitled **“**Assessment of Energy Consumption in brewery industry **-**Case Study in Dashen **Brewery”** is my original work and has not been presented for a degree in any other university and that all sources of materials used for the study have been duly acknowledged.

Declared By:

Name: <u>Zewge Worku Setegn</u>

Signature: _____________________

Date: _____________________

Acknowledgement

Above all, I would like to praise the Almighty God for everything done for me on the accomplishment of this thesis work.

I am deeply grateful to my thesis advisor Dr. Solomon T/Mariam for his day to day support, advice, creative ideas, assistance and suggestions greatly contributed to this thesis work. This thesis would not have been possible without my advisor's persistent technical and moral support.

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Acronym

TJ	Terra Joule
GDP	Gross domestic product
IEA	International Energy Agency
VFD	variable frequency drive
HL	Hectoliter
MJ	Mega joule
CSIR	Council of Scientific and Industrial Research c
GJ	Giga joule
GWH	Giga watt hour
MJ	Mega joule
SEC	Specific energy consumption
ISO	International standard organization
Cfm	Cubic feet meter
FAD	Free air delivery
TPH	Ton per hour
HFO	Heavy fuel oil
USASB	Up flow Anaerobic Sludge Blanket
COD	Chemical Oxygen Demand
Ksh	Kenyan shilling

Abstract

Dashen Brewery factory is one of the biggest energy consuming brewery factory in Ethiopia. There are many processes involved in the manufacture of beer and these processes involve the use of thermal energy generated with heavy fuel oil and also electricity to drive pumps, motors, compressors, lighting and others. The 2019 of the factory energy bill data showed that the total electricity consumption of factory was around 36.2GWh and a thermal energy (heavy fuel oil) consumption of 96346.5GJ. The specific energy consumption of the factory for both thermal and electricity has been analyzed and compared with the international best performed factories. This has been done by collecting the historical energy consumption and production data of the factory. The purpose of this assessment is to identify energy saving opportunities and to recommend possible measures with their technical and financial feasibilities.

To conduct this assessment different similar studies on breweries were assessed and detail analysis were not observed in many of the researches especially on leakage testing on air compressors, saving calculations from heat loss on valves and flanges, and heat recovery system on flue gas. In this study, the above research gaps have been addressed and saving potentials also been estimated.

According to the preliminary analysis, the average total specific energy consumption of the plant is 98.14kWh/HL which is higher than the recommended international bench mark by 42kWh/HL. This initiates the researcher to conduct a detail energy consumption assessment on selected on major energy consuming devices like compressor, boilers, electric motors, and lightings. To conduct the assessment, historical data of the factory were collected and measurement was also taken for detail assessment by using portable instruments. Energy conservation measures have been identified and their saving potentials have also been estimated. Optimizing the compressed air usages and arresting the leakage a total annual electric energy of around 337,104kWh can be saved. This is equivalent to a monetary annual saving of 404000Birr. The energy consumption assessment study on one of the boilers indicated that, reducing the excess air, insulating the valves and flanges, and installing economizer at the stack, an annual fuel and cost saving of around 235,200 litter and 838,764 birr can be achieved respectively. The envisaged annual energy saving potential by retrofitting inefficient lightings by light emitting diode, LED, is 221,000 kWh per year equivalent to a monetary saving of about Birr 265,849 per year. Finally, the efficiency reduction due to under loading of electric motor was analyzed and some of them were found to be a loading of 50% and below. This efficiency reduction can be improved by installing variable frequency drive,VFD or other means. Improving the loading on electric motors, an annual energy saving of 80,800kWh and equivalent cost saving of 96,900 Birr can be achieved. Generally the study on the selected areas of the factory indicates that a total of 639428kWh electricity and 235249 litter of heavy fuel oil can be saved if the recommended energy conservation measures in each area are implemented. Additional energy might be saved by conducting energy consumption assessment on other sections other than the selected focus areas such as detail studies on pumps, cooling sections, cooling tower, waste water treatment, and on other remaining areas. Additional benefits of implementing the energy saving opportunities come from decreasing environmental impacts, improving working conditions of the plant employees and higher energy security at the plant.

CHAPTER 1

Introduction

1.1 Background

Energy has always been and remains one of the main strategic premises for the development of any economy and the foundation of all forms of social life. Fast growing economies as well as rapid population growth lead to inevitable increase in energy consumption. The key indicator table by the International Energy Agency [IEA] shows that in 2019 the total energy production of Ethiopia was 1867239 TJ. This number is expected to grow not only in an exponential rate but with a faster rate than the Gross Domestic Product (GDP) per Capita. The main source of energy production is from biomass which accounts for 1625032TJ which is almost 87% of the total energy consumption. The remaining energy was generated from hydroelectric dams 52429 TJ, 2.8% of the total consumption and from modern fossil fuel 187798TJ which is 10% of the total energy consumption of the country. In order to meet the increasing energy demand for industries as well as to decrease negative environmental impacts, it is important to constantly search for untapped energy efficiency potential. Moreover, new energy policies as well as demands from customers motivate companies to analyze their energy consumption more carefully and take actions, aimed on finding ways of improving energy performances of company’s operations [1].

Energy efficiency is one of the key factors which allow any industry to stay competitive regionally and globally. Moreover, today companies pay more attention to reduce consumption of resources in order to answer modern challenges of energy security, new governmental policies, air pollution and climate change. An energy consumption assessment study is an instrument, which can be used for understanding how the energy is used and identify possible energy saving opportunities.

Conducting energy performance assessment on a regular basis is a way to identify possible improvements in terms of energy efficiency. The main objective is to identify, evaluate and recommend energy saving opportunities, which can become a solid basis for elaborating and implementing energy efficiency programs. Main advantages of conducting energy performance assessment and implementing energy saving measures are resource conservation, operational cost reduction, for sustainable energy supply, improve operational quality of energy intensive industries and improve safety and productivity [2].

There are different high energy consuming industries such as sugar industries, brewery industries, textile industries, cement industries, etc. Brewery industries are one of the most energy intensive plants. Energy used in a brewery breaks down into two primary units. Thermal energy is used to generate hot water and steam, which is then used in brewing, packaging and general building heating. Electrical energy is used to power all equipment, with the largest user being refrigeration. Thermal sources average 70% of the energy consumed in the brewery [3].

Dashen Brewery Factory is found in Gonder, in Amhara Regional State. The factory uses heavy fuel oil and electric energy to generate thermal and electric energy in its production. In this factory the energy performances of compressor, boilers, steam distribution system, electric motor and lightings, have been assessed to identify and recommend energy conservation opportunities.

1.2 Statement of Problem

Industries use electrical and/or thermal energy for machines or equipment like boilers, motors, pumps, compressors, furnaces, diesel generating engines, refrigerators, etc. However, there are many problems in the industry sectors to efficiently use their energy. Due to this the factories are exposed to high energy bills, environmental problems, non-profitability and less competitiveness [4].

A preliminary assessment has been conducted in Dashen Brewery Factory to identify the energy utilization challenges when compared with the literature. In case of Dashen Brewery Factory the gaps (problems) identified were: Firstly, high cost of energy was observed and from the information gathered, high fuel consumption of one of the two boilers as compared with the second similar type boiler was identified. Secondly, there is no heat recovering device (Economizer) installed on the stack of the boiler even if the flue gas temperature is significant for recovering (more than 250^0C). Thirdly, as observed from the factory visit, there are significant air leakages; and electric motors are operating at lower efficiency. Compressed air leakage through the couplings, old hoses, or worn and leaking seal are the other problem observed during the visit.

Thus, this research paper conducts energy audit of the factory and suggests better energy conservation opportunities and measures to improve the efficiency of the factory.

1.3 Objective

1.3.1 General objective

The general objective of this thesis research is to assess the energy use of Gonder Dashen Beer Factory, to identify energy conservation opportunities and recommend possible measures.

1.3.2 Specific Objectives

The specific objectives are:

- To identify the energy consuming equipment, machines and system of the factory
- To assess the energy performance of the factory using historical data and by conducting measurements.
- To identify energy conservation opportunities
- To conduct the technical and economic evaluation of the identified energy conservation opportunities
- To recommend possible energy saving measures and propose plan of action to the factory.

1.4 Scope of the study

The research was limited to a site-specific study. Elaborated energy management opportunities were evaluated on the basis of present conditions at the Dashen beer factory. After the first walk-through visit to the plant it was decided to analyze the following systems (areas) at the Dashen beer factory site in the frames of the energy performance assessment:

1. Boiler performance
2. Steam distribution system
3. Air compression system
4. Electric motors
5. Lighting system in the facility

The above focues areas have been selected and prioritized based on their energy consumption level, time and measurement limitation issues. The energy consumption share of heating, ventilation and air conditioning system (HVAC) in the factory is estimated to be around 10%. Due to the low energy consumption share, HVAC is not considered in the study. The performance of the electric motors of the different pumps is evaluated but not the pump performance as a system due to lack of proper functional flow meter. Other energy consuming areas like blowers and fans are not also considered in this research due to insignificant energy consumption share.

1.5 Organization of the thesis

This thesis research paper is organized in to 6 chapters with the following details.

- ✓ Chapter 1: it discusses the need of conducting energy performance assessment, the background behind the study, problem statement, the scope covered by this assessment research, and the general and specific objectives of the thesis research.
- ✓ Chapter 2: Presents the literature review. Here the Breweries energy performance is discussed and also the research gap is identified.
- ✓ Chapter 3: Discusses the methodology applied for the research. It presents the brief introduction of Dashen Brewery Factory including: its foundation, location, structure of organization, employees, the utilities *etc*. It discusses the process flow diagram and specific energy consumption. The sector specific energy performance assessment methodology is presented here on Compressor, Boiler, Motors, and Lightings.
- ✓ Chapter 4: Deals with the factory energy bill, energy consumption patterns of the factory and specific energy of the factory.
- ✓ Chapter 5: It presents the result and discussion part of the research. The current energy consumption of the factory, sector specific energy performance analysis and discussion based on the result of the analysis has been briefly discussed here. Energy saving potential on each focus areas like compressors, boiler, electric motor and lightings is estimated and energy conservation measures are also presented here.
- ✓ At the end of the paper reference and appendixes are also included.

CHAPTER 2

Literature Review

2.1 Review on breweries' energy performance

The efficient use of energy is of prime importance in all sector of the economy. Energy cost is a significant factor in economic activity on the same level with factors of production like capital, land and labor [5]. Energy audit concept is a measure of the efficiency of energy utilization in a manufacturing process, thus leading to interest in energy performance of machines and plants directly associated with production process [6]. It is important to account for total consumption, cost and how energy is used for each commodity such as steam, water, air and natural gas. Attention is focused by Energy managers on how to reduce energy consumption per unit of production. To obtain best possible savings, good audit and survey must be carried out. An energy audit helps in energy cost optimization, pollution control, safety aspects and suggests the methods to improve the operating and maintenance practices of the system. Energy Audit attempts to balance the total energy inputs with its use and serves to identify all the energy streams in the systems and quantifies energy usages according to its discrete function [7]. Proper maintenance helps conserve energy by keeping operational efficiencies at their best level.
The brewing process is energy intensive with 30% to 50% of the energy in the form of electricity been used in cooling during the cooling of the "wort" alone and another 30% to 50% in cooling the fermentation tanks. There are many processes involved in the manufacture of beer and these processes involve the use of thermal energy, usually generated with oil or gas and also electricity to drive pumps, motors, compressors and fans and some time for direct heating of process streams [8]. Measures to reduce energy consumption and optimize the hot water balance can be based on equipment or changes in operation. Both possibilities are critically reviewed and evaluated. Such measures discussed are standard in newly built industrial brew houses but can also be implemented as upgrades in existing plants. Opportunities for saving energy in specific applications should be identified and evaluated by the application of energy management. A general prerequisite of any energy efficiency assessment study is that the implemented measures should not compromise product (beer) quality. On the contrary, they should help improve product quality.

It has been suggested that large overseas breweries can achieve a specific fuel requirement of 125 MJ/HL and a specific electricity requirement of 36 MJ/HL [7]. The council for scientific and industrial research (CSIR) estimated that, for an existing brewery

- 10.9% - potential energy savings with minimum technology and
- 14% - potential energy saving with significant change in technology [8]. These potential savings are expected to vary substantially from brewery to brewery.

In many brewing industry, process and heating applications continue to be powered by steam and hot water. Heating, which accounts for about 70% of energy requirements, is achieved with steam [9]. The mainstay technology for generating heating or process energy is the traditional boiler. Whether fire tube or the various water tube forms, the commercial or package boiler has proven to be efficient and cost effective in generating energy for many processes and heating applications. For proper boiler operation that can lead to greater efficiency, the following measures can be applied:

- Boiler Blow-down, Heat Recover and Control
- Proper Excess Air
- Reduce Scaling and Soot Losses
- Radiation and Convection Heat Loss Minimization
- Reduction of Boiler Steam Pressure •
- Variable Speed Control

Heat can be recovered from boiler blow-down using heat exchanger to preheat boiler makeup water. Any boiler with continuous blow down exceeding 5% of the steam rate is a good candidate for the introduction of blow-down waste heat recovery [10]. For example, an efficiency improvement of over 2 percent can be achieved at a 10 percent blow-down rate on a 10.34bar boiler.

