AN EVALUATION OF RENEWABLE ENERGY ADOPTION IN KENYA. A CASE STUDY OF BIOMASS BRIQUETTE PRODUCTION AND ITS USE IN INDUSTRIAL BOILER OPERATIONS.

BY

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A Research Project submitted in partial fulfillment of the requirement for the award of the Degree of Master of Arts in Environmental Planning and Management, Department of Geography and Environmental Studies, University of Nairobi.

2018

DECLARATION

I declare that this project is my original work and has never been presented to any university for any examination and award.

Signature: ……………………… Date: ……………………….

SHADRACK OMWENGA

C50/67606/2013

Supervisor's Declaration

This research project has been submitted for examination with my approval as the University supervisor.

Signature: ……………………………… Date: ……………………………

DR. SHADRACK KITHIIA

DEDICATION

I dedicate this Research Project to my late father Mr. Felix Omwenga and the family at large for their support and encouragement throughout the study. I also thank God Almighty for His favour, mercy and blessings that has seen me through this Programme.

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My gratitude goes to all who have given me support towards the completion of this research project. My humble appreciation goes to my Supervisor Dr. Shadrack Kithiia for his advice and guidance during this study. I would also wish to thank the former Chairman of the Department of Geography and Environmental studies, Dr. Samuel Owour, for his training in research Methods and Mr. Ndolo for his coaching in statistics.

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ABSTRACT

The study sought to establish the adoption of renewable energy in Kenya based on a case study of biomass briquette production and its use in industrial boiler operations. Among the specific objectives, the study was to evaluate potential environmental impacts in the production of biomass fuel briquettes, to determine the social-economic benefits accrued from the production of fuel briquettes, to determine how cost of fossil fuel influences the adoption of biomass briquette use and to measure the proportion of volatile matter, moisture content, ash content and fixed carbon in biomass fuel briquettes. The research study was carried out in four counties in Kenya namely; Kisumu County, Meru County, Nairobi County and Kiambu County. Briquette manufacturing was taking place in Kisumu County while its use in boiler operations was taking place in the counties of Meru, Nairobi and Kiambu. The study employed both qualitative and quantitative research designs. Field surveys and statistical analyses were used which enabled collection of relevant data for testing research hypotheses. Field surveys and in-depth interviews were helpful in defining and developing approaches to the problems. Statistical analyses were used to quantify the problems and understand how prevalent they are by looking for projectable results to the larger population. This type of data was organized and presented in form of graphs, tables, averages, maps and other statistical presentations. The hypotheses of the study were tested using chi square and Z-test.

The study found that majority of the respondents (68%) agreed that the production and adoption of fuel briquettes in boiler operations has to a number of socio-economic benefits such as infrastructure development and employment creation. The study did a correlation Analysis of cost of fossil fuel and biomass briquette and found that high cost of fossil fuel variable scores go with high tonnage briquette used variable scores and vice versa. The study also found that when prices of Heavy Fuel Oil go down boiler operators preferred to run fossil operated boilers as opposed to biomass boilers. The research also carried out proximate analysis of the biomass briquettes made of (40%) sawdust and (60%) bagasse. Possible actions to improve production of biomass briquettes and its adoption in boiler operations have been suggested. This includes enactment of policies that will regulate the use and cost of Heavy Fuel Oil and policies that will encourage investment in briquette production. Avenues for further research have also been explored and explained.

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ABBREVIATIONS

BTEC-Biomass Thermal Energy Council

CFCs-Chlorofluorocarbons

EU-European Union

FAO-Food and Agriculture Organization

GHGs-Green House Gases

GoK- Government of Kenya

GVEP-Global Village Energy Partnership

IEA-International Energy Agency

IPCC- Intergovernmental Panel on Climate Change

KIPPRA- Kenya Institute for Public Policy Research and Analysis

KNBS-Kenya National Bureau of Statistics

NYSERD-New York State Energy Research and Development Authority

OECD- Organisation for Economic Co-operation and Development

PAC- Percentage of Ash Content

PFC- Percentage Fixed Carbon

PMC- Percentage Moisture Content

PVM-Percentage of Volatile Matter

TDI-The Delta Institute

UNFCC- United Nations Framework Convention on Climate Change

UNEP-United Nations Environmental Programme

USNRDC-United States Natural Resources Defense Council

UNOSD- United Nations Office for Sustainable Development

VOCs- Volatile organic compounds

CHAPTER ONE

BACKGROUND OF THE STUDY

1.1 Introduction

There has been an improved trend in the energy sector in Kenya with positive changes in the demand and supply situation. Energy use in Kenya mainly concentrates in four areas, namely the commercial sector, manufacturing and allied, transport and households. In the recent past there has been growth in demand for energy in power plants and, street lighting. The manufacturing industry is one of the largest consumers of fossil fuel products; it closely follows the transport sector which is the largest, then followed by other industries such as power generation, agriculture, government and tourism (KIPPRA, 2010).

From the National Energy Matrix (Kenya), in 2009 Kenya consumed approximately 14,353.8 tonnes of oil equivalent energy resources against a total supply of 18,215.99 tonnes. Petroleum fuels represented approximately 28.57% of the net consumption while electricity supplies represented 3.11% and combustible renewables 67.65% (KIPPRA, 2010).

The energy sector is subdivided into two: renewable energy sources and non-renewable energy sources. Renewable energy sources adopted in Kenya are quite diverse and majorly include: hydroelectric, geothermal, solar, wind and biomass. Biomass use in Kenya is moderate. Kenya has enough capacity to produce biomass material for modern energy generation. The Kenyan government, through the ministry of energy has identified a number of biomass materials from forestry and agro-industry residues with substantial potential for power generation including sawdust and bagasse (Birgit, 2012).

Biomass can be transformed into briquettes to form formidable source of fuel. This type of fuel is largely consumed by the manufacturing industry to run boilers for the production of steam. Thermal energy is generated by industrial boilers in the form of saturated/dry steam or superheated steam or hot water at required pressure needed to run processes, machinery or to generate power for manufacturing operations (TDI, 2002).

Briquetting involves collection of combustible material loose material such as bagasse or rice husk and condensing them into a solid fuel with enough density and of a convenient shape that can be used in replacing charcoal or wood. Agromass materials such as baggase, tree barks, straws, sawdust and coffee husks have been briquetted with much success (Cosgrove *et al.*, 1985). *Figure 1-1* shows Lignocellulisic components of some Biomass sources.

Figure 1-1 Lignocellustic components of some biomass (R. Saidur 2011)

In Kenya the industrial briquette industry was commercialized from around 2007 and mainly in the sugar belt region west of the country. The location was optimal as bagasse, from the sugar manufacturing process, is one of the largest sources of consistent agromass wastes.

The usage of fossil fuels has harmful effects on environment as well as on humans. The emissions from the boilers include Sulphur oxides, nitrogen oxides, carbon dioxide causing acid rains, global warming, respiratory problems, lung diseases, asthma etc. Fuel selection is one of the key decisions made that has a direct correlation with atmospheric emissions (Rao, 2016). However, it has been found that agromass use in boilers both loose and condensed has a number of positive impacts touching on environmental, social and economic issues and they include: financial savings, creation of job opportunities, preservation of fossil fuel resources and reduction of NOx and CO_2 emissions (Saidura, 2010).

1.2 Statement of Research Problem

Presently, 82% of world prime energy sources is comprised of hydrocarbon fuels such as coal, oil and natural gas, though it is projected that in the next 40-50 years some of these sources of energy will be exhausted. However, in the next 20-30 years their use is expected to grow in absolute terms especially if policies that promote low-carbon emission sources will not be in place (IPCC, 2007). According to British Petroleum Company (2005), the largest constituent of fossil fuels used was oil at (35%), then coal at (25%) and gas at (21%) (IPCC, 2001).

Fossil fuel oil used in Boilers operations emit a number of pollutants associated with combustion processes including those pollutants, such as carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx) and particulate matter (PM), as well as air contaminants. The main air toxics include: hydrogen chloride, lead, cadmium, formaldehyde, mercury, dioxins/furans and polynuclear aromatic hydrocarbons (PAHs).

It is estimated that 85% of the anthropogenic CO_2 emissions produced annually emanates from burning of fossil fuels (IPCC, 2003). Steam production in industries heavily rely on fossil fuels with some sub-sectors having significant proportions: pulp and paper processing (81%), food processing (57%), chemicals (42%), petroleum oil refining (23%), and primary metals production (10%) (Saidura, 2010).

Power generation roughly represents 70% of all greenhouse-gases and CO_2 emissions and has been rising in the past century to even higher levels. Other greenhouse gases that do not last long in the in the atmosphere but have a high potential for global warming include gases such as nitrous oxide (NO) and methane (CH_4) which are both emitted by the energy sector (Birol, 2015).

Air pollution has its adverse effects on the environment; globally 6.5 million premature deaths that occur annually have been attributed to air pollution. The world has been forced to adopt green energy resources which are environmentally less destructive such as biomass, wind, solar and ocean wave energy. There is an attempt to reduce carbon emissions from the use and production of hydrocarbon fuels by 80% as it is anticipated that the consequences of environmental damages caused by global warming such as, urban smog and acid rain is going to be brutal than it has been in the past.

The Intergovernmental Panel on Climate Change (IPCC, 2001) reported that an increase in temperature of between 1.4 and 5.8^{0}C is expected over the period between1990 to 2100, if the rate of fossil fuel use remains constant. Carbon dioxide (CO_2) is the main source of greenhouse gas emissions from boiler systems with the combustion of fossil fuels being the primary contributor. Leakages in natural gas distribution lines may be a contributing source of GHGs such as methane (CH_4) while the combustion process may release CH_4 and nitrous oxide (N_2O) as byproducts (Saidura, 2010).

According to the Kenya National Bureau of Statistics (2015) the manufacturing sector in Kenya consumes 15.5 percent of the imported petroleum (fossil fuel) products and a higher percentage being used to run boilers. Kenya's balance of trade hurts as the deficit keeps growing year by year.

It was with this background that the study endeavored to evaluate the contribution of biomass Briquette use in Industrial Boiler Operations to renewable energy development in Kenya. Three Indicators of sustainable development: economic, social and environmental dimensions formed the basis of assessment in this study; they were all measured and evaluated in an attempt to evaluate the contribution of this sector to sustainable development.