Uncontrolled continuous blow-down is very wasteful. For example, a 10% blow-down in a 15 kg/cm^2 boiler results in 3% efficiency loss. Automatic blow-down controls can be installed that sense and respond to boiler water conductivity and pH, thereby increasing boiler efficiency[3].

Proper excess air application in steam production process is another very important factor in boiler efficiency improvement. Oxygen trim controls can be added to the burner-control system. These controls continuously regulate the oxygen level in the boiler-flue gases and adjust the quantity of air delivered to the burner, minimizing the excess air delivered. In conventional control systems, excess air levels typically are 10-20 percent. With oxygen trim controls, excess air levels can be reduced to 5 percent or less. Reducing Scaling and soot Losses is another important factor for efficiency improvement. In oil and coal-fired boilers, soot buildup on tubes acts as an insulator against heat transfer. Any such deposits should be removed on a regular basis. An estimated 1% efficiency loss occurs with every increase in stack temperature. Stack temperature should be checked and recorded regularly as an indicator of soot deposits. An upward trend in flue gas temperatures over weeks or months usually indicates that a deposit has built up on either the fireside or waterside of boiler heat-exchange surfaces. The boiler should be inspected promptly [3].

It is recommended that repairing or augmenting insulation can reduce heat loss through boiler walls and piping to minimize radiation and convection heat Loss.

Reduction of boiler steam Pressure is the other most effective means of reducing fuel consumption by as much as 1 to 2%. Any reduction of boiler pressure reduces the specific volume of the steam in the boiler, and effectively reduces the boiler output [3].

Refrigeration normally accounts for 25-45% of the total electricity use (including compressors, condensers, and pumps). A large quantity of energy is lost in the water vapors of cooling towers. It was calculated for a brewery that this loss could be reduced with a rate of return of 104%, by installing a double heat exchanger before the condensers to heat water [3]. The CO_2 plant requires significantly lower refrigerant temperatures than for the rest of the plant. It has thus been suggested that it is more economical to have a separate refrigeration plant for CO_2 and operate the main refrigeration plant at a higher temperature [11].

Compressed air is considered to be a free source of energy by many employees, but is actually one of the most expensive utilities within a brewery. At its best, a system is 12 to 15% efficient [3]. This means that for every kW of energy used to produce compressed air, only 12-15% is delivered to the source. The remainder of the energy is lost in the form of heat. Therefore it is imperative to reduce compressed air usage whenever possible. Setting compressor air pressure to the lowest possible level, and above all finding and fixing air leaks on a continuous basis is the key activities to reduce energy consumption in air compression and process. Compressed air leaks are very common. Leaks are a major source of inefficiency and in some cases will account for 30% - 40% of compressed air system [3]. Leaks also increase the system pressure drop, requiring additional compressors to be put on line or operating the single compressor at full load to maintain system pressure. This higher pressure takes more energy to produce, shortens the life span of equipment, and causes equipment that need compressed air to operate less efficiently. About 5-10% of brewery plant electricity is used for air compression. Spent grains removal is a large user of compressed air. It is claimed that pneumatic conveying requires about 10 times more electricity than mechanical transport, and thus mechanical transport could be considered for grain transport. Individual distant users of compressed air can result in significant distribution losses. It has been suggested that distant users should have a decentralized local source of compressed air [3].

Mashing is also another area for energy saving. Increasing the temperature in the mash-tun by make-up with hot water is a possible area for energy reduction in mashing. However this scheme may interfere with stringent brewing parameters. Packaging normally accounts for over one third of total steam usage and over 12% of total electricity usage, and consequently packaging deserves close examination [12]. The largest users of steam and electricity in packaging are the washers and pasteurizers. It is claimed that in general, for can pasteurizers only about 27% of the usable energy finds its way into the beer [13]. The rest is lost in space heating, plant heating, can rinsing, starting and stopping losses, standing losses, and radiation losses. Pasteurization is thus an area of potential energy saving. It is advised that pasteurizers and washers should be checked to see if they are not being heated up for too long, and whether everything is turned off during shutdown.

Another possible area is to deploy a renewable source of energy in brewery factories. A pilot solar water heater system for pasteurization was installed on the packaging hall roof of a brewery in the USA. All collected energy was stored in a thermal capacitor, providing hot water at temperatures between 72°C and 86°C continuously. An economic evaluation of solar water heating on a brewery was carried out and showed it to be feasible only when a 50% tax credit was assumed [14]. For Ethiopia where energy costs are lower in comparison, such a system is not expected to be economically feasible unless a more tax credit or duty free importation of all the solar water heating system is allowed.

Energy saving opportunities in pumping of liquids is another area which should to be considered. Pumping accounts for about 34% of the power consumption in a brewery. Proper specification and maintenance of pumps thus deserves attention. If the average pump efficiency can be increased from 60% to 70% this should reduce the total electrical consumption by 4 to 5%. Speed controlling system is also an area to be considered in pumping system [15].

Lighting is another area to be considered. There are many low-cost and no-cost measures that can be utilized to help reduce energy costs, without adversely affecting working conditions. In most cases upgrading the existing lighting system will save 30% to 40% of the current electrical energy consumed for lighting systems in an average-sized plant [3].

2.2 Research gap

Most of the reviewed energy efficiency studies on brewery industries mainly focus on analyzing the energy performance parameters such as energy intensity, energy productivity and normalized performance indicator (NPI).These parameters have showed the general energy performance of the industries, the detail analysis on performance parameters of individual technologies such as boiler system, air compression system, and other energy intensive technologies have not been assessed in many of the researches. The study on Dashen beer factory give attention on the detail analysis on some selected energy intensive technologies particularly on Boiler, motors air compression systems and lightings. However, there are some areas which have not been covered by this research due to lack of adequate data, measuring devices , complexity of the system and it would have been taken long time if all the areas or facilities are included in this study. The gaps of this research are:

- Energy performance assessment on electric pumps has not been included due to lack of flow meters and adequate data for efficiency analysis of pumps.
- Refrigeration system performance analysis has not been included in this study as the technology employed in the facility was observed to be very efficient and it has been assumed that no significant energy saving will not be achieved.
- Heat recovery from blow down hasn’t been included as the investment cost assumed to be higher and as a consequence it will have longer payback period.

CHAPTER 3

Methodology

This section deals with the methods to be implemented during the energy consumption analysis. Cross-cutting approaches and sector specific approaches are the two methods which can be applied to assess the energy performance of factories [16].

3.1 Cross-cutting methods

In the cross-cutting method, energy performance assessment procedures, facility descriptions, details of the factory's process flow, the description of measuring instruments, energy consumption details and calculation of specific energy consumption are the main parts to be presented. It is also recommended to start the assessment by reviewing different research works of similar studies as well as guidebooks.

3.1.1 Energy performance assessment procedure

Step1	Primary data gathering: products/service of the facility, process flow diagram and identify major energy consuming systems of the factory
Step 2	Measurement
Step 3	Analysis: Energy/mass balance and energy loss/waste analysis
Step 4	Identification and development of energy conservation opportunities
Step 5	Conduct cost benefit analysis: Technical and economic feasibility
Step 6	Preparing and recommending the factory about the energy conservation opportunities for implementation.

3.1.2 Measuring Instruments

A wide array of latest, sophisticated, portable, diagnostic measuring instruments were used to measure different parameters which can help for the detail analysis. These instruments are described in Table 3.1 and illustrated in in Figure 3.1.

Table 3-1 Description of measuring instruments

No	**Instrument Description**	**Instrument Function**
1	Flue gas analyzer	This instrument has in-built chemical cells which measure various gases such as O2, CO, combustion efficiency, excess air etc. and temperature of the flue gas.
2	Three phase power quality analyzer	Three Phase Power and Harmonic Analyzer
3	Infrared thermometer	Used to measure the temperature of solid bodies
4	Thermal Imager	Capturing temperature and heat Profile of boiler body, steam pipes and others
5	Power clamp meter	Used to measure instantaneous current, voltage, power, and power factor
6	Anemometer	Used to measure the velocity of the suction air to the compressor

Flue gas analyzer *Power Analyzer* *Infrared thermometer* *Thermal Imager* *Power clamp meter* *Anemometer*

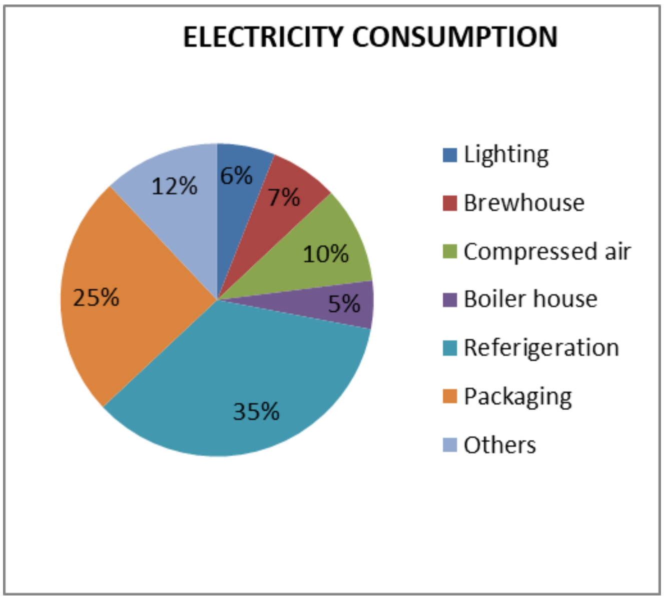
Figure 3.1 Measuring instruments

The detail specification of the equipment are presented in Annex 3

3.1.3 Plant description

The name Dashen is taken from the famous mount Rasdashen, which is located 100km from the brewery; Ethiopia's highest mountain (Elevation 4523 meters) and a home for rare endemic found and flora. Dashen brewery factory is located in historical town of Gondar. The brewery is situated on the area of 85,000 square meters with building area of 12,000sqm. DB S.C is established in September 1992 E.C, with an initial capital of over 340 million birr. It is owned by Amhara regional state rehabilitation development organization. Dashen brewery factory utilizes state of the art technology and highly qualified exports that will enable it to compete on the exports market with the leading of the international beer producing and marketing companies. Before expansion Dashen brewery factory had annual production capacity300.000 hectoliter by expanding its capacity in to three fold the brewery has now annual production capacity 769000 hector liter or 42000 bottle/ hr. The factory uses 57% of its energy source from electricity and 43% from heavy fuel oil. The thermal energy, supplied by heavy fuel oil, is used to provide process steam and hot water. The electricity source is used to run different motors, compressors, cooling system, pumping, lightings and others.

Energy usage in breweries varies depending on size, location, and product. Refrigeration generally creates the largest electrical load, while brewing consumes the largest amount of thermal energy. Below are graphs that illustrate the percentage of energy both electricity and thermal used throughout the operation in Dashen Brewery.



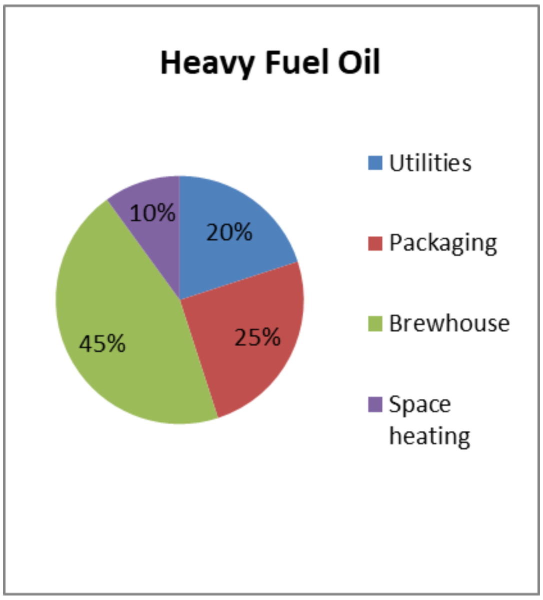


Figure 3.2 Energy consumption percentages in Dashen Brewery

Currently, the total work force in the Dashen brewery factory 760 employees of which 666 permanent and 94 are contracts employees. Dashen brewery factory participates in different development activities such as education, health, sports art and environmental conservation and job opportunities.

3.1.4 Brewing process and flow chart

The brewing process in the Dashen beer factory has to go through the phases of Malting, Milling, Mashing, Lautering, Boiling, Fermenting, Conditioning, Filtering, and Packaging. Each step has been briefly discussed followed by a brewing flowchart (Figure 3-2):

Malting: Here the conversion from carbohydrates to dextrin and maltose takes place. The grain used as the raw material is usually barley.

Milling: The malt is then mixed with water to complete the conversion of starches in the grain to sugar. After that the grain is milled to create the proper consistency to the malt.

Mashing: This process converts the starches released during the malting stage, into sugars that can be fermented.

Lautering: The liquid containing the sugar extracted during mashing is now separated from the grains. It is then generally termed as wort.

Boiling and Hopping: Wort boiling requires a lot of energy (24-54 MJ/ hl) with a temp of 118-122 ^{0}C & it is fitted with coils or a jacketed bottom for steam heating and is designed to boil the wort under carefully controlled conditions. Boiling the wort, ensures its sterility, and thus prevents a lot of infections. Hops are added during this stage of boiling. Hops are used to add flavor and aroma to balance the sweetness of the malt.

Fermenting: The yeast is now added and the beer is fermented. The yeast breaks down the sugars extracted from the malt to form alcohol and CO_2.

Conditioning: Fermented beer contains suspended particles, lacks sufficient carbonation, lacks taste and aroma, and less stable. Conditioning reduces the levels of these undesirable compounds to produce a more finished product

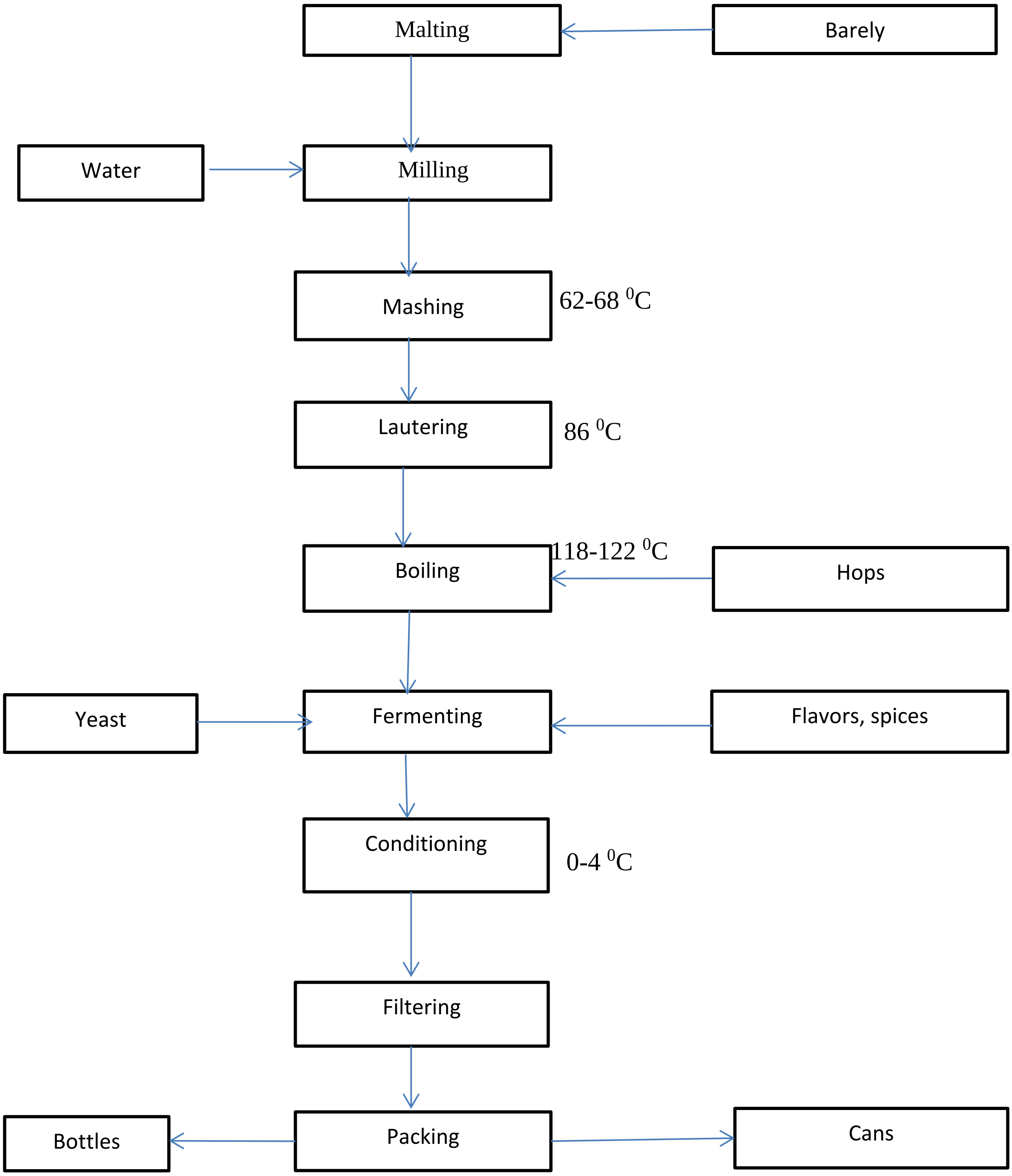


Figure 3-3 Brewery process flow

Filtering: Filtration helps to remove excess of the yeast and any solids, like hops or grain particles, remaining in the Beer. Filtering is the process which produces the clear, bright and stable Beer.

Packaging: Packaging is putting the beer into the bottles, cans or some other high volume vessels. One of the most important things in packaging is to exclude oxygen away from the Beer.

3.1.5 Specific Energy Consumption

Specific energy consumption (SEC) is generally defined as how much energy is used for producing a unit of product. It is calculated by dividing the amount of energy used with the amount of products. SEC can be calculated for the total amount of products or for individual products from the product mix. Similarly, SEC can be calculated for the total primary energy used or for specific energy carriers, e.g., how much electricity and heat separately has been used for producing a unit of product. SEC in international standards, such as e.g., ISO 50006:2017 [4], is recommended for being used as an energy performance indicator. This is because it indicates measurement of the energy performance and thus the performance of benchmarking.

SEC is calculated as a ratio of energy used for producing a product:

$$SEC = E/P \qquad 3.1$$

Where,

SEC Specific energy consumption

E Total energy used for producing total product, P

P Total amount of product

3.2 Sector-specific methods

One should go beyond cross-cutting method when identifying the energy saving opportunity is required. This will be implemented in case of sector-specific methods where detail references and data are to be considered. The energy assessment study in the factory involved an energy performance analysis of some specific areas especially on electrical motors, compressors, pumps, boilers, and on steam distribution system. Due to the fact that the focus areas are fairly unique, specific methods were applied to each of them, in addition to the above mentioned ones. The description of the specific methods and information, required for analysis for each of the focus areas, is presented below.

3.2.1 Air Compression System

Data and information that should be collected from the name plate: -

- Number and type of the air compressing equipment
- Power rating of the motor of the compressor
- Flow rate
- Loading and unloading Pressure

The current compressor operating practices in the factory is also considered as a factor in identifying the energy saving opportunity. The plant has installed three screw air compressors two of them are 97 kW and the remaining one is 110 kW to meet the compressed air requirement of various applications. In this study, the 110 kW-compressor is considered since it is the only compressor operating to meet the current demand.

Table 3.2 Name plate data of the compressor

Air Compressor reference	**Unit**	**Compressor 1**
Make		Belgium
Type		Screw compressor
No. of stages	Stage	2
Discharge capacity	Cfm	674
Discharge pressure	Bar	8.6
Motor rating		
Power	kW	110
Full-load current	Ampere	180
Voltage	Volt	400
Power factor		0.96
Frequency	HZ	50
Specifiec Power Consumption	kW/cfm	0.163

Required measurements and experiments:

In order to define the amount of energy, which can be saved by optimizing the work of the air compression equipment, the following measurements and experiments were conducted.

I. **Free air delivery (FAD) test**

Free air delivery (FAD) test can be conducted in two ways namely suction velocity method and pump up method.

Since the plant was in continuous operation, suction velocity method was adopted.

The Procedure used for Suction velocity method

- ✓ Measure the area of the inlet
- ✓ Take at least 4 trials of air inlet speed measurement for both loading and unloading cases using anemometer and shown in Figure3.3 below

- ✓ Take the average of the speed in meter per second

Calculation methodologies for FAD test

The actual amount of free air delivery (Q) to the compressor is calculated by equation 3.2 below.[17][18]

$$free\ air\ delivery = Average\ in\ let\ air\ speed * Area\ of\ the\ inlet$$

$$Q = V_{av} \times A \qquad 3.2$$

II. Leakage (No Load) test

Ideally speaking, compressed air system should not have any leaks at all but in practice it is rather difficult to have a zero leakage system. Depending upon the industry and type of air usage patterns up to 10% air leakage is allowed.

Procedure for leakage test is described below.

To do this no load test, it was required to wait up to maintenance time which usually occurs one in a day for about 20 minutes. The following steps to be followed during the leakage test.

Step 1 Switch off the compressor
Step 2 Close air receiver outlet and drain valves
Step 3 Open compressor discharge and air receiver discharge valves
Step 4 Close all end use points not to add the end use air as leakage
Step 5 Start now the compressor and allow the pressure to build up
Step 6 Note the time when it unloads
Step 7 Note the time when it loads
Step 8 Repeat this exercise for four or five times
Step 9 Switch off the compressor

At least conduct four trials and register the loading and unloading time.

Calculation methodologies for leakage test.

Total percentage system leakage loss can be determined using Equation (3. 3).[18]

$$L\% = \frac{T \times 100}{T + t} \qquad 3.3$$

Where,

L% leakage percentage

T on load time in minute

t off load time in minute

The total system leakage Loss (L) is the product of the percentage loss and the total discharge capacity of the compressor

$$L = Q \times L\% \qquad 3.4$$

Power wasted due to leakage can be calculated as:-

Power wasted is the product of the total system leakage and the specific energy consumption as stated equation 3.5

$$\text{power wasted} = \text{total system leakage} \times \text{specific energy consumptio}n$$

$$P_w = L \times SPC \qquad 3.5$$

Annual Energy wastage is calculated by multiplying the power wasted with the annual operating hours of the compressor, Equation 3.6

$$\text{Annual Energy Wastage, kWh} = \text{power wasted} \times \text{Annual operating hour}$$

$$E_w = P_w \times h \qquad 3.6$$

The actual specific power consumption of the compressor is defined as the ratio of the actual input power to the volume flow rate which is shown in Equation 3.7.

$$SPC = P_{in} \div Q \qquad 3.7$$

Where

SPC Specific power consumption

P_{in} Actual input power

3.2.2 Steam generation and distribution system

The plant has installed two similar boilers of fuel fired tube, Figure 3.4, to provide hot water and steam for different processes in the factory. These two boilers generate hot water and steam mainly for mashing process, wort boiling, pasteurization and bottle washing.

Figure 3.4 Fuel fired boilers of the factory

Data and information that should be collected

- The type, volume, and quantity of boilers used.
- The present practice of operating the boilers
- Feed water temperature and pressure

Table 3- 3 Parameters of the boilers

Nº	Parameter reference	Unit	Boiler 1	Boiler2
1	Type of Boiler	Fire tube boiler		
2	Quantity of steam generated	TPH	8	8
3	Steam pressure	Bar	7	7
4	Steam temperature	^oC	240	240
5	Fuel used		Heavy fuel oil	Heavy fuel oil
6	Quantity of fuel consumed	TPH	208002.889 litter/year	208002 litter/year
7	GCV of fuel	kcal/kg	10941	10941
8	Feed water temperature	$^o C$	91	91

Required measurements and experiments:

To calculate the efficiency of the boilers using the indirect method, the following experiment and measurement were conducted:

- The Flue gas temperature, CO_2 and O_2 percentage in flue gas were measured and registered using the sophisticated flue gas analyser.
- A detailed survey was also carried on various distribution lines and equipment.

- The surface temperatures were measured using Thermograph camera to check the adequacy of insulation.
- The statues and functionality of steam traps were assessed by measuring the temperature of the steam trap inlet and outlet using infrared thermometer.

The boiler efficiency can be determined using **indirect method**. To evaluate the efficiency of the boilers using the indirect method, the different losses should be evaluated first. These losses are:-

- Dry flue gas loss
- Heat loss due to H_2 in fuel
- Heat loss due to moisture in fuel
- Heat loss due to moisture in air
- Heat loss due to surface radiation and convection

Determining of boiler efficiency by indirect method

The stoichiometric air fuel ratio is the exact amount of air required to burn one kilogram of fuel. Depending up on the fuel type to ensure complete combustion, additional air (excess air) is required. There are different research works which recommend the amount of excess air required for a given type of fuel. If the boiler uses less amount of excess air than the recommended it leads to incomplete combustion. If it uses more amount of excess air, it may lead to a significant heat loss through the flue gas.