1.3 Research Questions

a) What are the potential environmental impacts in the production of biomass fuel briquettes?
b) What are the social-economic benefits accrued from the production of biomass fuel briquettes?
c) How does the cost of fossil fuel influence the adoption of biomass briquette use?
d) What is the proportion of volatile matter, moisture content, ash content and fixed carbon in biomass fuel briquettes?

1.4 Objectives of the study and research questions

1.4.1 Overall objective

The general objective of the study was to evaluate the adoption of biomass briquette production and its use in boiler operations.

1.4.2 Specific Objectives

The study was guided by the following objectives:

a) To evaluate potential environmental impacts in the production of biomass fuel briquettes.
b) To determine the social-economic benefits accrued from the production of biomass fuel briquettes.
c) To determine how cost of fossil fuel influences the adoption of biomass briquette use.
d) To measure the proportion of volatile matter, moisture content, ash content and fixed carbon in biomass fuel briquettes.

1.5 Research hypotheses

H_0There are no significant socio-economic benefits in the production and use of biomass briquettes.

H_1There are significant socio-economic benefits in the production and use of biomass briquettes.

H_0There are no significant potential negative environmental impacts in adopting the use of fossil fuels as opposed to biomass briquette fuels in boiler operations.

H_1There are potential significant negative environmental impacts in adopting the use of fossil fuels as opposed to biomass briquette fuels in boiler operations.

H_0The price of fossil fuel does not significantly influence the adoption of biomass briquette use in boiler operations.

H_1The price of fossil fuel significantly influences the adoption of biomass briquette use in boiler operations.

1.6 Justification of the study

Kenyan Manufacturing plants are heavily reliant on fossil fuels for their boiler operations. This has proved to be disingenuous in recent past as documented by Intergovernmental Panel on Climate Change (IPCC) and United Nations Environmental Programme (UNEP) among other international bodies**.**

According to Birol *et al.* (2015) owing to deescalating cost of fuel in the world market, there has been a negative outcome on green energy adoption; industries opt to run boilers and other heavy equipments on fossil fuels rather than on renewables. OECD in 2009 stated that 81% of the world's energy source comes from fossil fuels and that CO_2 emissions associated with fossil fuel use account for over 90 percent of energy-related emissions.

Globally, it is estimated that by using fossil fuels close to 30 billion tonnes of CO_2 is produced annually. Over time a huge percentage of this carbon dioxide has been released to the atmosphere. Researchers in the past theorized that the additional carbon dioxide being generated and released to the atmosphere could be accommodated by the atmospheric sink as it was considered to be large enough however, the ratio of carbon dioxide in the atmosphere has risen over time, by over thirty percent compared to the beginning of the industrial revolution when carbon dioxide by volume only constituted 280 parts per million (ppm) compared to the present 385 ppm (Klaus, 2010).

The release of greenhouse gases to the atmosphere may cause global warming especially because they relatively stay longer in the atmosphere notably nitrous oxide (N_2O), Ozone (O_3), methane (CH_4) and chlorofluorocarbons (CFCs) such as Freons mainly used as a refrigerant gas. These gases tend to have a wide dispersion area creating a global problem compared to acid gases which tend to localized. These gases have a high affinity for heat energy absorption and in particular infrared radiation which would have been otherwise radiated back to space from the atmosphere which results to the warming of the troposphere (lower atmosphere). It is estimated that anthropogenic activities such as burning of fossil fuels account for more than 75% of the increasing CO_2 levels in the troposphere. Increase of CO_2 levels is considered as the main cause of global warming accounting for about 50% of the greenhouse gas phenomena (Roddie, 1990).

Accounts of severe climate change have been associated with the rapid increase of CO_2 levels in the atmosphere and there has been a considerable effort in trying to understand the scale and severity of global warming (Klaus, 2010). Reduced amount of precipitation and changes in its distribution is one of the effects of climate change; large disparities in average soil moisture content; and melting of earth's largest ice blocks in the polar regions and the thermal expansion of the oceans, which result in raised sea levels and flooding of the coastal belt (Roddie, 1990).

The use of fossil fuel has further been linked to adverse health conditions especially from the source point. For instance studies conducted by U.S Environmental Protection Agency (1998) have shown that greenhouse gasses emanating from the combustion of fossil fuels have some adverse health risks. Inhalation of oxides of Nitrogen has been linked to asthmatic symptoms, aggradation of allergies and inflammation of the airways due to its toxic effect. In addition, nitrogen oxides form smog (ozone) when in the presence of sunlight it reacts with volatile organic compounds (VOCs). Smog manifests as a brown haze layer contributes to increased respiratory symptoms, increased lung malfunction, more of emergency medical related needs, increased hospital admissions, more asthmatic attacks and increased cases of premature deaths (US NRDC, 2011).

As such, it is very important to scale up the adoption of renewables; low carbon emitting technologies that will reduce the over dependence on hydrocarbon fuels and ameliorate the effects of climate change. Therefore this research will provide more information to the manufacturer on the importance of using renewable sources of energy.

Biomass is an abundant natural occurring renewable energy source with enough potential to replace fossil energy resources. Biomass is one world's largest primary energy source coming third after coal and oil and it still forms a significant percentage of energy sources in the manufacturing industry. The decreasing availability of fuel wood in Kenya (Less than 10% forest cover) has necessitated the efforts to be made towards efficient utilization of agricultural resources exemplified by bagasse in the sugar belt region and coffee husks in central Kenya (Sugumaran, 2010).

As much as biomass briquettes surpass fossil fuels in environmental standings, most of its wastes contain elements that are a health risk; organic compounds such as dioxins, heavy metals and chlorine elements have been found in biomass briquettes. Thy *et al.,* (2009) notes that complete volatilization of mercury occurs when biomass is burnt at temperatures around $575^{o}C$ leaving residues in form of solid ash or slag with low mercury detection levels of about (5 ppb). Mercury levels in fly ash can be as many as 40 times as the fuel source. According to Ravindrana (2008), Trimble (1984) and Duval (2001) biomass may have a significant undesirable impact on the environment. Biomass energy sources may have no impact on the carbon cycle 'carbon neutral' but have a significant negative impact on land and water, natural biota, nutrient levels, nutrient removal and losses, soil erosion and water run-off, habitats and wildlife, loss of biodiversity and lastly land degradation (Saidura, 2010).

Less emphasis has been given to biomass briquette use in industrial sector in Kenya. An in depth study of its economic, social and environmental impact from its manufacturing to its use will give a clear understanding of factors contributing to its rate of adoption or rejection and thereby influence policy development and adoption. Findings of this study will further help to understand the relationship between the adoption of biomass briquette use and the cost of fossil fuel.

1.7 Scope of the Study

The study sought to assess the impact of biomass briquette industry as part of renewable energy development in Kenya. The study used Lean Energy Solutions company briquette manufacturing plant in Muhoroni Sub-County and boiler operations in thirty factories spread in three counties. The study focused on three dimensions of sustainable development which are social, environmental and economic development. Geographically, the study focused its activities on four counties namely: Kiambu, Nairobi, Meru and Kisumu Counties. The study was limited by lack of properly documented information on the briquetting industry in Kenya and the lack of consolidated statistics on the amount of fuel oil imported. Fuel oil price is unregulated in Kenya and therefore its price is determined by market forces.

1.8 Study Limitations

a. Finance

Due to financial constraints the study laboratory analysis only covered proximate analysis of briquettes. Field studies were also carried out intermittently whenever funds were available.

b. Time

Time was a major constraint because the research was conducted on a part time basis. Travelling to the field was done intermittently on days that the researcher was off from work.

1.9 Operational Definition of Terms

Briquette is a product of compaction or densification of loose biomass material to form solid material with high density (from 150-200 kg/m^3 to 900 to 1300 kg/m^3) (FAO, 2014).

Briquetting is therefore a process that is mechanical in nature and that results in the densification of bulky materials. With this process, biomass material/particles can be re-engineered to form a designated shape. Briquetting can be viewed as a process that controls wastes especially agricultural wastes such as bagasse, which is an end waste product from sugar production. As a measure to prevent a number of ecological problems, briquetting can be used to provide a formidable fuel; this also depends with the source of raw material to be used. Depending on choice of technology it is preferred that briquetting should be carried out at relatively high temperatures or at standard room temperature this is because briquetting is a high pressure process (Mohammad, 2005).

Briquetting ensures that fine material that is made denser and into a regular shape and size does not disintegrate when it is being transported or during storage. Bonding in briquettes is very important, some biomass materials require adhesives such as starch or starch rich materials for proper bounding to be achieved; so that all fine and loose particles are bound together. However, some biomass materials can simply be bound together without any addition of binders (binderless briquettes) (Mangena and Cann, 2007).

Generally, briquetting has concentrated more on the use of agricultural wastes and charcoal dust to produce smokeless solid fuels. Some biomass materials such as agricultural wastes such as bagasse and wood chips require more force per unit area as more pressure is required to subdue the natural resistance of these materials. Fundamentally, this process entails a mechanical process that through a combination of heat and pressure cell walls of biomass materials are destroyed. The power consumed in the process of making organic briquettes is costlier than that of carbonized briquettes.

There is a variety of briquetting machines available in the market ranging from highly mechanized ones that are powered using electricity and those that are simple and have been designed to be operated manually. Generally, there are two forms of briquetting operations: worm screw type and mechanically compression press type (hydraulic or pistons).

Biomass is a term used to identify any organic material that is a derived from the environment. It includes both plant and animal material, plant material such as agricultural and forest left overs, seaweed, forest products such as wood, industrial organic wastes, human and animal wastes. Biomass therefore, is a terminology used to encompass plant biomass or phytomass and animal biomass or zoomass. Plant material intercepts sun’s energy and converts it into chemical energy that is fixed or stored in form of aquatic and terrestrial vegetation through the process of photosynthesis. Animals convert vegetation (used as food) when grazing into animal biomass (zoomass) and excreta. Energy can be derived from excreta from terrestrial animals, and more importantly from dairy animals, it is difficult to collect excreta from aquatic animals as the environment they live is difficult to collect it and utilize it in energy production (Saidur, 2011).

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter contains a background on briquetting and an evaluation of the past studies. The goal of this review is to examine in depth what other researchers and scholars have accomplished in past studies touching on the same subject area. To avoid duplication of previous works done this literature review will offer critical analysis of past research and form a guideline on how the study will be conducted.

2.2 Historical Background of Briquetting Process

The process of condensing combustible loose materials for purposes of making a fuel has been with humanity for thousands of years though, industrial technological advancements in the process only dates back to eighteenth century. There is a report dating back to 1865 that discusses how machines can be used to manufacture fuel briquettes from natural occurring organic matter (peats), it is believed that the machines mentioned in this report are the predecessors of the current designs found in the market. Since then, there has been tremendous worldwide spread of the process incorporating peat and brown coal.

Densification of organic material to form biomass briquettes is relatively a new process when compared to the use of different forms of coal to form briquettes. Briquetting became common in the early to mid-20th century and evidently it was widespread in 1930s in United States of America during the depression and in Japan and East Asia during World War II.

It was in Switzerland that the modern mechanical briquetting machines were engineered developing designs that had been conceptualized in Germany in the 1930s.

During World War II use of saw dust to make briquettes became widespread because there was a fuel shortage experienced across Europe and America. However, after the war, fossil fuels took over and phased out briquettes because of its availability and cost effectiveness.

Advantages of briquette production:

i. An inexpensive source of fuel for industrial purposes, which is affordable by all boiler run industrial establishments.

ii. Helps to conserve natural resources since briquettes are good substitutes of fuel oil and firewood. Therefore, it reduces the amount of fuel such as oil, gas and firewood used to generate energy for the production of steam.

iii. Source of employment creation; briquette production requires personnel in machine operation, feeding raw materials, drying of raw materials, packaging and sorting of briquettes and transportation of both raw materials and briquettes (Grover *et al.,* 1996).

2.3 Potential of agro-residues for briquette production

Sources of agromass material are usually quite diverse and spread out making it difficult to manage its use to levels that will create an impact as an energy source nationally. For a biomass material to qualify as feedstock for briquetting there are a number of factors that need to be considered. Other than its availability in enough quantities, it should have the following characteristics:

2.3.1 **Moisture content**

The moisture content of the raw material to be used should be as low as possible; 10-15 percent is generally the accepted range. High moisture percentage on input material affects grinding and may cause some mechanical problems to the machines; to achieve the required levels excessive energy may be required which is expensive.

2.3.2 **Ash content and composition**

It is important that the ash content should be low, Proximate Analysis carried out on biomass materials have indicated that most materials have a much lower ash content (aside from rice husk which has an ash content of 20%) but their ashes are more alkaline with minerals such as potash. During combustion the constituents of these materials have a propensity to volatilize, be loose, then settle and condense in tubes especially those that achieve very high temperatures (super heaters). Ash deposit’s itself on boilers especially on the exposed surfaces because the sintering temperature of ash is occasionally lowered by these constituents (Grover *et al.*, 1996).

2.3.3 **Flow characteristics**

The flow of the material entails ease of its handling; it is important that the material should be easy to handle, able to stream easily when storing in silos and bunkers and therefore materials that are grainy are recommended.

a. Rice husk

When rice husk is compared with other biomass materials such as sawdust, rice husk has higher ash content and a higher percentage of potash. However, rice husk is a remarkable agro-mass material. It is usually available with low moisture content; normally with less than 10%. Rice husk has good flow ability, further its ash has a high sintering temperature because of the fewer alkaline metals that constitutes it (Grover, 1996). Rice husk is a remarkable biomass material when used to make briquettes even though its calorific value (CV) is lower than that of dry wood and other agromass wastes.

b. Groundnut shell

Ground nut shell is an excellent material for briquetting especially because of its' low ash content (2-3%) and a moisture content of less than 10%.

c. Cotton sticks

Cotton sticks should be cut into small pieces for it to be used as a briquetting material. It should be stored only when it is fully dry as it degrades faster when in storage. Another downside of cotton sticks is that its alkaline content is usually very high making it an environmental risk.

d. Bagasse/bagasse pith

Bagasse requires a lot of drying and it is energy intensive. These residues come from cane millers with high moisture of around 50%. Bagasse is a good briquetting raw material because it has relatively high heating value of around 4300 kcal/kg and a low ash content of about 10%.

e. Coffee husk

Coffee husk is an excellent raw material for making briquettes, it has low moisture; less than 10% and after combustion its residue is relatively low. In Kenya, coffee husk is mostly found in factories found in coffee growing areas of Kiambu County and the former larger central province.

Others: Other biomass materials that can form good briquettes include sawdust, lentil stalks, tea wastes and pineapple farm wastes.

2.3.4 **Calorific Value (CV)**

The calorific value should be high, according to IEA Bioenergy (2002), through thermochemical and biochemical processes biomass materials can be used to generate power or form energy carriers such as oil, gas and charcoal. Because solid biomass fuels are usually cost effective and highly reliable, its combustion technologies are the most advanced and most regularly applied. During combustion in biomass and at temperatures of up to 100^{o}C, particles release their heat value releasing embedded moisture content. Volatile gases such as methane (CH_4), carbon dioxide CO and other gaseous components are released when dried biomass particles heats up. Approximately two thirds of the heating value of biomass is contributed by these gases in any given combustion. Ash remains as a residue of this process after char is oxidized (Gravalos, 2010).

The CV of any given material is normally measured in terms of total amount of energy produced per unit volume, or mass; hence MJ/kg for solids, MJ/l for liquids or MJ/Nm^3 for gases. The Calorific Value of a fuel can be expressed in various forms, the gross CV (GCV), or higher heating value (HHV) and the net CV (NCV), or lower heating value (LHV).

The HHV is the total energy content discharged when the fuel is burnt in air, including the latent heat contained in the water vapor and subsequently speaks to the greatest measure of energy possibly recoverable from a given biomass source.

Technological advancement in energy heating systems determines the actual energy amount that can be recovered in any given system as well as the type of energy being used i.e. fuel oil, flammable gas or steam.

In reasonable terms, it is difficult to successfully utilize the latent heat embedded in water vapor and therefore, the Lower Heating Value is the suitable incentive to use for the energy available for subsequent use (McKendry P, 2001).

2.3.5 **Volatile Matter Content**

Volatile matter in biomass materials refers to the component of biomass that breakaway and is released when biomass is heated up to high temperatures of over 400^{o}C. The heating process disintegrates biomass material into volatile gases and solid char. When compared to other solid fuels, biomass materials normally have high levels of volatile matter of up to 80 percent, coal, with less than 20 percent and anthracite coal, a negligible one (McKendry P, 2001).

2.3.6 **Alkali metal content**

For any thermo-chemical conversion process in any biomass material it is very important to understand its alkali content such as K, Na, P, Mg and Ca. Airways in boiler plants and furnaces can be blocked by formations that are sticky or in mobile liquid phase when alkali metals react with silica elements present in ash. It should be noted that even though the inherent silica content of biomass material might be low, there is a risk of it increasing in percentage significantly when it is contaminated with soil during gathering and sun drying. Increase of silica content is a major concern to boiler operators as it leads to serious difficulties during operations (McKendry P, 2001).

2.4 Aspects of Briquetting

2.4.1 **Pressure Compaction**

Compaction of biomass wastes is carried out with the goal of making it compact for use as energy fuel. Feeder materials such as biomass wastes from wood industries, agricultural activities and other combustible wastes are good sources for making briquettes. Based on the densification typology, technologies used in forming briquettes can be divided into the following categories:

- High pressure densification
- Medium pressure densification using heat and
- Low pressure densification using a binder

The strength of such bonds is caused by intermolecular forces, van der Waal’s forces or interlocking. High pressure forces can activate natural components of the materials to become binders. However, some materials will require binders even when subjected to high pressure conditions (Grover, 1996).

2.4.2 **Biomass briquetting technologies**

Densification of biomass presents a number of technologies that coverts biomass wastes into a convenient fuel. The mechanical technological knowhow is also known as agglomeration or briquetting.

It can be categorized into five main types, depending with the type of equipment used:

- Piston press densification

- Roll press densification
- Screw press densification
- Pelletizing
- Low pressure or manual presses

a. Piston press densification

Piston press is of two types:

1. Hydraulic press and;

2. The die and punch type.

In the hydraulic press technology the process involves two sets of movement; first, biomass is compacted in a vertical direction then again in a horizontal direction. To produce about 1.8 tonnes per hour around 37kW of continuous power is required. The size of briquette produced varies with the size machine used though the standard size weighs around 5kg and it measures: 450 mm x 160 mm x 80 mm. Hydraulic press technology can handle biomass material with moisture content of up to 20 percent. The technology is slower in performance when compared to die and punch process with speeds of 7 cycles/minutes (cpm) against 270 cpm for die and punch technology. Hydraulic slow process helps to reduce wear and tear rate of replaceable parts. In the punch and die type, which is also known as the ram and die, agromass material is pressed into a die by a ram in opposite motion with great force per square inch so that the material is densified to make a compacted product. This kind of machine produces briquettes that are standard at 60 mm, diameter. With this type of technology around 25kW of power is required is required to run a machine with production capacity of 700kg per hour (Grover *et al.*, 1995).

b. Screw press

The densification ratio of screw press machines varies between 2.5:1 to 6:1 or even more. The process involves continuous extrusion of biomass material by a single or multiple screws passing through a taper die that is exposed to heat even externally to lower resistance. The high pressures and temperatures subjected to the raw material make the lignin present to be fluid which then becomes the binding element. The process carbonizes the skin of the briquettes being extruded which are tubular in shape promoting better combustion. The regular size of this type of briquette is 60 mm diameter (Koopmans, 1996).

c. Roller Press

In a roller press machine, biomass material is fed in between two rollers moving in either directions and the material is condensed into oval-shaped briquettes. This type of briquetting process requires a binding material and is usually used to produce charcoal briquettes by carbonizing biomass material.

d. Pelletizing

Pelletizing is a briquetting process where smaller dies of approximately 30mm are used to produce small sized briquettes also referred as pellets. The pellet making machine has a number of extrusions (dies) made/drilled on a heavy steel beam and biomass material is pressed against the dies arranged as holes by a set of rollers which are usually two or three. There are two main types of pellet machines: ring type and flat/disk type. Other designs of pellet making machines include the Cog-Wheel and the Punch press machines. Pellet making machine produce briquettes that are cylindrical with diameter of between 5mm and 30mm and of variable length. Pellets have a good combustion characteristic and good mechanical strength. In industrial applications where automatic feeding is required pellets become the most formidable source of fuel. Pellet making machines can produce up to 1000 kgs of pellets per hour.

e. Manual Presses and Low pressure Briquetting

Manual presses for making briquettes out of biomass feedstocks come in different forms. They may be designed specifically for making briquettes or be re-engineered from existing machines used for other closely related works. These machines can be used to compact raw biomass material or charcoal dust. It is advantageous to use low pressure briquetting machines because of its low capital requirement, low levels of skilled manpower required and low operating costs required. Manual presses are best suited for densifying green organic matter such as sugar cane waste (bagasse) and coir. Low pressure briquettes machines shape biomass material while still wet in simple extrusion presses or block presses. This type of briquette will require drying before it can be used as a fuel and is denser than the former loose biomass material. The downside of briquettes manufactured in this manner is that they have little mechanical strength and breaks easily. It is therefore very important to use a binder when manufacturing briquettes using such machines (GVEP, 2010).