To calculate the different losses mentioned above, first the theoretical (stoichiometric) air, excess air and actual mass of air required for combustion could be calculated using equations 3.8, 3.9 and 3.10, [19]

$$(A/F)_T = [11.6C + 34.8(H_2 - (O_2/8)) + 4.35S]/100 \qquad 3.8$$

Where,

$(A/F)_T$ the theoretical (stoichiometric) air fuel ratio, kg of air per kg of fuel

The percentage of the parameters (carbon, hydrogen, sulpher and oxygen) of the fuel is given in Appendix 1.

Percentage of excess air is calculated using Equation 3.9.[19]

$$E_A = \frac{\%O_2}{21\% - \%O_2} 100 \qquad 3.9$$

This actual percentage of excess air should be determined by taking the measured oxygen percentage reading taken from the flue gas using a flue gas analyzer. The actual mass of air consumed by the boiler then can be calculated using equation 3.10. Actual mass of air supplied to the boiler is:-

$$AAS = (1 + \frac{EA}{100})(A/F)_T \quad 3.10$$

If the actual excess air exceeds the recommended value, it indicates the presence of heat loss from the chimney together with the exhaust gases. Hence, one has to determine the difference between the factories actual mass of air and the expected air supply calculated using the recommended percentage excess air which depends on the specific type of fuel.

The different possible boiler loses can be calculated by the following formulas.[19], [20]

i. Percentage of heat loss in dry flue gas (L1)

$$L1 = \frac{mc_p(T_f - T_a)}{GCV} 100\% \quad 3.11$$

Where,

m mass of dry flue gas in kg/kg of fuel

It is the mass sum of CO_2, SO_2, N_2 and O_2

$$m = \frac{\%C \times 44}{12} + \frac{\%S \times 64}{32} + \frac{AAS \times 77}{100} + ((AAS - (A/F)_T) \times \left(\frac{23}{100}\right)) \quad 3.12$$

C_p specific heat of dry flue gas, kcal/kg.^oC

T_f dry flue gas temperature, ^oC

T_a ambient temperature, ^oC

ii. Evaporation heat loss due to H_2 in fuel (%)

$$L2 = \frac{9H_2\left(584 + c_p\left(T_f - T_a\right)\right)}{GCV} 100\% \quad 3.13$$

C_p is specific heat of superheated steam (0.45kcal/kg^0 C)

iii. % of Heat loss due to moisture in fuel (L3)

$$L3 = \frac{M*(584 + Cp*(Tf - Ta))}{\text{GCV of fuel}} 100 \quad 3.14$$

Where

M is moisture percentage in the fuel

iv. % of Heat loss due to moisture in air (L4)

$$L4 = \frac{AAS \times HF \times Cp(Tf - Ta)}{\text{GCV of fuel}} 100 \quad 3.15$$

Where,

HF humidity factor (0.024)

v. % of Radiation and convection loss (L5)

This loss can be assumed as 0.5 to 1% based on the body temperature of the boiler [19][20] . In this case, the body temperature of the boiler is 42^{0}C. Therefore, the % of radiation and convection loss can be estimated as 0.75.

The efficiency of boilers by Indirect Method is calculated as:- [19], [20]$\eta = 100 - (\mathrm{L1 + L2 + L3 + L4 + L5})$ 3.16

Other Observed Loses in the Boilers

Other losses such as losses from uninsulated steam valves and flanges have also been estimated. The total heat loss on an insulated steam pipes is calculated as

$$H_s = S \times A_s \quad 3.17$$

The Surface heat loss can be calculated as

$$S = (10 + \left(\frac{T_s - T_a}{20}\right))(T_s - T_a) \quad 3.18$$

Where:

S = Sur face heat loss in kcal/ hr m^2

A = Surface area in m^2

T_s = Hot surface temperature in ^{0}C

T_a = ambient temperature in ^{0}C

During the study, it was observed that there is no any economizer installed at the stack to re-use the temperature being lost through the flue gas. The temperature for boiler1 measured in the flue gas is about 251^{o}C.This indicates that there a potential to recover heat from the flue gases.

Assuming that the lost to surrounding and heat transfer efficiency is 100%, the Heat lost by flue gas E_{FG} (kJ/hr) is equal to the Heat gained by feed water E_W (kJ/hr)

$$E_{fg} = m_{fg} \times C_{pf} \times (T_{f1} - T_{f2}) \quad 3.19$$

$$E_w = m_w \times C_{pw} \times (T_{w2} - T_{w1}) \quad 3.20$$

Where: Subscript f refers to flue gas and subscript w to feed water

Subscript 1 refers to the entering flow and subscript 2 to the existing flow

m = mass flow rate (kg/hr.)

C_p= specific heat (kJ/kg. ◦C)

T = temperature (◦C)

E_{fg} = The Heat lost by flue gas (kJ/hr) E_W = The Heat gained by feed water (kJ/hr.)

E_w may be less than E_{fg} due to some of this heat (1 to 5% maximum) being lost by the economizer surface. The heated feed water entering the boiler requires less heat to boil. Hence, the heat gained in the economizer directly reduces the fuel consumption of the boiler. The reduction in fuel cost can be estimated from the following relationship:

$$Boiler\ fuel\ cost\ saved \left(\frac{Birr}{hr}\right) = \frac{(\mathrm{C_{fuel}} \times \text{heat gained by feed water})}{\text{boiler efficiency}} \quad 3.21$$

Where: C_{fuel} = cost of fuel (Birr/kJ)

3.2.3 Electric Motor

- **Data and information that should be collected:**

The major energy consuming electric motor in the factory is assessed and from the name plate the following main parameters are taken:

- Current,
- Voltage,
- Power factor,
- Active power and reactive power of each identified electric motors were collected. The important parameters of the motors are listed below in table 3-11

Table 3- 4 List of major energy consuming electric motors

No	Motor Reference	Power (kW)	Voltage (V)	FLA (Amp)	Power Factor	Speed (rpm)	Insulation Class
1	Ammonia Cooling compressor	132	400	205	0.92	3000	CIF
		132	400	205	0.92	3000	CIF
		132	400	205	0.92	3000	CIF
		110	400	205	0.92	3000	CIF
		110	400	205	0.92	3000	CIF
2	Air compressor	110	400	180	0.9	2980	
3	Pumps						
	surface pump motor	37	400	70	0.84	1465	CIF
	ground water pump 1	22	400	40	0.92	2950	S1
	ground water pump 6	22	400	40	0.92	2950	S1
	hot water pump to miller	11	400	17	0.93	3000	S1
4	Miller						
	crushing roller1	22	400	35	0.9	2900	S1
	crushing roller 2	22	400	35	o.9	2900	S1
5	Blowers						
	Blowers for boiler1	22	400	43	0.91	2800	S1
	Blowers for boiler 2	22	400	43	0.91	2800	S1
6	Filling, finishing and packing section						
	Bottle washer 1	11	400	17	0.93	3000	CIF
	Bottle washer 2	11	400	17	0.93	3000	CIF

- **Required measurements and experiments:**

The actual input power, voltage, current and power factor is measured by using power clamp meter. Using these data, the actual percentage of motor loading is calculated by the following equation.[21]

$$P_L = \frac{P_{in}}{(\frac{P_{shaft}}{\eta}} \quad 3.22$$

Where,

P_L Percentage loading

P_{in} Actual input power

P_{shaft} Shaft power of the motor

η Efficiency of the motor

3.2.4 Lighting system

There are many low-cost and no-cost measures that can be utilized to help reduce energy costs, without adversely affecting working conditions. In most cases upgrading the existing lighting system will save 30% to 40% of the current electrical energy consumed for lighting systems in an average-sized plant [3]. Choosing a sustainable, efficient lighting Solution is an excellent way to reduce energy consumption and overall operational costs. Likewise, sustainable lighting solutions can provide better, task-appropriate lighting that can increase productivity, reduce errors, and improve employee well-being throughout a facility.

This section provides background of the existing lighting fixture in the factory and the possible efficient lightings that can replace the inefficient one with its saving potentials. The investment cost and payback period also be presented.

Data and information that should be collected:

- ✓ Type, number and electrical power of the lighting devices
- ✓ Operating practices of the lighting system in the factory.

The lighting fixtures used in the plant include fluorescent tube lamps (FTL) and halogen lamps in the indoor and outdoor area of the factory. The various lighting fixtures and their description is given in the table below.

Table 3- 5 Details of Lighting Fixtures

No	Type of lamp	Number of fixtures	Rating, W	Total consumption, kW
1	Fluorescent lamps	309	36	11.124
2	Fluorescent lamps	11	58	0.64
3	Halogen			
	Indoor	143	250	35.8
	Out door	77	250	19.3

- **Required measurements and experiments:**
  - ✓ No additional measurements or experiments were required in this focus area

3.3 Energy efficiency Measures

After analyzing the measured data and using the observation obtained, technically and economically feasible energy efficiency measures are proposed.

Simple payback period

Payback period defines the time required to recover capital investments. Simple payback period technique is usually excludes the following aspects: timing of cash flow, inflation rate, interest rate of capital cost, depreciation, opportunity costs, etc. However, the method is able to give a result within reasonable accuracy [3], [22]

Simple payback period method is used for all the focus areas. It was calculated, according to the following formula:

$$PB = C_i/(Y_b - Y_c) \qquad 3.23$$

Where:

PB payback period

C_i Initial cost

Y_b Yearly benefit

Y_c Yearly cost

CHAPTER 4

RESULT and DISCUSSION

Based on the data collected, this section has presented and discussed the results using the predefined methodologies. First, the key performance indicator (specific energy consumption) has been analyzed to compare the factory's current energy consumption performance with the international benchmarks. This has led to identify the main energy consuming sections in the factory (boiler, compressor, Electric motors, and lightings) for further analysis. Finally, the possible energy saving potentials, energy conservation measures and payback period have been presented.

4.1 Current energy consumption of the Factory

Gonder Dashen beer factory uses electricity and thermal energy for the production process. All the electric motors and other many appliances are operated using electricity supply and thermal energy using heavy fuel oil is used to generate hot water and steam, which is then used mainly in brewing and packaging. The factory uses 58% of its energy source from electricity and 42% from thermal.

Electricity Consumption

The electricity consumption data over the last one year (Jan 2019-Dec 2019) of the factory and the specific electric energy consumption is presented in Table 4.1.The specific electric energy consumption is calculated using Equation 3.1.

Table 4- 1 Electricity consumption data and specific energy consumption

Month	Production, hector litter (HL)	Electricity in kWh	Electricity specific energy consumption (kWh/HL)
Jan-19	55488	2,992,038.66	53.92
Feb-19	51872	3,135,664.91	60.45
Mar-19	50028	3,037,952.73	60.73
Apr-19	49225.8	3,124,473.42	63.47
May-19	48408.3	2,895,625.46	59.82
Jun-19	47147.51	3,421,078.45	72.56
Jul-19	45529.23	2,851,396.78	62.63
Aug-19	37680.02	2,094,696.79	55.59
Sep-19	67761.86	3,099,241.73	45.74
Oct-19	63920.89	3,030,740.40	47.41
Nov-19	61403.36	2,831,891.12	46.12
Dec-19	69242.42	3,694,855.42	53.36
Average specific electricity consumption			**56.80**

The average specific electricity consumption of the factory is found to be around 56.8 kWh/ HL. However, this value is 38.2kWh/HL higher than the maximum recommended international benchmark which is in the range of 10.2-18.6 kWh/hl [3], [4].

Heavy fuel oil (HFO) Consumption

The monthly furnace oil consumption is presented in Table 4-2.The composition of the fuel, heavy fuel oil, is shown in Appendix I

Table 4- 2 Monthly heavy fuel Oil and specific energy consumption

Month	Production, hector litter	Total consumption, in MJ	HFO specific energy consumption(MJ/HL)
19-Jan	55488	8253840	148.75
19-Feb	51872	7715960	148.75
19-Mar	50028	7441665	148.75
19-Apr	49225.8	7322338	148.75
19-May	48408.3	7200735	148.75
19-Jun	47147.51	7013192	148.75
19-Jul	45529.23	6772473	148.75
19-Aug	37680.02	5604903	148.75
19-Sep	67761.86	10079577	148.75
19-Oct	63920.89	9508232	148.75
19-Nov	61403.36	9133750	148.75
19-Dec	69242.42	10299810	148.75
Average specific oil Consumption			**148.75**

The average specific oil consumption is estimated to be 148.75MJ/hl, which is by 38.75 MJ/HL higher than the best international benchmark of 110 MJ/HL [3], [4].

Total Specific energy consumption

Based on the data collected such as production of beer in hector litter, electricity consumption and HFO consumption, the total specific energy consumption for beer production in Dashen Brewery Factory is evaluated and tabulated in Table4-3.

Table 4- 3 Total specific energy consumption

Month	Production, hector litter	Electricity in kWh	HFO in kWh	Total energy consumption in kWh	Specific energy consumption (KWh/ hL)
Jan-19	55488	2,992,038.66	2,292,733	5,284,771.66	95.24
Feb-19	51872	3,135,664.91	2,143,322	5,278,986.91	101.77
Mar-19	50028	3,037,952.73	2,067,129	5,105,081.73	102.04
Apr-19	49225.8	3,124,473.42	2,033,983	5,158,456.42	104.79
May-19	48408.3	2,895,625.46	2,000,204	4,895,829.46	101.14
Jun-19	47147.51	3,421,078.45	1,948,109	5,369,187.45	113.88
Jul-19	45529.23	2,851,396.78	1,881,243	4,732,639.78	103.95
Aug-19	37680.02	2,094,696.79	1,556,918	3,651,614.79	96.91
Sep-19	67761.86	3,099,241.73	2,799,883	5,899,124.73	87.06
Oct-19	63920.89	3,030,740.40	2,641,176	5,671,916.40	88.73
Nov-19	61403.36	2,831,891.12	2,537,153	5,369,044.12	87.44
Dec-19	69242.42	3,694,855.42	2,861,058	6,555,913.42	94.68
Average	**Total Specific Energy Consumption of the factory**				**98.14**

The average total specific energy consumption of the plant is 98.14 kWh/ hL whereas the international benchmark ranges between 42.5 and 56 kWh/HL [3]. This shows that the total specific energy consumption of the plant to be 42kwh/HL higher than the recommended international bench mark. These cross-cutting results show that there is in general a significant energy loss in the major energy consuming sectors. Hence analysis on the major energy consuming sectors (sector specific analysis) will be discussed in the next sub-sections.

4.2 Air Compression System

The plant has installed three screw air compressors two of them with 97 kW and the remaining one with 110 kW capacities. The factory is currently working only with the 110 kW compressors to meet the current demand. Compressed air in the factory is used to position kegs, bottles and cans for filling, moves spent grain, and is necessary for control valves to operate. The different losses in air compression systems are tested using the different methods mentioned in the methodology section. These are free air delivery test, specific power consumption and leakage test.

Free air delivery (FAD) test result

Free air delivery (FAD) test has been conducted using suction velocity method by measuring the velocity of free air delivery in the inlet section using Anemometer at 9 different positions. Readings have been taken at different positions. The average of these velocities at each position in both loading and unloading conditions have been measured and tabulated in Table 4-4.

Measurement has been taken at 9 different location of the rectangular air inlet as shown in Figure4.1. The length and width of the rectangular air inlet are 47cm and 7cm respectively.

Table 4- 4 the measured inlet air speed to the compressor

Average of the trials	Location where speed was measured (x, y)	Speed during loading(km/hr)	Speed during unloading(km/hr)
1	(40,6)	20.5	2.5
2	(40,1)	19.7	4.7
3	(30,4)	34.6	3.9
4	(15,5)	32.2	3.6
5	(15,2)	35.3	6.7
6	(25,4)	36.5	3.6
7	(24,3)	38.0	3.7
8	(23,4)	37.6	3.8
9	(23.5,3.5)	40.0	3.9
Average		**32.7**	**4.04**

- ✓ The air inlet area is rectangular with length 47cm and width of 7cm and it is drawn in Figure4.1.
- ✓ The velocity of the inlet air was measured at 9 different positions of the rectangular air inlet. This drawn in the x-y coordinates to show position where velocity measurement was taken. The x coordinate represents the length and the y coordinate represents the width of the rectangle. The velocities measured at 9 different positions are shown in Table4-5.
- ✓ The average of the velocities is used to calculate the free air delivery,Q to the compressor.

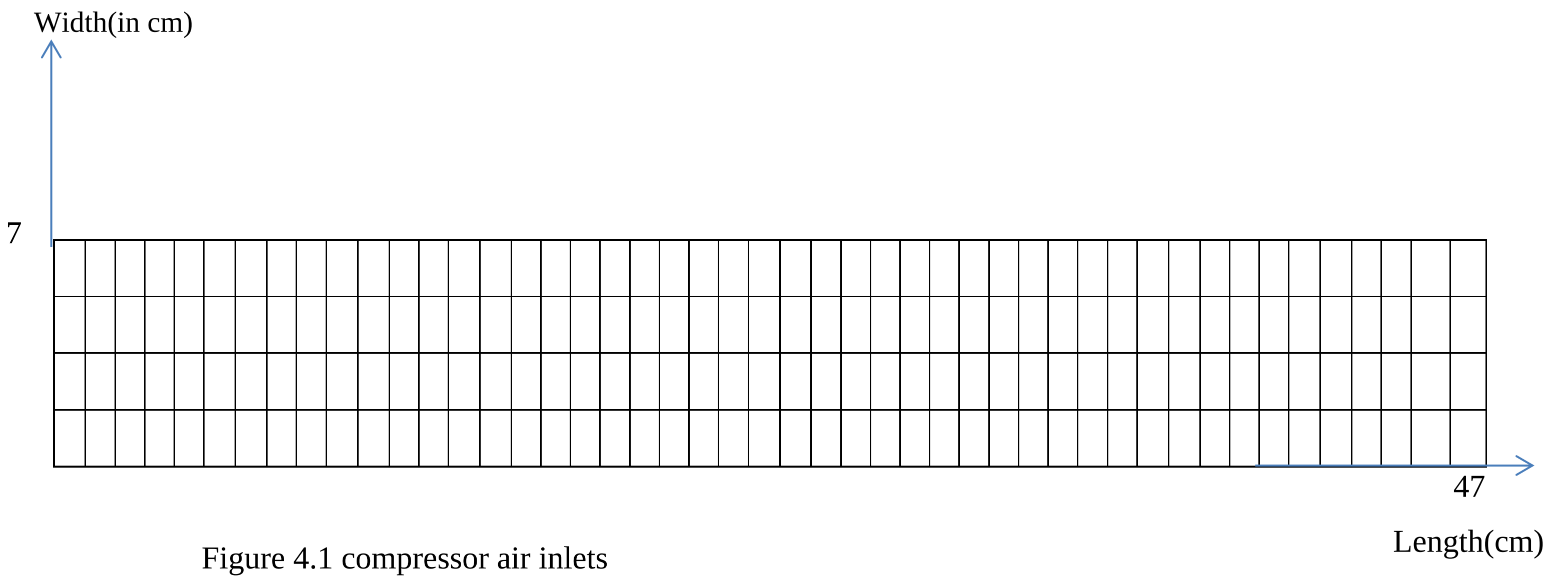


Figure 4.1 compressor air inlets

$Area = 7cm \times 47cm = 329cm^2 = 0.0329m^2$

The actual amount of free air delivery (Q) to the compressor is calculated by using Equation 3.2 and is calculated to be:

$$Q = 0.0329m^2 \times 9.08\frac{m}{s} = 0.3\frac{m^3}{s} = 18\frac{m^3}{min} = 635\ cfm$$

The design discharge capacity is 674 cfm while the actual discharge rate is about 635 cfm. This shows that the percentage loading of the compressor is about 94.2%. Compressors optimum operational loading recommended not being more than 75%. It means that the motor of the compressor is overloaded and high current is being drawn by the motor. This brings about a significant energy loss and the life of the compressor to be shortened.

Specific power Consumption of Air Compressors

Specific energy consumption depends on the compressor type, capacity, stages and operating pressure etc. The specific power consumption of the air compressor shows that how much power is being consumed by the compressor in order to deliver a unit cubic feet per minute (cfm) of air to the reservoir. The specific power consumption of the compressor is calculated using Equation 3.1 and is found to be 0.18 kW/cfm and is given in Table 4-5.

Table 4-5 Specific power consumption of Compressor

Design parameters	**Unit**	
Make		Atlas copco
Model		Alas,ZR-110
Type		Screw type
Capacity	Cfm	674
Pressure	Bar	8.6
Motor power	kW	110
Actual Parameters		
Air velocity	m/s	9.08
Area	m^2	0.033
Air flow rate	Cfm	635
Loading pressure	Bar	6.5
Unloading pressure	Bar	7.2
Input power	kW	115.2
SPC	kW/cfm	0.18

Leakage (No Load) test result

Ideally speaking, compressed air system should not have any leaks at all but in practice it is rather difficult to have a zero leakage system. Depending upon the industry and type of air usage patterns up to 10% air leakage is allowed [17], [23].

To conduct no load test, it was required to wait up to maintenance time which usually occurs once in a day for only 20 minutes. Based on the procedure stated in Section 3.2, the following 4 trials were conducted and tabulated as follows.

Table 4-6 loading and unloading time trials for leakage test

Trials	**Loading time(in minute)**	**Unloading(in min)**
1	0:35:00	1:11
2	0:40:37	1:25
3	0:40:74	1:26
4	0:42:91	1:26
Average time	**0:39:75**	**1:22**

Total percentage system leakage loss can be determined using Equation 3.3, and is calculate to be

$$L\% = \frac{0.67 \times 100}{0.67 + 1.37} = 33\%$$

Hence, the total system leakage Loss (L) is calculated using equation 3.4

$$L = 33\% \times 635cfm = 209.5\ cfm$$

Power wasted due to leakage (kW) is calculated using equation 3.5 and is found to be

$$209\ \text{cfm} \times \frac{0.18\ \text{kW}}{\text{cfm}} = 37.62\ \text{kW}$$

Therefore, the Annual energy wastage (kWh) due to the leakage is calculated using equation3.6 and is found to be

$$209\ \text{cfm} \times \frac{0.18\ \text{kW}}{\text{cfm}} \times 7200\text{hrs} = 279{,}864\ \text{kWh}$$

Energy Conservation Proposals

From the observations/ findings during the factory visit and the above quantitative analysis, the following major energy conservation measures (ECMs) have been identified.

1) **Optimizing the compressed air usages and reduce compressors generation pressure by 1 bar.**

Operating pressure of the air compressor is between 6.5 to 7.2 bars. The Compressed air is mainly used for instrumentation purpose. The pressure required at user end is in between 4 and 6 bar.

Hence, it is recommended to reduce the generation pressure of the compressor by 1 bar. The pressure switches must be adjusted such that the compressor load (cuts-in) at pressure 5.5bar and unload (cuts-out) at pressure 6.2 bars. Also it is suggested to install air receivers near to finishing and cooling to deliver stabilized air pressure to the process area.

It will also help to meet demand variation and minimize the pressure drop at far end from the compressor.

- A reduction in the delivery pressure by 1 bar in a compressor would reduce the power consumption by 6 – 10 % [17]. Based on this research result, it has been tried to calculate the saving and tabulated in Table 4-7. Due to the reduction in the delivery pressure by 1 Bar, the power consumption reduction is assumed to be 8%.

Energy saving

Table 4-7 Energy saving due to pressure reduction

Present compressed air requirement	635cfm
Operating generation pressure of the air compressor	6.5 to 7.2 Bar
Proposed generation pressure	5.5 to 7.2 Bar
Power saving:	9.2kW
Annual operating hours:	7200 hrs. (24 hrs. and 300days)
Annual energy saving:	66,240 kWh
Annual Cost saving	79,488 Birr

2) Optimizing the compressed air by arresting the leakages

The leakage test for air compressors was carried out during the maintenance time when plant was not in operation. During leakage test, no usage of compressed air in plant and compressor operates at loading / unloading condition mainly because of leakages. The leakage was observed mainly around the packing section

Compressed air leaks are very common. Leaks are a major source of inefficiency and in some cases will account for 30% - 40% of compressed air system [17], [23].

Finally, it is recommended to arrest the leakages and optimize compressed air usages. The leak arresting mechanism is mainly done by welding which leads to additional cost of around 7000birr.These is estimated based on the past history of the factory that costs it about 1000 birr to mend or weld a single leak point. For this study it has been visually identified 7 leak points through which compressed air is being lost. The total cost is estimated based on this rough assumption.

Energy savings

Table 4-8 Energy saving due to leakage arresting

Present comp power consumption:	115.5 kW
Estimated power saving: (After arresting leakages)	37.62 kW
Annual operating hours (24hres x 300 days)	7200 hr
Annual energy saving :	279,864 kWh
Annual Cost Savings (@ 1.2 birr/kWh) :	Birr 325036
Investment cost	Birr 70,00
Simple Payback period	8 days (Immediate)

4.3 Steam generation, distribution and utilization

The plant has installed two boilers to meet the steam and hot water demand for the brewery production process. These two boilers generate Steam and hot water mashing process, wort boiling, pasteurization, bottle washing and for other processes. The observations and results of the analysis on the steam generation, distribution and utilization are presented in the following sub-sections.