2.5 Global outlook on Briquettes and Boiler Operations

The use of biomass energy is one of the best solutions to reverse atmospheric degradation today (Khan, 2008). There has been tremendous growth within the European Union (EU) over the past few years on the use of biomass energy sources and EU has future plans to increase its ratio in the total energy mix (Nakicenovic, 2000). According to Mishrah and Grover (1996) biomass briquettes biomass briquettes are not only used in developing countries but they are used and endorsed by developed countries.

Studies conducted in Nepal by Kim and Lu on the effects of fossil fuels vis a vis biomass briquettes on climate change realized that combustion in boilers of hydrocarbons such as coal, pertroleum oil and propane gas among other fossil fuels emit harmful emissions such as nitrogen oxides (NO) and sulfur dioxide (SO_2), which are a major causes of environmental pollution such as smog, acid rain, increase of particulate matter, global warming and climate change.

In his studies on “Biobriquettes-an Alternative Fuel for Sustainable Development” Ramesh, (2009) noted that in South Asia most industrial boilers furnaces and kilns use coal as the major source of fuel with fuel wood, biobriquettes and agro/forest wastes are used only as additives. Ramesh further noted that the use of biobriquettes is not different in composition as they are manufactured using coal, lignite and different biomasses waste.

2.6 Kenya’s Outlook on Biomass Energy

Studies conducted in Kenya on briquette use have not tackled the issue of energy consumption in industries/large scale energy consumers. Information on sector specific consumption of biomass energy and the different forms of biomass energy seem to be scanty with most research giving variable estimations.

According to Mugo *et al.,* (2010) in 2000 charcoal was still the main source of fuel in Kenya with 16.5 million tonnes of wood processed in earthen Kilns with low levels of efficiency of up to 10% while 15.1 million tonnes of wood was used directly as fuel (fuel wood) making the net tonnes of biomass fuel used to be over 34.3 million tonnes. In total renewable energy sources accounted for 43% of the country’s energy consumption while non-renewable energy sources accounted for 57%. GVEP International (2010) noted that charcoal was in use by a number of Kenyan industries especially where a longer or cleaner burning fuel other than firewood was required.

A study on socio-economic factors that influence adoption of improved biomass energy technologies for cooking and households' acceptance and willingness to switch from one fuel and technology to another was carried out in rural and urban Kitui Central with a view to future uptake of alternative biomass fuels and improved biomass energy technologies for cooking. The study found out that household wealth played an important role in the adoption of improved biomass energy technologies for cooking. Adoption of biogas and briquette fuels and improved firewood technologies was found to be low and there was no adoption of liquid biofuels and briquette technology. Rural and urban households showed a distinct pattern of adoption with regard to biomass fuels and technologies due to different levels of awareness, household wealth, perceptions and constraints (Mutea, 2015). Though she didn't focus on renewable energy alone Gatama in 2010 carried out a study on factors influencing household energy consumption in Kenya and found out that there was a significant relationship between age, household size, education and cost of energy and the energy consumption by a household.

In a study conducted by Mbura (2013) titled "Evaluating fuel briquette technologies and their Implications on greenhouse gases and livelihoods in Kenya". The researcher found that charcoal fuel briquettes consumption was affected by household income with families that produce for their own consumption gaining more savings on cooking fuel expenses. The study also found out that income that women generated through selling briquettes or saved through use of briquettes was spent on other livelihood needs such as food, health, school fees and paying rent. The study also looked at charcoal briquettes contribution to food security and saving of trees and found out that cooking a meal with charcoal briquettes was cheaper by 7% and 12% when compared with kerosene and charcoal fuels respectively.

According to Kenya's National Energy Policy of 2004 biomass energy resources was identified to be one of the most important fuel sources in Kenya with 68% of the primary energy source being wood fuels. The policy acknowledged the huge potential that biomass (forest resources) has for power generation and agro-industry residues including bagasse from the sugar industry, enough to generate power for supply to the grid. The policy also acknowledged the need for clean energy resources that will increase and protect the environment and sustain its carrying capacity.

The literature reviewed above indicate that studies carried out in Kenya related to briquettes focused mostly on domestic charcoal briquettes and the responses were mainly from household level.

2.7 Combustion of Briquettes in Boiler Furnaces

Briquettes are best suited for industrial boiler furnaces which have been designed for burning of wood or coal because their configuration and consistent structure give better fuel efficiency when compared with the use of loose biomass and other fuels. Briquettes are at least twice as powerful as coal so long as secondary and primary air is well distributed and forced draft fans installed are of the right capacity to supply air. Briquettes that are loosely compacted tend to break during combustion and the residues depending with the size of particles either gets carried away with gases or pass through the grate bars into the ash collector or block the grate bars, the latter restricts the combustion ratio in the furnace chamber. On the other hand, highly compacted briquette fuels give much better combustion performance and do not showcase these tendencies. When operating a heating furnace using either type of briquette, the distribution of both primary and secondary air has to be observed and regulated to the right parameters. When compared to coal briquettes require more of secondary air as opposed to primary air. On the flip side, wood requires more air because of its high density and therefore its distribution components should be maintained at the original ratio. However, the specific consumption of total air in terms of m^3/hr. kWh remains the same (Grover, 1996).

2.8 Comparative Impacts of Fossil Fuels and Biomass briquettes in Boiler operations

In nearly all major industrial establishments today boiler systems are crucial sources of energy. In the US, steam generated from boilers in industries consume up to 37% of fossil fuel burned. Steam is used to concentrate and distill liquids, to heat processes, or is used directly as a feedstock (Saidur, 2011).

Most industries that require energy in significant proportions rely heavily on fossil fuels for steam production: pulp and paper (81%), food processing (57%), chemicals (42%), petroleum refining (23%), and primary metals (10%). Since large steam systems are common in diverse industrial set ups, it is prudent that energy efficiency measures should be sought and adopted. Saidur and Mekhilef reported that the rubber industry in Malaysia consume about 20% of the total energy produced in that country (Saidur, 2011).

2.8.1 **Biomass briquette as a carbon neutral source of energy**

Biomass material can be converted into fuel briquettes, or any other type of fuel such as charcoal, ethanol or methane. This means that with technology or by natural means biomass can be processed to form solid, liquid or gaseous fuels. When biomass briquette is burned in the presence of air it reacts with oxygen (O) to form carbon dioxide (CO_2) which is released into the atmosphere. This means that if fully combusted the amount of carbon dioxide taken from the atmosphere during the growing stage is equal to the amount which is produced. Meaning that there is no net addition of CO_2 in the system and biomass can be regarded as a carbon sink. This is known as the carbon cycle or zero carbon emissions.

In nature, when biomass material is left on open ground over a period of time it will disintegrate and release carbon dioxide and pack energy slowly. Burning releases the energy packed in biomass quickly and most times in a useful way. On the other hand when fossil fuel is burnt it increases the net of CO_2 in atmosphere. By burning large portions of fossil fuels, it leads to release enormous quantities of CO_2 within a very short time of about 200 years (Saidur, 2011).

2.9 Literature on economic and social impacts of biomass briquettes

a. Local Benefits

Briquette production creates employment through a number of channels. Typically the briquetting process consists of the following series of steps:

1. Collection of biomass material to be compacted.
2. Preparation of material (drying, grinding etc.).
3. Densification of material.
4. Collection of end product, cooling and storing (Cosgrove *et al.*, 1985).

b. National Benefits

Use of locally sourced biomass material help to safeguard foreign exchange that would have been otherwise spent on imported fossil fuels. Industrial use of biomass briquettes will improve national energy security and the fulfillment of international obligations concerning the environmental protection and climate change.

c. Global Benefits

Globally the use of biomass fuels is a positive environmental action as is reduces the amount of greenhouse gases (GHG emissions) that could have been released to the atmosphere if fossil fuels were to be used. This however depends if the biomass material was sourced sustainably; biomass is regarded as a zero-emission fuel.

d. Economics of Briquette use

Even though governments, businesses and international organizations may promote biomass briquetting in the presence of environmental policies, favorable economics will keep such projects afloat and running (Demirbas, 2003; 2010). There are several types of agromass material that can be grown for the sole purpose of making fuels. In history, crops have been used as energy sources. However, there are two main considerations that one has to weigh when determining if a crop is suitable as a fuel source. The first one is the crop capacity to yield dry material in tons per hectare or per unit of land. A crop that yields high volumes of material is economical as it minimizes the size of land required. Secondly, the net amount of energy used to produce the crop, the crop should not consume more energy it can be garnered from it. Usually, fossil fuels costs more getting energy from it when compared to biomass fuels. Biomass material is not only a formidable potential source of fuel but economically it makes a lot of sense when compared to other sources of renewable (Demirbas, 2005; 2010).

Biomass has many applications that have numerous economic advantages such as: reduction of use of hydrocarbons, reduction of overdependence on fossil fuel imports, reduced production of greenhouse gases from the use of hydrocarbon fuels, increased usage of forest and agricultural wastes, use of fallow land, and reduction of waste disposal (Spliethoff, 1998; Hein, 1998; Demirbas, 2010).

When biomass material has to be ferried over long distances for boiler use, it can prove to be expensive when compared with fossil fuels. Because of these economics, boiler conversion from fossil fuel to briquette fired will be unfeasible. If the point of use of biomass briquette is close to the source, and the volume justifies the costs incurred in handling and transporting the said briquettes, and when compared to fossil fuel it is still the cheaper fuel then such a situation permits the usage of briquettes.