4.3.1 Heat Loss Analysis

Boiler efficiency

During the audit period, the performance of the two boilers was measured using the flue gas analyzer. Operating parameters of the boiler such as feed water temperature, steam pressure, flue gas temperature, and the O_2 & CO_2 percentage at boiler outlet were also measured. The measured parameters are given in Table 4-9.

Table 4-9 Monitored boilers parameters

Parameter reference	Unit	Boiler1	Boiler2
Feed water temperature	^oC	91	91
Oxygen in flue gas	%	13.4	1.6
Carbon dioxide in flue gas	%	5.6	14.6
CO in PPM	PPM	96	20
Flue gas temperature (T_f)	^oC	251	171
Ambient temperature (T_a)	^oC	23.4	23.4
Relative Humidity in air (RH)	kg /kg of dry air	58.6%	58.6%

The boiler efficiency test was conducted by using **indirect method**. To evaluate the efficiency of the boilers using the indirect method, the different losses have been evaluated first. These losses are:-

- Dry flue gas loss
- Heat loss due to H_2 in fuel
- Heat loss due to moisture in fuel
- Heat loss due to moisture in air
- Heat loss due to surface radiation and convection

The theoretical air required for combustion is calculated using Equation 3.8 and is found to be:-

$(11.6 \times 86) + 34.8\left(12.5 - \frac{0.7}{8}\right) + \frac{4.35 \times 0.5}{100}$ =14.31 kg of air per kg of oil

The theoretical air required for the two boilers is the same as both of them use the same type of fuel.

Next, Percentage of Excess air for both of the boilers is calculated using Equation 3.9 and is found to be

$\frac{13.4}{21-13.4} \times 100 = 176\%$ (Boiler 1)

$\frac{1.6}{21-1.6} \times 100 = 8.2\%$ (Boiler 2)

To ensure complete combustion of the fuel used, combustion chambers are supplied with excess air. Excess air increases the amount of oxygen to the combustion and the combustion of fuel. When fuel and oxygen from the air are in perfect balance - the combustion is said to be stoichiometric.

The typical excess air needed to achieve the highest possible efficiency for fuel oil is in the range of *5 - 20%*. Hence, the excess air which is being used in boiler1 is too much, 176% , as compared with the required amount. The excess air in boiler2 which is calculated above, 8.2% is in normal condition.

Actual mass of air supplied to the boilers is now calculated by using Equation 3.10 and is calculated as

$\left(1 + \frac{176}{100}\right) 14.31 = 39.35 kg\ per\ kg\ of\ fuel$ (Boiler 1)

$\left(1 + \frac{8.2}{100}\right) 14.31 = 15.49 kg\ per\ kg\ of\ fuel$ (Boiler 2)

Now, the different boiler losses are going to be calculated using the different equations formulated in methodology section.

Percentage of dry flue gas loss (L1) in boiler1

To calculate the percentage of heat loss in dry flue gas, the mass of dry flue gas in kg/kg of fuel should be calculated first. It is actually the mass sum of CO_2, SO_2, N_2 and O_2 in the flue gas and is calculated by using Equation 3.12.

$$= \frac{0.86 \times 44}{12} + \frac{0.005 \times 64}{32} + \frac{39.35 \times 77}{100} + \left((39.35 - 14.31) \times \left(\frac{23}{100} \right) \right)$$

$$= 39.2\ kg\ per\ kg\ of\ fuel$$

Using Equation 3.11, it is now possible to calculate the estimated amount of dry flue gas loss and is found to be.

$$L1 = \frac{39.2 \times 0.23(251 - 23.4)}{10941} \times 100 = 18.75\%$$

Heat loss due to evaporation of water as a result of H_2 in fuel (%) (L2) in boiler1

It is calculated using Equation3.13 and is found to be

$$L2 = \frac{9 \times 0.125(584 + 0.45(251 - 23.4))}{10941} 100 = 7.05\%$$

Percentage of heat loss due to moisture in fuel (L3) in boiler 1

The percentage of heat load due to moisture in fuel is calculated by using Equation 3.14 and is found to be

$$L3 = \frac{0.004(584 + 0.45(251 - 23.4))}{10941} 100 = 0.025\%$$

Percentage of Heat loss due to moisture in air (L4) in boiler1

The percentage of heat loss due to moisture in air is calculated by using Equation 3.15 as shown below

$$L4 = \frac{39.35 \times 0.024 \times 0.45(251 - 23.4)}{10941} 100 = 0.89\%$$

Percentage of Radiation and convection loss (L5)

This loss can be assumed as 0.5 to 1% based on the body temperature of the boiler [24]. In this case, the body temperature of the boiler is measured to be 42^{o}C. Therefore, the percentage of radiation and convection loss can be estimated as 0.75%.

Overall efficiency

The overall efficiency of boile1using Indirect Method is calculated using Equation16 and is found to be

$\eta = 100 - (18.75 + 7.05 + 0.025 + 0.89 + 0.75) = 72.53\%$

Similar approach has been applied for Boiler 2.The summarized results of both boilers are tabulated in Table4-10.

Table 4-10 Boiler loses

The different boiler losses	Unit	Boiler 1	Boiler2
Dry flue gas losses(L1)	%	18.75	4.77
Heat loss due to H_2 in fuel (L2)	%	7.05	6.69
% of Heat loss due to moisture in fuel(L3)	%	0.05	0.025
% of Heat loss due to moisture in air(L4)	%	0.89	0.23
% of Radiation and convection loss (L5)	%	0.75	0.5
Boiler efficiency	%	72.53	87.8

The efficiency of Boiler 1 and Boiler 2 by indirect method is around 72.53 and 87.8 % respectively.

For boiler-1, Oxygen percentage is 13.4% which is very high as compare to the standard (O_2 % of HFO fired boiler should be (4-6%)). This is mainly due to the higher excess air quantity being used which is about 176%.Whereas the recommended excess air to HFO fired boiler (25-30%) [17][23] . As a result energy is being lost in the form of heat with the flue gas through the stack. The temperature measured in the stack is about 251^{o}C. As a consequence the efficiency of the boiler is gets lower about 72.5%. The efficiency of boiler 2 is in a better condition and its excess air quantity being supplied is not this much far from the standard.

Other heat loss areas

In the previous section, the different losses inside the boiler (Dry flue gas loss, heat loss due to H_2 in fuel, heat loss due to moisture in fuel, heat loss due to moisture in air and heat loss due to surface radiation and convection) have been determined to evaluate the efficiency of the boiler. In addition to this, a detailed survey has been carried on various distribution lines and equipment as shown in Figure 4-2. The surface temperatures were measured using Thermograph camera to check the adequacy of insulation. Boiler side, furnace surface temperature was around 45-50^{o}C which is found to be satisfactory. Insulation of steam line especially on the flanges and valves around the steam header is found to be poor.

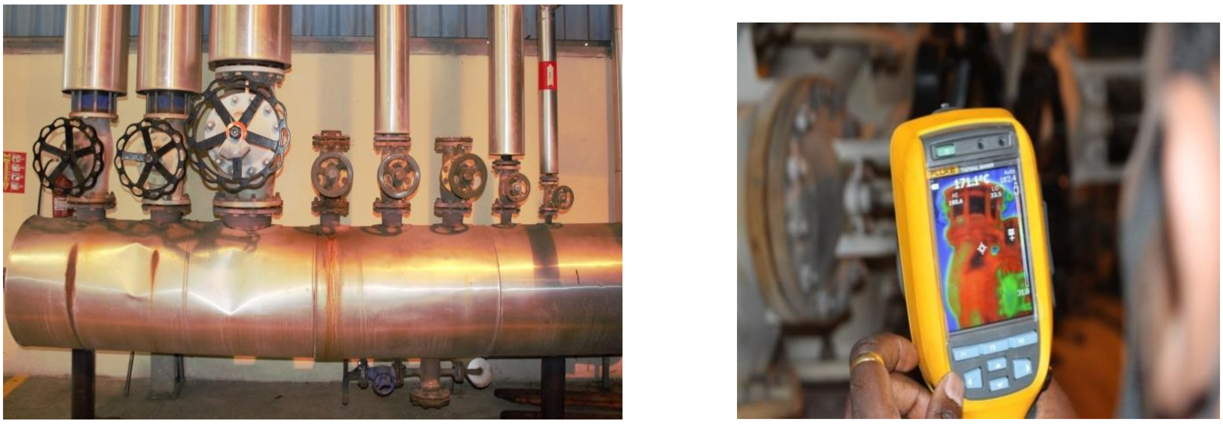


Figure 4-2 Temperature measurement on the steam header

Economizer and blow down

The overall thermal efficiency can be significantly increased if an economizer and a blow down are integrated in the system. However, it has been observed during survey these two heat recovery devices have not been available.

4.3.2 Energy Conservation Proposals

i. **Improving the efficiency of boiler by maintaining boiler parameters**

During the boiler performance test, it was found that the percentage of CO_2 and O_2 in flue gas of boiler1 were 5.6% and 13.4% respectively. And also the percentages of CO_2 and O_2 in flue gas of boiler 2 were 14.6 % and 1.6 % respectively. The evaluated efficiency of boiler1was 72.5% and that of boiler 2 is 88.7%. The efficiency of boiler 1 was less due to too much excess air supply which brings too much heat loss through the stack. The maximum excess air quantity requires for HFO fired boiler for completer combustion is around 25-30% but the actual excess air which is being supplied to boiler1 is around 176%. This is very high as compared to the standard. Whereas for Boiler 2, the excess air quantity (8.2%) is not too far from the standard and its total combustion efficiency, 88.7%, is in a good condition.

Also observed near to the burner in Boiler1, the temperature of HFO was in the range of 70-75^{o}C. Temperature of HFO should be maintained above 85^{0}C this will help for satisfactory atomization, ease of burning and avoid forming carbon on burner tips. Also it will help for proper combustion of fuel.

The exaggerated amount of excess air should be controlled. This may be achieved by inspecting and maintaining the burner. Controlling excess air to an optimum level always result in reduction in flue gas losses.

For every 1% reduction in excess air there is approximately 0.06% rise in efficiency [19]. Based on this assumption, by bringing down the actual excess air percentage (176%) to the international standard (25-30%), it is possible to achieve 9% HFO saving.

The average price of heavy fuel oil burner for the existing boiler with steam producing capacity of 6TPH and burner motor capacity of 22kW is about $4633 which is equivalent to the current 245,550 Ethiopian birr [25] .The transportation fee is an average of 11 dollar (616 Ethiopian birr) per kg to transport from china to Ethiopia .Tax rate is about 21% which is obtained from Ethiopian Custom Authority [26] . The detail break down is clearly calculated in Appendix3.

Energy savings

Table 4- 11 Energy saving on boiler parameter correction

Present HFO consumption	8320 litter/day
Estimated HFO savings	9% saving (748.8 litter/day)
Annual operating days	300days
Annual HFO savings	224,640 litter
Cost saving per annum (@Birr 50/litter	11,232,000 birr
Investment	970,600 Birr
Simple payback period	1.1month

ii. Improve the steam distribution system

During the audit period detailed survey was carried on various distribution lines and equipment. It was observed the poor insulation of steam line especially on the valves and flanges as shown below. The measured temperatures of the valves and flanges are about in the range of 140^0C to 180^0C.

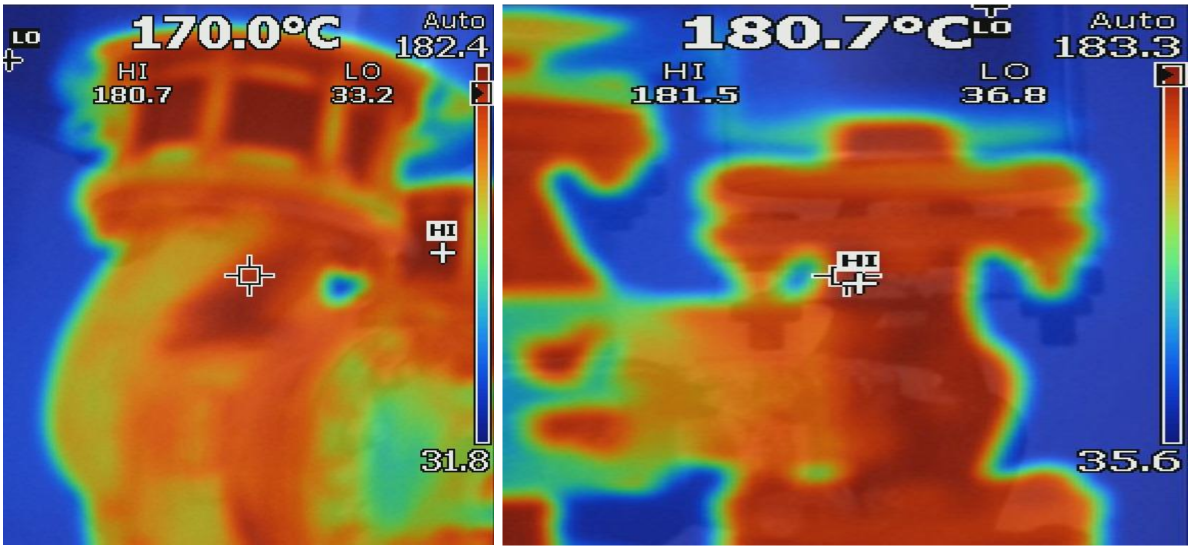


Figure 4-3 Thermal images on flanges and valves

It is suggested to insulate the flanges and valves with optimum thickness of insulation and cover the insulation using a suitable insulator.

Recommended Insulator Type

Conventional methods of industrial insulation applications are now supported and developed with different alternatives. The most striking of these new alternatives are removable flexible insulation jackets. These jackets can be used in steam turbines, heat exchangers, chimney & exhaust outlets, various equipment bodies, etc. and they are mostly used in fittings such as valves and flanges on pipelines [27].

Valve and Flange insulations are almost designed to be removable because these elements require frequent intervention during operation due to calibration, maintenance, or other needs. It is a more flexible and easy-to-apply method compared to other methods like metal boxes. Correctly designed valve jackets minimize the costs due to heat loss, while they are extremely practical products those are reusable after maintenance [27]

Figure 4-4 Insulation Jackets for flanges and valves

Estimation of energy savings from insulation of the flanges and valves

The heat losses from certain valves and flanges are reported to be equal to the heat losses from 1m and 0.5m long straight pipes of the same diameter respectively [28].

Therefore, the total heat loss from 1m and 0.5 m length of uninsulated steam pipe is first calculated then the heat loss from uninsulated 1m length of the pipe is taken as the loss from uninsulated valves and the heat loss from uninsulated 0.5m length of pipe is assumed as similar to the loss from flanges [28]

The measured internal diameters of 5 pipes are given in Table4-12

Table 4- 12 Steam pipe diameter

Number of pipes	Diameter(mm)
3	110
2	50

The surface heat loss therefore can be calculated using Equation3.18 as follows

$$S = \left(10 + \frac{175 - 23.4}{20}\right)(175 - 23.4) = 2665\,\frac{kcal}{hr.m^2}$$

The measured ambient and surface temperatures are 23.4 ^{0}C and 175 ^{0}C respectively.

To calculate the heat loss using equation3.17, the surface area of the pipes for different diameter should be calculated first:

For valves' loss

$A1(11\text{cm diameter pipes}) = 3.14 \times \text{diameter} \times \text{Length} = 3.14 \times 0.11 \times 1 = 0.35m^2$

$A2(5\text{cm diameter pipes}) = 3.14 \times \text{diameter} \times \text{Length} = 3.14 \times 0.05 \times 1 = 0.16m^2$

For flanges' loss

$A3(11\text{cm diameter pipes}) = 3.14 \times \text{diameter} \times \text{Length} = 3.14 \times 0.11 \times 0.5 = 0.17m^2$

$$A4(5\text{cm diameter pipes}) = 3.14 \times \text{diameter} \times \text{Length} = 3.14 \times 0.05 \times 0.5 = 0.079m^2$$

The Heat loss for un insulated valves, Hsv, is now estimated by using Equation3.17 as follows

$H_{sv} = S \times (3A1 + 2A2) = 2665(3 \times 0.35 + 2 \times 0.16) = 3651\ \text{kcal/hr}$

The Heat loss for un insulated flanges, Hsf, is now estimated using Equation3.17

$H_{sf} = S \times (3A1 + 2A2) = 2665(3 \times 0.17 + 2 \times 0.079) = 1780\ \text{kCal/hr}$

The total heat loss from flanges and valves is estimated to be

$$H_T = H_{sv} + H_{sf} = 365\frac{kcal}{hr} + 1780\frac{kcal}{hr} = 5431\frac{kcal}{hr}$$

The total heat loss from the uninsulated valves and flanges in a year is calculated as:

$\mathrm{H_T} = \frac{5431\text{kcal}}{\text{hr}} \times 300\text{days} \times 24\text{hrs} = 39103200\text{kcal}$**,** this is similar to a loss of 3994.2 litter of oil per year. If these flanges and valves are insulated, it will be possible to save a cost of 199710 birr per year.

The cost break down for the cost of the insulation is estimated in Appendix4.The average price of a single insulator for valves or flanges is about $30 [27]. This is similar to 1590 Ethiopian birr. The total energy and cost saving is indicated in Table 4- 13.

Table 4- 13 Energy saving on flanges and valves

Annual operating days	300 days
Annual HFO savings	3994.2 litter
Cost saving per annum (@Birr 50/litter	199710 birr
Investment	60775birr
Simple payback period	3.7 month

iii. Install heat exchanger (Economizer) at the stack

The data collected from the factory is tabulated below.

According to the flow meter installed on the condensate water pipe, the mass flow rate of the condensate water was registered to be around 2.05m^3/h.

Table 4- 14 Flue gas and condensate properties

Specific heat of water, C_{pw}	Mass flow rate of condensate water, m_w	Initial temperature of condensate return to economizer, (◦C)	Feed water temperature after economizer
4.2 kJ/ kg. ^{0}C	2.05 m^3/h	90 ^{0}C	130 ^{0}C

The heat recovered from the flue gas can be used to heat HFO so that atomization will be perfect and also can be used to heat the makeup water supplied to the condensate tank. The cost of the economizer depends on the size of the boiler in which it is installed, since a larger economizer is required for a greater flow of gases.

Energy and cost saving

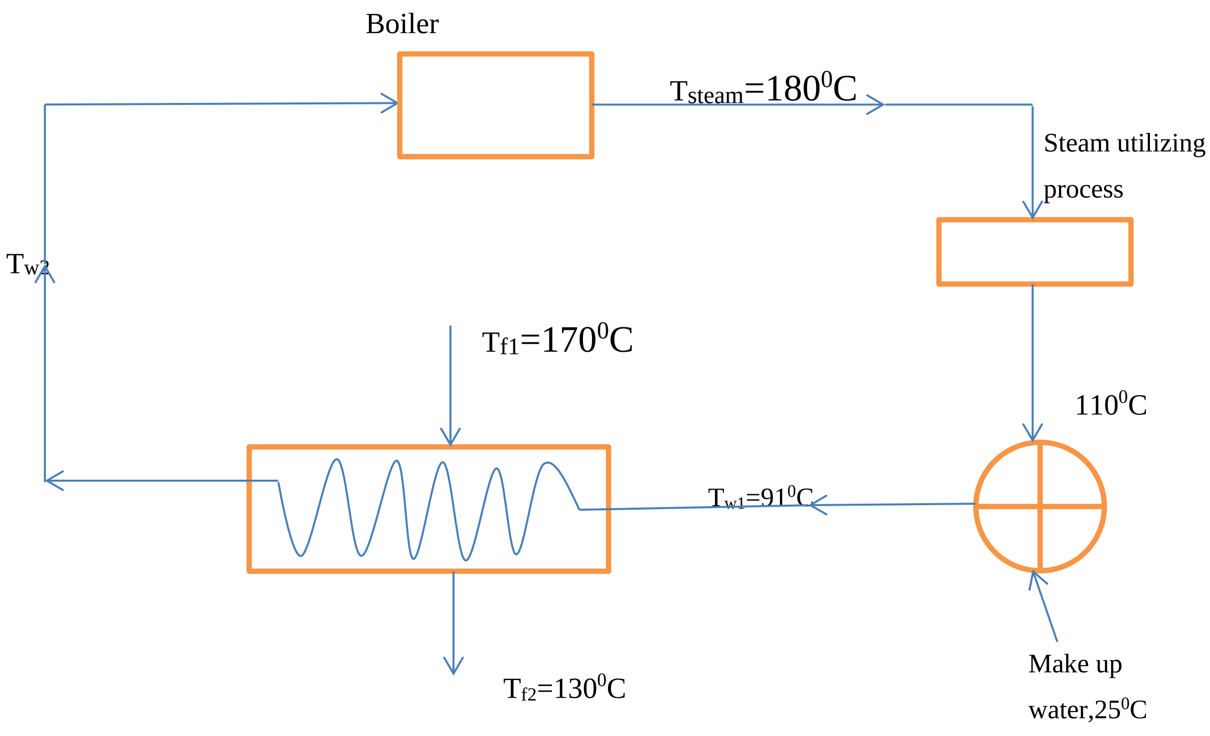


Figure 4-4 Economizer integration

Heat gained by feed water is calculated by using Equation3-20

$$E_w = m_w \times C_{pw} \times (T_{w1} - T_{w2}) = 2030\frac{kg}{hr} \times 4.2\frac{kj}{kg.°C} \times (131°C - 91°C) = 37674\frac{kj}{hr}$$

This energy saving is equivalent with a saving of 0.96 litter of HFO per hour. The cost saving becomes 48birr per hour.

The total boiler fuel cost that can be saved per annum is estimated as:

$$\text{Birr saved} = \frac{48\text{birr}}{\text{hr}} \times 24\text{hr} \times 300\text{days} = 345{,}600\text{birr}$$

Investment cost

The price of a heat exchanger or economizer for this specific application has been assessed from different international manufacturers through their websites and is found to be in an average of $ 650 which is equivalent to 34,450 Ethiopian birr [29].It has also been tried to assess the Ethiopian market who are importing such devices with similar type are selling it approximately with a total cost of 120,000 birr excluding installation cost.

Table 4- 15 Energy saving on economizer installation

Annual operating days	300
Annual HFO savings	$0.96 \times 24 \times 300 = 6912$ liter
Cost saving per annum (@Birr 50/litter	345600
Investment in birr	120000
Simple payback period	4.2 months

4.4 Electric Motors

The major energy consuming electric motor in the factory is assessed and its name plate data is taken. The actual operational data of the motors like the current, voltage, power factor, active power and reactive power of each identified electric motors were measured.

4.4.1 Observation and analysis

The name plate efficiencies of the motors are all recorded and the actual input power, voltage, current and power factor is measured by using power clamp meter. Using these data, the actual percentage of motor loading is calculated and recorded and tabulated in table Table4-14

Table 4- 16 Percentage of motor loading

No	Area	Rated power (kW)	Rated Efficiency	Measured Data				Motor Loading in %
				Voltage (V)	**Current (A)**	**Power factor**	**Input Power (kW)**	
1	Cooling	132	87	402	113.6	0.997	78.8	**52**
		132	87	401.5	109	0.94	79	**52**
		132	87	401	109.3	0.96	78	**52**
		110	87	400	80.8	0.998	55.8	**44**
		110	87	400	70.4	0.94	50	**44**
2	Compressor	110	92	401	188.3	0.88	115.2	**97**
3	Pump							
	Surface water pump	37	91	366.4	57.4	0.87	31.76	**78**
		37	92	367.5	57	0.85	30.93	
	Ground water pump,Borehole 1	22	78	368.5	49.6	0.87	26.56	**85**
	Borehole -6	22	78	377.8	42	0.874	24.03	**94**
	Hotwater pump to roller(miller)	11	92	412	10.99	0.991	7.77	**65**
4	Miller							
	Crushing Rooler 1	22	82	415	9.5	0.89	6.13	**23**
	Crushing Roller 2	22	82	415	10.3	o.91	7.4	**23**
5	Blowers							
	Airblower for boiler 1	22	87	416	24.21	0.87	15.32	**61**
	Air blower for boiler 2	22	87	412	116.4	0.56	6.616	**26**
6	Filling,finishing and packing section							
	Bottle washer 1	11	87	405	11.48	0.96	8.02	**63**
	Bottle washer 2	11	87	405	10.78	0.98	7.38	**58**

4.4.2 Energy Efficiency Measures

As the above table cleary showing, the calculated percentage loading of some of the electric motors is below 50%.This shows that the motors are working in under load condition. Under load results in reduce efficiency and power factor. Most of the time replacement of motors is recommended for those motors operating below 50% loading. It is also good to see the possibility of installing variable frequency drive, VFD, by carefully analyzing their operation.

The other observation is that the power rating of the compressor motor is 110KW,the actual operating power is about 115KW. It means that the motor is overloaded. This brings about the motor to be over heated and finally burnt.