It is complex to analyse the economics of co-firing biomass briquettes with fuel oil in boilers. Several parameters must be considered during the evaluation process. First, the cost of biomass fuel to the user is of key importance, it is usually the basis of analysis when considering whether to put up a briquetting plant; the economics must make sense and especially if it is expected that high ratios of biomass briquettes are to be used. Biomass briquettes prices can either be favorable or unfavorable when viewed in a wide price spectrum. Secondly, recurrent costs for operating and maintaining technologies used to manufacture, store or burn the fuel affect the efficiency of the fuel and at a macro level the boiler/plant performance. The matrices involved in projecting the overall cost can be complex depending with the nature of raw materials and the fuels produced (Demirbas, 2003; 2010).

e. Briquette Vs Wood fuel

Briquette fuel is a product of a chain of activities that require labour for growing crops, harvesting, collection of wastes, manufacturing, transporting and retailing the product. The biggest markets for industrial briquettes are generally factories and large establishments that have boilers normally located in towns and cities. Briquettes manufactured for domestic use is increasingly picking up in villages and in slum areas where cook stove and charcoal is traded. The cost of briquette is largely determined by operational cost such as, raw materials, labour, energy cost and transport, environmental costs doesn't reflect is such kind of analysis. In Malaysia palm biomass has been used to manufacture briquettes creating job opportunities ensuring social sustainability. Briquette manufacturing is labour intensive and therefore relatively expensive especially when energy crops have to be cultivated (Shuit *et al*., 2009). On the other hand, wood fuel is perceived to be abundant and still accounts for about ten percent of income for rural households, and about forty percent of their cash earnings. For poor households wood fuels is a safety net as they cannot afford the rigorous process required to produce briquettes for sale to industrial establishments.

Wood fuels serve over 2 billion people globally, used as fuel in industries and at domestic level (Saidur *et al.*, 2011). Prices of wood fuels vary, depending on markets. Some wood fuel markets up to 70% is not monetarized. Shortage of wood fuels create an upsurge of prices and the poor unemployed and landless people suffer the most as access to wood fuel favor factories and big establishments (www.nyserda.org; 2016).

2.10 Environmental effects of biomass briquettes

Biomass wastes extracted from Municipal Solid Waste (MSW) landfills contain toxic compounds that when burned may cause a number of health problems. Such biomass wastes when used to manufacture briquettes may contain: chlorine gas, heavy metals and organic compounds such as dioxins which are the most toxic chemicals known to science (Saidur *et al*., 2011).

Pollutants

Pollutants can be classified into two major classes:

1. Unburnt pollutants and

2. Pollutants that are produced by combustion.

The unburnt pollutant include: char particles, carbon monoxide (CO), hydrocarbon gas (HC), tar, polycyclic aromatic hydrocarbons (PAH), compounds of carbon (Cx) and compounds of hydrogen (Hy). These pollutants are normally as a result of poor combustion precipitated by low temperatures caused by insufficient mixing of fuel with air and a shortened combustion window. Unburnt pollutants are expected in all types of fuels depending on the firing system and the design of the furnace. Emissions of such kind of pollutants can be minimized by increasing burning efficiency (Khan *et al*., 2008).

The second category includes emissions that are not as a result of incomplete combustion. The pollutants include: nitrogen, Sulphur and ash. These pollutants are normally part of the biomass fuel and are generated during combustion. Specifically these pollutants include: oxides of Sulphur (SO_X and SO_2), oxides of nitrogen (NO, NO_X, N_2O and NO_2), particulate matter, heavy metals (embedded within fine ash or in gases emitted) and gaseous acidic emissions may also be emitted such as HCl. The chemical nature of gases formed in the atmosphere may be shaped by air-fuel stoichiometry and other combustion techniques /parameters Heavy metals are present in painted or treated woods mostly found in cities or briquettes produced from municipal solid wastes. (Khan *et al.,* 2008).

Ash is the incombustible residue left after complete combustion of biomass material; it is inorganic in nature and contains the bulk of the mineral elements found in the original biomass material (Khan *et al.,* 2008). Ash disposal has always been a major problem with briquette use in boiler operation. Of significance importance is volatile ash that when not well guarded will be emitted to the atmosphere.

2.11 Research gaps

In Kenya, there is considerable amount of research work on briquettes in relation to climate issues, (for example, Mugo *et al.,* (2010); Mutea, (2015); Mbura (2013) to mention but a few. However, we cannot say there is ample scientific knowledge available on industrial use of biomass briquettes and particularly in relation to fuel oil in boiler operations. Specifically most of the studies on briquettes in Kenya have tackled briquettes with additives of charcoal dust which are high concentrates of carbon.

It should also be noted that most briquette development and use studies in Kenya have concentrated on impacts at household level (for instance, Gatama, 2010). Besides, these studies have concentrated on small scale production and mostly focus on rural households and slum dwellers.

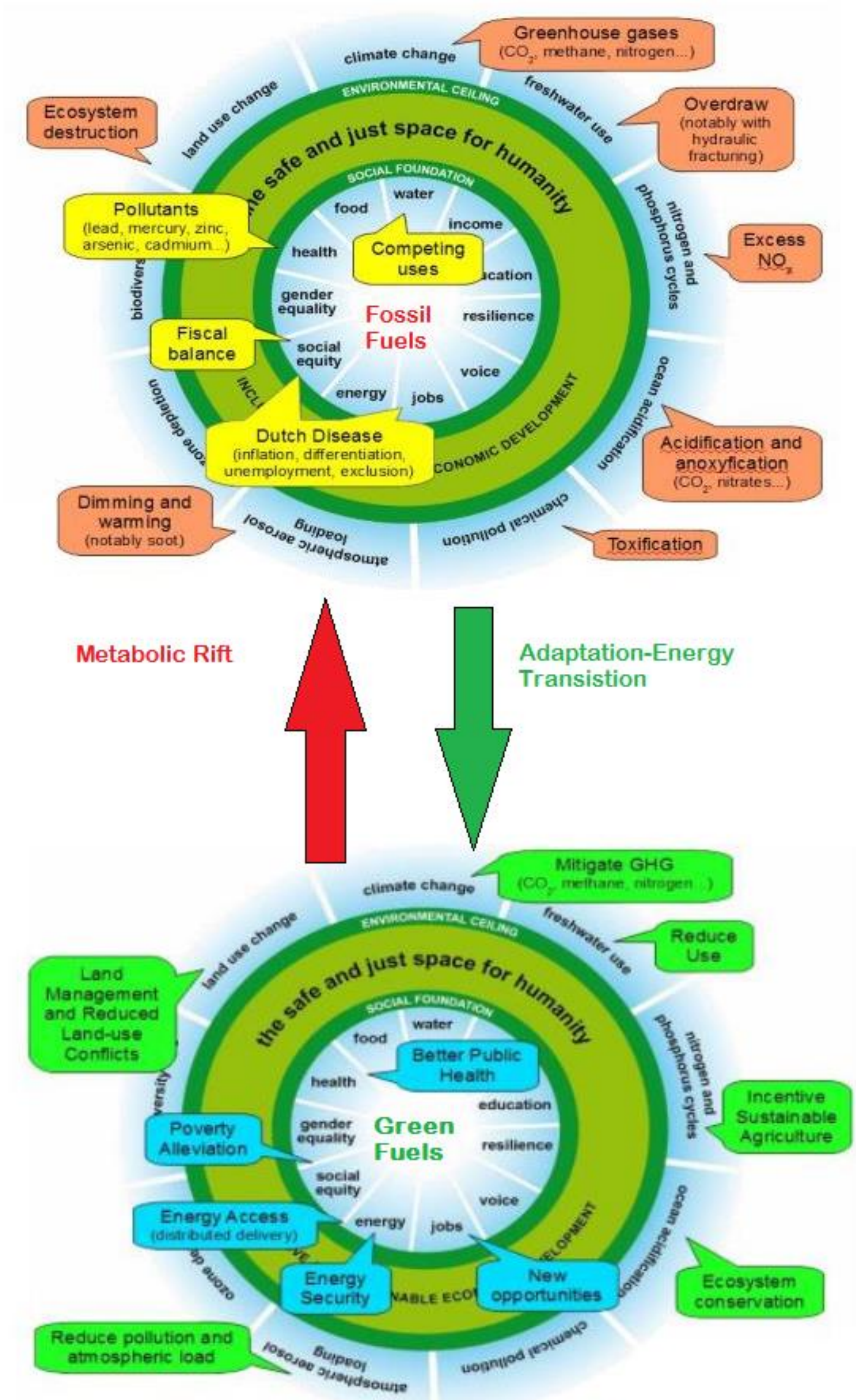
This study will therefore try to fill in this knowledge gap and will help Kenya implement effective and acceptable climate change adaptation measures with respect to energy fuels for industrial use.

2.12 The Theoretical Framework

The theoretical framework for this study is a summary of the relationship between adoption of biomass briquette use and its resultant effects on socio-economic and environmental dynamics as explained by Marx's theory of metabolic rift. In 2005 Clark observed that other than the theory serving as approach for conceptualizing relationships, it also provides the basis for processing the empirical reality of the nature-society relationship. Clark further noted that metabolism as used by ecologists and environmental sociologists denotes the relationship and exchanges within and between nature and humans (Chelsea, 2014).

According to Foster (2000) Metabolism most fundamentally expresses the notion of material exchange. The use of the word metabolism in the biological sciences, according to Frederick Engels, refers to "the organic exchange of matter. The exchanges have an impact on the social, economic and environmental conditions of an ecosystem" (Philip, 2008).

The metabolic rift arises when fossil fuels rather than green fuels are used in running industrial processes significantly bringing about negative impacts on the environment such as global warming. Such scenarios express a planetary metabolic rift where the natural processes of sequestration of carbon are interrupted (Philip, 2008).



Adapted and modified from UNOSD, 2015.

Figure 2-2 Theoretical Framework

2.13 The Conceptual Framework

Sustainable development is a result among others of green energy development achieved through technological advancement in briquette production and use. Biomass briquette use is a sustainable path that contributes to sustainable development i.e., environmental, economic and social. A model was developed to conceptualize how the change from the use of fuel oil to biomass briquettes impacts the environment. Figure 2-5 shows a schematic diagram of the conceptual framework adopted in this study.

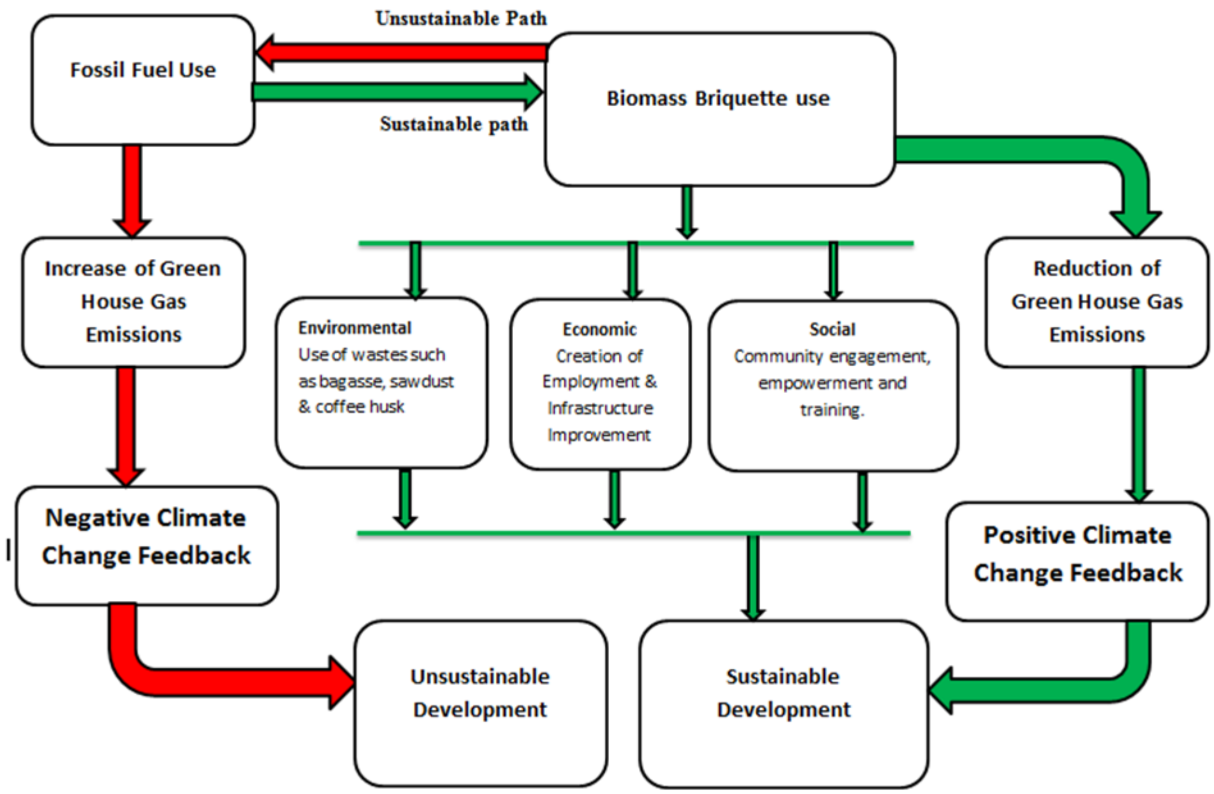


Figure 2-3 Conceptual framework adopted and modified from Nyaboke 2014

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter examined the research methods /approaches adopted in sourcing data in order to achieve the study objectives and answer the research questions. The chapter contains the study area, study design, definition of the target population, sample size, sampling techniques, data collection technique/tools and analysis methods.

3.2 The Study Area

The study was conducted in Kenya and focused on four counties namely: Kisumu County, Nairobi County, Kiambu County and Meru County. Briquette manufacturing was taking place in Kisumu County while the use of briquettes was in the counties of Nairobi, Kiambu and Meru. These locations were chosen for the study because they were reflective of what the study was about. Kenya is an East African country that borders Somalia to the North East, Ethiopia to the North, South Sudan to the North West, Uganda to the West, Tanzania to the South and Indian Ocean along the South Eastern border. The country lies along the equator and between Latitude 4° North to 4° South and Longitude 34° East to 41° East. It covers a total land area of about 582,650km^2 with its waters both inland and marine waters representing 2.3% (Kenya Ministry of Devolution and Planning 2013).

3.2.1 **Demography**

According to the 2009 population census, Kenya had a population of 38.6 million with a projected population of 46.6 million in 2016. The expected annual growth rate was 2.97% and a life expectancy of 66 years at birth. The country's population is fairly a young with those below 14 years representing 43% and those below 25years representing 62%. Agriculture is still the largest employer absorbing about 60% of the population both directly and indirectly (KNBS 2013).

3.2.2 **Environment**

Kenya is regarded as water scarce country with about 80% of her land area classified as arid and semi-arid and thus largely unfavourable for rain fed agriculture. The main economic activities in Kenya are tourism, agriculture and services industry. Kenya's climate ranges from tropical to temperate largely depending on the altitude (FAO, 2005).

3.2.3 **Agro-residues for Briquette Production in Kenya**

Agricultural residues in Kenya constitute a major part of the total annual production of biomass residues and are an important source of energy, both for domestic as well as industrial purposes. Little amount of residues are used as fuel, but a large amount is burnt and dumped in the field. There is a variety of biomass materials available in Kenya for briquette use and it includes: Sugar cane tops and Bagasse, majorly found in the former Western, Nyanza and Coast provinces. Maize husk, Maize cobs, Maize stalks, barley straws and wheat straws are majorly found in the former Rift Valley province which produces more than half of the country's output. Millet, sorghum and cassava stalks predominantly and traditionally grown in the former Eastern, Western, and Nyanza provinces. Coffee husk is found in the major coffee-growing regions such as the Aberdare Ranges, Kisii, Nyanza, Bungoma, Nakuru, Kericho and to a smaller scale in Machakos and Taita hills. Rice is mainly grown in Mwea, Ahero, Bunyala, West Kano and Yala Swamp (Kimutai S. K *et al.*, 2014).

3.2.4 **Muhoroni Sub-County**

The area under study where briquette production takes place is Muhoroni Sub-County in Kisumu County. The Sub-County lies between 34.75 degrees E and 34.764E longitude; while its latitude is between -0.079S degrees and 0.723S degrees. It borders Tinderet Sub County to the north, Kericho County to the North East, Nyakach Sub County to the South East, and Kisumu East Sub County to the South.

The area has a population size of 268,909, with 124,760 males and 144,149 females; with a land area of 319 km^2. The main commercial activity in the area is sugar cane farming. The mean temperature ranges from a minimum of 20^oC to a maximum of 35^oC, with an annual average of 23°C. Annual rainfall ranges between 1200mm and 1,300mm per annum (Akinyi, 2015).

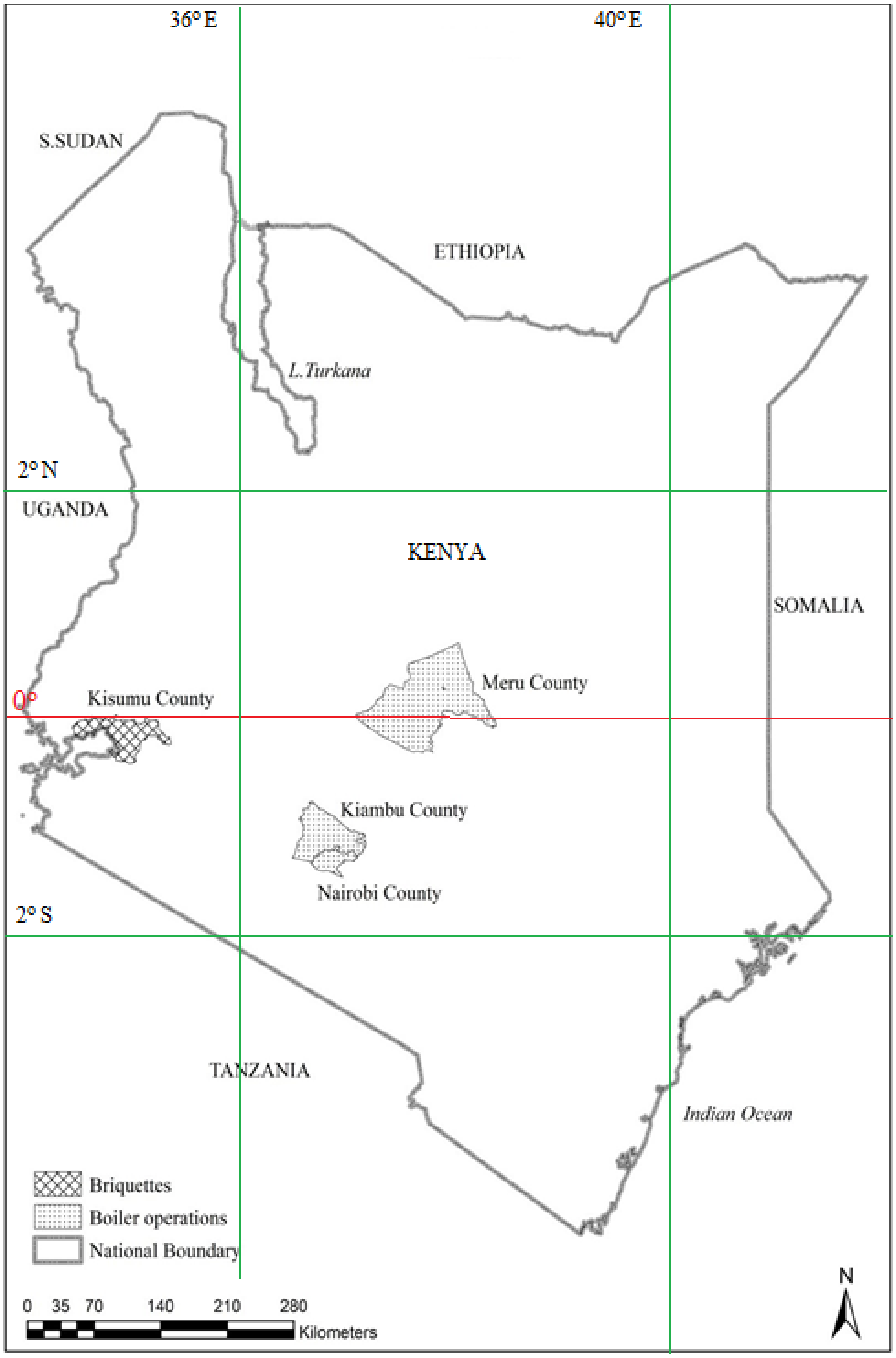


Figure 3-4 illustrates the map of Kenya showing Counties where the research data was collected

Source: Researcher (2016)

Figure 3-5 illustrates the map of Muhoroni Sub-County

Source: Researcher (2016)

3.3 Research Design

The study employed both quantitative and qualitative research designs. Field surveys and statistical analyses were used which enabled collection of relevant data for testing the research hypothesis. Field surveys and in-depth interviews were helpful in defining and developing approaches to the problems.