Energy Saving

The energy saving from electric motors operating below 50% is estimated by using the fact sheet of US department of energy [21], [30]. It is shown in table 4-15

Table 4- 17 energy saving on motor loading

Motor Type	Number	Rating (kW)	Old efficiency (%)	loading	Operating efficiency (%)	Power saving by adjusting the loading (kW)
Ammonia Compressor	2	110	92	44.13	90.2	5.31
Crushing Rooler 1	1	22	82	22.84	76	2.11
Crushing	1	22	82	23.4	76.5	2.1
Air blower for boiler 2	1	22	83	26	78	1.7
		Total power saving				11.22
		Annual Energy saving				**80784 kWh**

$\text{Cost saving} = 80784\text{kWh} \times 1.2\text{birr/kWh} = 96940.8\text{birr}$ Per annum

4.5 Lighting

The lighting fixtures used in the plant include fluorescent tube lamps (FTL) and halogen lamps in the indoor and outdoor area of the factory. The various lighting fixtures and their description is given in table

Table 4- 18 Details of Lighting Fixture

No	**Type of lamp**	**Number of fixtures**	**Rating(Watt)**	**Total consumption (kW)**
1	Fluorescent lamps	309	36	11.124
2	Fluorescent lamps	11	58	0.64
3	Halogen			
	Indoor	143	250	35.8
	Out door	77	250	19.3

Observation

During the study, the lighting fixtures used in all section of brewery factory were counted and their working condition was assessed, most lighting illuminations level were sufficient in most of the areas.

4.5.1 Energy conservation measures

Based on the observations/ findings during detailed energy audit conducted in the unit, the following major energy conservation measures (ECMs) have been identified. The details are given below.

Fluorescent tube lights of 36W FTLs and 58W FTLs with electro mechanical ballasts consume more energy compared with LED lamps. About 322 numbers such lamp fittings were found in different locations of the plant

Hence, it is proposed to replace all these 36 and 58W electro mechanical ballast FTLs with 18W LED lights.

Energy savings

The envisaged annual energy saving potential is 42660 kWh per year equivalent to a monetary saving of Birr 51196 per year. The investment requirement is Birr 227,300 with a simple payback period of 4.5 years for the 36W FTL lamps and 3.5 years for 58FTL lamps.

Table 4- 19 Energy saving on retrofitting lightings, FTL-T12, 36W to LED

Particulars	**Unit**	**Existing**	**Proposed**
Type of lamp	-	FTL-T12	LED
Wattage of lamps	W	36	18
Design Lumen (Approx.)	Lumen	3200	3300
No. of lamps to be replaced	No.	309	309
Average Operating Hours per day	Hours/Days	24	24
Operating day /year	No.	300	300
Energy Consumption/year	kWh/year	80092.8	40046.4
Energy savings	kWh/year		**40046.4**
Energy Cost	Birr/kWh		1.2
Energy cost savings	Birr year		48055
Initial retrofitting cost	Birr		216300
Payback period	Years		4.5

Table 4- 20 Energy saving on retrofitting lightings, FTL-T12, 36W to LED

Particulars	Unit	Existing	Proposed
Type of lamp	-	FTL-T12	LED
Wattage of lamps	W	58	25-28
Design Lumen (Approx.)	Lumen	-	-
No. of lamps to be replaced	No.	11	11
Average Operating Hours per day	Hours/Days	24	24
Operating day /year	No.	300	300
Energy Consumption/year	kWh/year	4593.6	2098.8
Energy savings	kWh/year		**2494.8**
Energy Cost	Birr/kWh		1.2
Energy cost savings	Birr year		2993.76
Initial retrofitting cost	Birr		11000
Payback period	Years		3.7

1) **Replacement of existing Halogen lamps with LED flood lamps**

Halogen lamps of 250W consume more energy compared with LED flood lamps. About 220 numbers such lamp fittings were found in different locations of the plant both indoor and outdoor of the factory.

Therefore, it is proposed to replace all these 250W halogen lamps with 100 W LED flood lights.

Energy savings

The envisaged annual energy saving potential is 178200kwh per year equivalent to a monetary saving of Birr 213840 per year. The investment requirement is Birr 770000 with a simple payback period of 3.6 years. As from the assessment made in Ethiopian market, a 100W LED lamp is costing about 3500Birr.

Table 4- 21 Energy saving on lighting

Particulars	Unit	Existing	Proposed
Type of lamp	-	Halogen	LED
Wattage of lamps	W	250	100
Design Lumen (Approx.)	Lumen	4200	4000
No. of lamps to be replaced	No.	220	220
Average Operating Hours per day	Hours/Days	18	18
Operating day /year	No.	300	300
Total energy consumption per year	kWh	297000	118800
Energy savings	kWh/year		179000
Energy Cost	Birr/kWh		1.2
Energy cost savings	Birr year		214,800
Initial retrofitting cost / lamps	Birr		3500
Total investment cost	Birr		770,000
Payback period	Years		3.6

Table 4- 22 Summary of Results

No	Focus area	Energy conservation measures	Annual energy saving(kWh)	Annual fuel saving (litter)	annual cost saving (Birr)	Estimated Capital cost(Birr)	Payback period
SHORT TERM MEASURES							
1	**Air compression system**	Optimization of the compressed air usages and reduce compressors generation pressure by 1 bar	66240	-	79488	No	Immediate
		Optimization the compressed air by arresting the leakages	270864	-	325036	70,000	2.6 months
2	**Steam generation, distribution and utilization**	Improving the efficiency of boiler by maintaining boiler parameters	-	224640	11,232,000	970,600	1.1months
		Insulate Valves and Flanges	-	3994.2	199,710	60,775	3.7 months
		Install heat exchanger (Economizer) at the stack	-	6912	345600	120000	4.2 months
MEDIUM TERM MEASURES							
3	**Electric motors**	Install variable frequency drive for blowers and pumps, and soft starter for big motors in cooling section	80784	-	96940	230000	2.4years
LONG TERM MEASURES							
4	**Lighting system**	Replacement of existing FTL lamps with LED lamps	40046.4 for 36W 2494.8 for 58W	-	○ 48055 ○ 2994	○ 216300 ○ 11000	○ 4.5 years for 36FTL ○ 3.7 years for 58FTL
		Replacement of existing Halogen lamps with LED flood lamps	179000	-	214840	770,000	3.6 year
Total			**639428**	**235,249**	**12,544,662**	**2,448,675**	

CHAPTER5

Conclusion and Recommendation

5.1 Conclusion

This energy consumption assessment study was a plant specific study, thus all the results and conclusions were based on the specific plant conditions and are applicable only to the Gonder Dashen beer factory. However, the methodology, which was used for analyzing the focus areas, can be applied to other industrial facilities with the same type of equipment. Also, the energy performance indicators can serve as a base for benchmarking or comparative analyses in other similar studies.

In the current study almost 6 energy-consuming areas were analyzed. These focus areas were pre-defined in the frames of the preliminary energy audit. Every area was analyzed separately, with application of specific methods and engaging certain specialists from industry if it was required. All of the recommendations were put in order according to the amount of investments needed for their implementation. The specific energy consumption of the factory both electricity and thermal specific energy consumption is calculated and compared with the international benchmark.

According to the results of the study, the average total specific energy consumption of the plant is 98.14kWh/HL whereas the international benchmark ranges between 42.5 and 56 kWh/HL. This shows that the total specific energy consumption of the plant is 42kwh/HL higher than the recommended international bench mark. This showed that there is a significant energy saving potential in the factory and as a result a detail survey and measurement was needed on some selected energy intensive areas. The assessment was successful for the selected focus areas. Most of the goals were achieved, which is a list of recommendations for each of the areas, was generated. Analysis showed that some of the equipment requires changes in operating practices and no or low financial investment, when other need substantial modifications and introduction of new technologies and replacement.

The detail energy consumption assessment with the implementation of the suggestions, which require no, low or medium investments, it is possible to save a total of 639428kWh of electricity per year, which corresponds to an annual cost saving of 767352 birr. And also an annual total heavy fuel oil saving potential of 235249litter was identified**.** Additional energy might be saved by conducting energy audit on other sections other than these selected focus areas such as detail studies on pumps, cooling sections, cooling tower, waste water treatment, and on other remaining areas. Additional benefits of implementing the energy saving opportunities come from decreasing environmental impacts, improving working conditions of the plant employees and higher energy security at the plant.

The result of the energy audit can be a solid base for establishing an energy management program at the plant, which will include performance targets, required resources and a clear procedure of the improvements realization. Since a separate evaluation of every area is given, the management of the plant can prioritize the introduction of the energy saving measures, according to the company needs

5.2 Recommendation for future work

Solar thermal process is the best environmental friendly source of energy for the countries located in between tropic of Cancer and tropic of Capricorn. These countries have high potential of solar irradiation and average sun light length of more than 10hour per day throughout the year. Ethiopia is one of these naturally gifted countries having enormous amount of solar energy potential. But, the country didn't use this source of energy as expected.

The integration of solar thermal system to low temperature industrial processes is feasible and can save significant amount of energy. Brewery factory is one of a low temperature industrial process and suitable for application of solar thermal system for various systems specially for brewing. The followings are recommendation for future work or research to be conducted on Dashen brewery factory or on similar factories.

1. Integration of Solar Thermal for Preheating of makeup water

In Dashen brewery factory the central system for heat supply is working with mainly steam. Solar systems can be coupled with the conventional heat supply system for preheating water used for steam generation. This requires detail studies such as characteristics of the loads, collecting sufficient irradiation data of the area and others.

2. Integration of Solar Thermal into the Existing Heating System

The integration of solar thermal heat into industrial processes can also be done by integrating the solar heat directly into the existing heating system

This integration of solar thermal is feasible only on some processes in the brewery factory. This is because most research studies show that the maximum temperature that can be achived from solar thermal collectors is about 100^0C. As the data obtained from the factory, the temperature for mashing and bottle cleaning are 52^0C and 78^0C respectively. Therefore hot water for these processes can be supplied from solar thermal. The conventional thermal energy consumption for the above processes should be analyzed first before the integration.

During the study, it was observed that there is an anaerobic waste water treatment which can produce biogas as a by-product. A research work can be conducted on the possibility of using the biogas as an alternative source of fuel for boilers. As the Kenyan breweries limited experience shows that it is possible to use this bio-gas to support the cost of fuel for boiler application. Burner modification also very critical for the integration. This will be a very good experience for Ethiopian Brewery factories to adopt this biogas production possibility to reuse it for any heat application in the factories. This study can be done as a research by universities or other researchers.

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Appendix 1: **composition of heavy fuel oil (HFO) of the factory**

Boiler Performance Analysis

The following are the data collected for the boiler fired by heavy fuel oil. The efficiency of the boilers is calculated by **indirect method**.

No	Parameter references	Unit	Reading
1	**Ultimate analysis**		
	Carbon	%	86
	Hydrogen	%	12.5
	Oxygen	%	0.7
	Sulfer	%	o.5
	Nitrogen	%	0.5
	Moisture	%	0.4
	Ash	%	0.06
2	Humidity	%	RH=58.6
	GCV of fuel	Kcal/kg	10941

Appendix 2: Dashen beer factory production energy data

Month	Production, hector litter	Electricity in kWh	HFO in kWh	Total energy consumption in kWh
Jan-19	55488	2,992,038.66	2,292,733	5,284,771.66
Feb-19	51872	3,135,664.91	2,143,322	5,278,986.91
Mar-19	50028	3,037,952.73	2,067,129	5,105,081.73
Apr-19	49225.8	3,124,473.42	2,033,983	5,158,456.42
May-19	48408.3	2,895,625.46	2,000,204	4,895,829.46
Jun-19	47147.51	3,421,078.45	1,948,109	5,369,187.45
Jul-19	45529.23	2,851,396.78	1,881,243	4,732,639.78
Aug-19	37680.02	2,094,696.79	1,556,918	3,651,614.79
Sep-19	67761.86	3,099,241.73	2,799,883	5,899,124.73
Oct-19	63920.89	3,030,740.40	2,641,176	5,671,916.40
Nov-19	61403.36	2,831,891.12	2,537,153	5,369,044.12
Dec-19	69242.42	3,694,855.42	2,861,058	6,555,913.42
Average Total Specific Energy Consumption of the factory				

Appendix3: Break down for the total cost of installing new efficient burner for the boiler in the factory.

Transportation	Total burner weight	Shipping fee per kg	Total shipping price
	350kg	$11=583Birr	204,050Birr
Price of the burner			245550 Birr
Tax	Tax rate	Price of a burner	Fee for taxation
	29%	245,550	71,210 Birr
Installation cost			450,000 Birr
Total estimated investment Cost			**970,600 Birr**

Appendix4

Break down for the total cost of Insulation for flanges and valves.

The maximum price of an insulator is around 50 dollar (1590Birr) which is obtained from Alibaba market website. The total breakdown is done in the table below

	Quantity	Estimated price per insulator(Birr)	Total cost	Tax	Estimated installation cost(Birr)	Total investment cost(Birr)
Flanges	5	2650	13250	35%=4637	25000	60775
Valves	5	2650	13250	35%=4637		

The transportation cost can be ignored because it is light weighted and can be imported together with other items.

Appendix 5: Assumptions taken

Annual Plant operation days	300
Daily operation time	24hours
HFO price per litter	50 Birr
Electricity price per kWh	1.2 Birr