Statistical analyses were used as they are conclusive on their purpose to quantify the problems and understand how prevalent they are by looking for projectable results to the larger population. The study targeted various stakeholders including a briquette manufacturer, residents living around the briquetting plant and factories using briquettes to run their boilers.

3.4 Study population

The universe was defined as all biomass briquette manufacturers for industrial use and fossil fuel boiler operators in Kenya.

3.5 Accessible population

The study targeted community residents of Muhoroni sub-county in Kisumu County where Lean Energy Solutions Limited briquetting plant is located. For purposes of carrying out meaningful analysis, it was found necessary to identify boiler operators in various sectors. This categorization looked at most of the similar functions or operational actions within factories. The researcher felt that an analysis per sector would allow better and meaningful analysis and valid findings. The boilers under research were identified and grouped into five categories as follows:

i. Knitting and Cloth Making Factories
ii. Dairy Processing Factories
iii. Soft Drink Manufacturing Factories
iv. Edible oil Products Manufacturing Factories
v. Hotels

Table 3-1 List of boiler operators interviewed in the counties of Nairobi, Kiambu and Meru

County	Factories Interviewed
Nairobi	Pepsi Cola (EA) Limited, White Marble Enterprises Ltd, Glaciers Products Ltd, Dawa Ltd, Sameer Agriculture & Livestock Limited (Daima), PZ Cussons, East African Breweries Ltd, East African Paper Mills, Synresins Limited, Patco Industries Limited, Edible Oils Limited, Unilever Kenya Ltd, Kenafric Industries Limited, United Aryan Epz Ltd, Loreal East Africa, The Wrigley Co (East Africa) Ltd, Dodhia Packaging Ltd, Golden Africa, Malachite Ltd, Kates Bakers, Sigma Feeds.(21)
Kiambu	Bata Kenya Ltd, Spinners & Spinners Ltd, Pascha Uplands Premium Dairies & Foods Ltd, TransAfrica Paper Mills, Kiambaa Dairy Farmers Co-operative Society Limited, Ndumberi Dairy Farmers Co-Operative Society Ltd, Kenafric Bakery Limited. Windsor Hotel.(7)

Meru	Meru Dairy Co-operative Union Limited, Kiegoi Tea Factory Company Limited - KTDA. (2)

3.6 Sources of Data

The study used organizational reports from Government of Kenya, county governments, International organization reports; sector associations, management authorities such as National Environmental Management Authority, institutions such as Kenya Agricultural & Livestock Research Organization and desktop study.

Field questionnaires and interviews supplemented with observations and photography were the primary sources of data. Questionnaires had both open and closed ended questions. Respondents were asked to provide demographical data on sex, age, and level of education. For the interview, the interviewee was guided by questions.

Laboratory results were used after conducting proximate analysis to measure: the ash content; the moisture content, the percentage of volatile matter and fixed carbon was measured.

3.7 Methods of Data collection

Methods of data collection increase the interpretability and reliability of the study, and strengthen the statistical analysis of the study.

Secondary sources of data included: Library, desktop and government records among other published works.

The primary sources of data used included: Laboratory reports, Questionnaires and Interviews

3.7.1 **Questionnaires**

The questionnaires were developed after considering the variables of the study to ensure that they captured the intended objectives of the study. Therefore there were both closed and open ended questions so as to give respondents freedom to describe some issues in details as well as restrict them in some areas.

3.7.2 **Interviews**

Interviews with both structured and semi-structured formats were conducted by the researcher in order to obtain as much information as possible. Observation was also employed to read the behaviour of the respondents.

3.7.3 **Laboratory Analysis**

Proximate analysis of biomass briquettes.

Proximate Analysis is a laboratory procedure that establishes the percentage of the main components of a fuel. This was carried out to establish the average percentage of volatile matter content, percentage of moisture content, percentage of fixed carbon and percentage of ash content.

a. *Percentage volatile matter*

The percentage of volatile matter (PVM) was determined using a sample of 2 grams of material that was cut from the briquette sample and placed in a crucible then was heat in an oven until a constant weight was achieved. The sample was then heated further in a furnace for 10 minutes at 550^{o}C and weighed after cooling in a desiccator. The PVM was then calculated using the Equation below:

$$\text{PVM} = \frac{A-B}{A} \times 100 \qquad \text{[Equation 1]}$$

Source: Efomah *et al* 2015.

Where A was the weight of the sample after being dried in the oven and B was the weight of the sample after being heated 550°C for 10 minutes in the furnace.

b. *Percentage ash content*

The percentage of ash content (PAC) was determined using a sample of 2 grams of material that was cut from the briquette sample and for 4 hours it was placed in a furnace at 550^{o}C and was after cooling in a dessicator to obtain the weight of ash (C).

The PAC was determined using the Equation below:

$$PAC = \frac{C}{A} \times 100 \qquad \text{[Equation 2]}$$

Source: Efomah *et al.*, 2015.

c. Percentage moisture content

The percentage moisture content (PMC) was determined using a sample of 2 grams of material (E) that was cut from the briquette sample and was oved dried at 105°C until a constant weight was achieved. The sample was further dried for 60 minutes and the change in weight measured (D) and was then used to determine the sample's PMC using the Equation below:

$$PMC = \frac{D}{E} X100 \qquad \text{[Equation 3]}$$

Source: Efomah *et al.*, 2015.

d. Percentage fixed carbon

The percentage fixed carbon (PFC) was determined by subtracting the sum of PVM and PAC from 100 as shown in the Equation below:

Fixed Carbon= 100%- (PAC+ PVM) [Equation 4]

This procedure was adopted from Efomah *et al.*, 2015.

3.8 Sample size and sampling technique

Both probability and non-probability sampling methods were used in selecting the samples. Since there was no available documented data on the number of briquetting companies and boiler operators using briquettes in Kenya non-probability sampling was used to identify the case sample. Probability sampling was used to identify respondents in Muhoroni Sub-County.

3.8.1 **Non-probability Sampling**

Judgmental sampling or Purposive sampling

The briquetting plant and boiler operators were selected based on particular characteristics that were of interest to the researcher such as high production capacity of biomass briquettes and existing boiler operations. The purposive sampling technique employed was heterogeneous sampling where data captures a wide range of perspectives relating to the focus of the study. The basic principle behind purposive sampling is to gain greater insights into a phenomenon by looking at it from all angles (Creswell, 2009).

3.8.2 **Probability Sampling**

Systematic Sampling

In identifying the respondents in Muhoroni sub-county for social, economic and environmental impacts systematic sampling was used. The sampling frame for the purpose of this study was all households within Muhoroni sub-County. Equal proportions stratified sampling technique was employed (Israel, 1992).

The sample size was determined scientifically by the formula:-

$$n = \frac{N}{(1+Ne^2} \qquad \text{[Equation 5]}$$

Source: Israel, 1992

Where

n= desired sample size for the study area

N=total no. of house-holds in the study area

e=desired margin error

Thus $n=53781/(1+53781*0.05^2)$

n=398

Due to financial and logistical constraints 20% of the sample size was used in this research study. The study therefore utilized a sample size of 80 households.

.Simple Random Sampling

A briquette sample for proximate analysis was drawn from a tone of briquettes which contained a finite number of N units. These units were distinguished from one another; the number of distinct samples of size n that was drawn from N units was given by the combinatorial formula.

$$NC_n = \frac{N!}{((n!)X((N-n)!))} \qquad \text{[Equation 6]}$$

Source: Israel, 1992

3.9 Data Analysis and Presentation

The data collected was edited where necessary and analysed using Excel worksheets and presented in tables by frequency, percentages, and graphs. Proximate analysis was also done and presented in a table and a graph.

Proximate Analysis was used to determine the percentage of volatile matter, moisture content, fixed Carbon and ash content. Data that was obtained from semi-structured questions was coded, numbered and classified under each variable for easy identification and then summarised in answer summary sheet. Similarly, responses from unstructured questions on opinion testing was recorded in a separate sheet and organised in themes. Mugenda & Mugenda (1999) observed that statistical computation in descriptive statistics includes: frequencies, percentages, means, standard deviation, variances and these were used in this study.

3.9.1 **Measures of Relationship**

Two methods of determining the relationship between variables were used.

(i) Simple Regression Analysis was used to formulate a mathematical model for purposes of predicting values of dependent variable and

(ii) Karl Pearson's coefficient of correlation analysis was used to measure the strength of the relationship between independent variable and dependent variable.

a) Simple Regression Analysis

Simple regression analysis was used to describe the relationship between cost of fuel the independent variable and tonnes of briquette used the dependent variable. Regression analysis can only explain a physical relationship between two variables; how *X* the independent variable affects the dependent variable *Y*. The basic relationship between the two variables *X* and *Y* is given by

$$Y=a+Bx \qquad \text{[Equation 7]}$$

Where the symbol *Y* denotes the estimated value of *Y* for a given value of *X*. This equation is known as the regression equation of *Y* on *X* which means that each unit change in *X* produces a change of *b* in *Y*, which is positive for direct and negative for inverse relationships (Kothari C.R, 2004).

b) Karl Pearson's coefficient of correlation analysis

Karl Pearson's coefficient of correlation analysis was used to determine the statistical relationship between the cost of fuel oil and the consumption of briquettes in a period of five years. According to Kothari (2004) in Karl Pearson's coefficient of correlation analysis, there are only two variables, one variable (defined as independent) is the cause of the behaviour of another one (defined as dependent variable). In other terms, Pearson correlation coefficient is a measure of strength of a linear association between two variables and is denoted by *r*. The "*r*" can take a range of values from -1 to +1. A value less than 0 indicates there is no association between variables while a value greater than 0 indicates a positive association on the other hand a value less than 0 indicates a negative association.

This coefficient assumes the following:

i. That there is linear relationship between the two variables;
ii. That the two variables are casually related which means that one of the variables is independent and the other one is dependent; and
iii. A large number of independent causes are operating in both variables so as to produce a normal distribution.

Karl Pearson's coefficient of correlation can be worked using the below equation.

$$r=\frac{\Sigma(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\Sigma(x_i-\bar{x})^2}\sqrt{(y_i-\bar{y})^2}} \qquad \text{[Equation 8]}$$

<u>Key</u>

X: X Values

Y: Y Values

M_x: Mean of X Values

M_y: Mean of Y Values

$X - M_x$ & $Y - M_y$: Deviation scores

$(X - M_x)^2$ & $(Y - M_y)^2$: Deviation Squared

$(X - M_x)(Y - M_y)$: Product of Deviation Scores

Source: Kothari (2004)

3.10 Hypothesis Testing

Two statistical methods were used to test the formulated hypotheses:

- Chi-Square and
- Z-Test

3.10.1 **Chi-square**

Chi square test was used to test the null hypotheses because the data met the required conditions for the chi square test. Chi-square is a statistical technique which attempts to establish a relationship between two variables which are categorical in nature. The chi- square tests the difference between what is observed and what is expected. Observed frequencies consist of counts within categories obtained from a sample. Expected frequencies are counts obtained from past proportions. The past proportions are proportions expected to find in the sample data. Chi – square compares the proportion observed in each of the categories under study with what would be expected assuming independence between two variables. If the calculated chi – square value is greater than the critical chi -square value, the null hypothesis is rejected.

The chi- square contingency table test is a hypothesis test applied to a table with at least two rows and two columns of data in the form of counts or observed frequencies (Kothari C.R 2004). The contingency table Chi square test is also used when it is necessary to determine if two variables are independent or dependent. Put another way, this test is used to determine if two variables are related or not related. Level of significance of a test as defined by Kothari C.R (2004) is the chance one is willing to take in making a wrong decision in believing the alternative hypothesis. It is also defined as the risk one is willing to take in rejecting the correct hypothesis. It is denoted by alpha

(a). Common alpha levels are 0.01 (1 %), 0.05(5%) and 0.10 (10%).

Level of significance that was used in this case was 5% or 0.05/ 95 % confidence level

The degree of freedom was worked out using the formula:

Degree of freedom = (rows-1) (columns-1) = (2-1) (3-1) =2

Using the critical values of chi-square table, the critical chi square reading at 0.05 level of confidence and two degrees of freedom was 5.99147 expressed as,

$$X^2 \text{ critical} = X^2\ 0.05, 2 = 5.99147$$

It was necessary to determine the expected values and these were determined using the formula applied in the case of a chi square contingency table which is

$$\text{Expected value} = \frac{(\text{row total})(\text{column total})}{\text{Sample size}}$$

The total of the observed and the expected frequencies must be the same and equal to the size of n.

The expected numbers are always calculated to 2 decimal places and never rounded because

$$n(O) = n(E).$$

The chi square was calculated using the formula:

$$X^2 = \sum \frac{O-E^2}{E} \qquad \text{[Equation 9]}$$

Source: Kothari C.R (2004)

Where:

O was the observed values

E was the expected values

3.10.2 **Z-Test**

Single-Group Statistical Tests with a Binary Dependent Variable

Z-test was used to test hypothesis. In a simple statistical test that is analogous to the single sample z-test is used to investigate whether there are significantly more "yes" than "no" responses. The statistical test investigates whether there are significantly more "yes" than "no" responses.

This is called the *z-test for the difference between two proportions*. The formula is as below:

$$Z = \frac{P-\pi}{\sqrt{\pi}(1-\pi)n} \qquad \text{[Equation 10]}$$

In the formula, *p* is the proportion of the sample choosing one of the options in the survey (e.g., "yes"), π is the null hypothesis value (i.e., the proportion expected if there is no difference between "yes" and "no"), and *n* is the sample size. The formula parallels the single-group t-test, because the denominator (bottom portion) is a standard error, which we could call S_X

$$Z = \frac{P-\pi}{S_X} \qquad \text{[Equation 11]}$$

Where $S_X=\sqrt{\pi}(1-\pi)n$ for the standard error. (Adam M., *et al* 2006).

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

The purpose of this chapter is to present results of responses obtained from various participants in the research project. The results are based on the data collected between May 2015 and January 2016. Data was collected from community members residing in Muhoroni Sub-county where a briquette manufacturing is located, and from boiler operators spread in four counties namely: Nairobi, Kisumu, Kiambu and Meru where briquettes were used. Results presented here include; the social-economic benefits accrued from the production of biomass fuel briquettes, potential environmental impacts in the production of biomass fuel briquettes, determination of how the cost of fossil fuel influences the adoption of biomass briquettes and proportions of volatile matter, moisture content, ash content and fixed carbon in biomass fuel briquettes. Different approaches were used to present the findings, which include use of charts, graphs, and tables for descriptive analysis.

4.2 Response Rate

The research was conducted on a sample of 110 respondents in two sets, 80 of which were household residents of Muhoroni Sub-County and 30 from factories where briquettes were consumed. However, out of the 80 questionnaires issued to respondents in Muhoroni sub-county only 66 were returned duly filled, making a response rate of 82.5%, which was sufficient for statistical reporting. There was a 100% response rate from the 30 respondents in factories spread across the counties of Nairobi, Kiambu and Meru. An interview was also conducted with the staff of Lean Energy Solutions Limited, a key informant. The respondents were able to participate and provide useful information that was easier to interpret and analyse. Based on the response rate, the researcher commenced the process of data analysis. The following sections present findings as arranged on the research instrument.

4.3 Results from Community Members of Muhoroni Sub-County

4.3.1 Gender of the Respondents

The study sought to ascertain the information on the respondents involved in the study concerning the gender and education level. From the findings, majority of the respondents 65.15% were female and 34.85% were male. The implication of this finding is that the high representation of female respondents brings in gender related biases on results touching on environmental impacts of briquette production as well as in the determination of social-economic benefits accruing from production of biomass fuel briquettes.

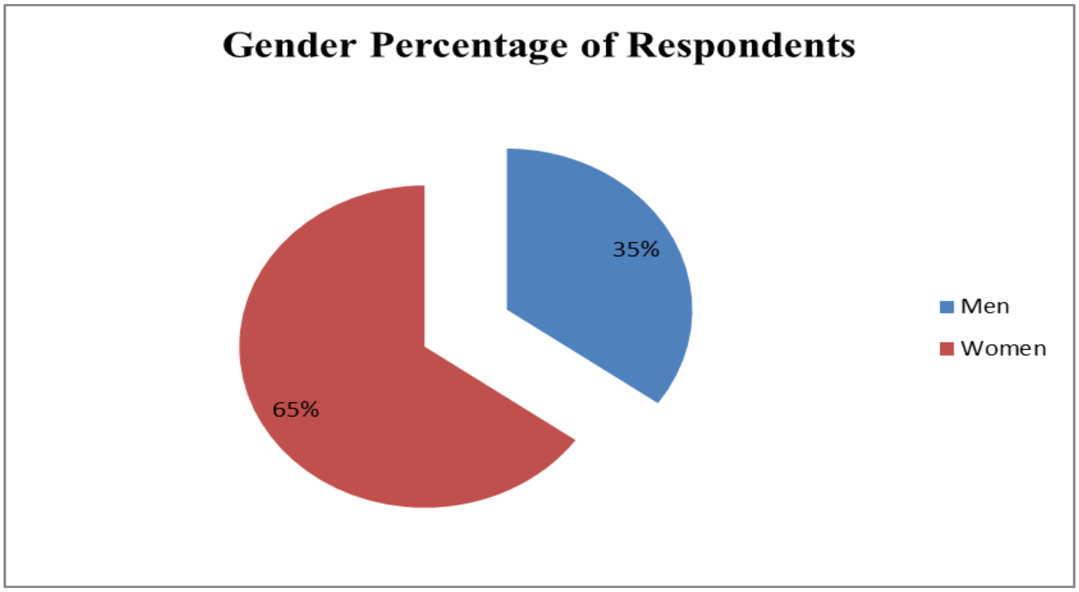


Figure 4-6 Percentages of respondents by Gender

Source: Field data (2016)

4.3.2 **Respondents' Educational Level**

The respondents were requested to indicate their level of academic qualification. Figure 4-9 illustrates the study findings.

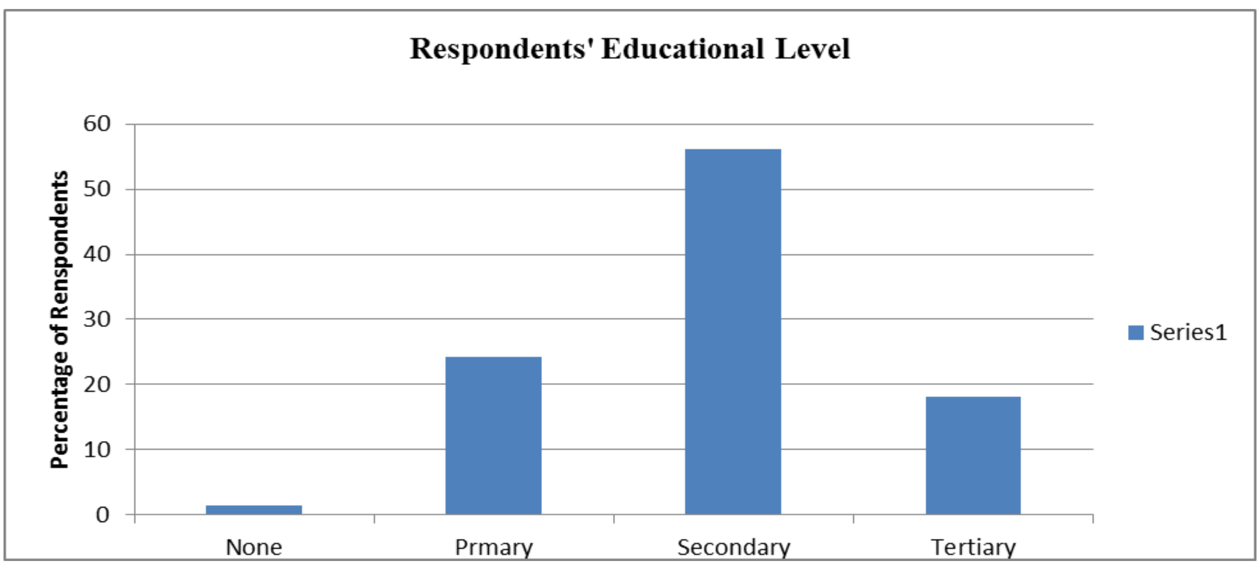


Figure 4-7 Respondents Education Level

Source: Field data (2016)

The study found that respondents who had acquired secondary education composed 56% and those with primary levels of education composed 24%. They were followed by those who had tertiary level education at 18% while 1.5% had no education at all. The high literacy levels imply that majority of the respondents had substantial academic education which enabled them to interpret the impacts of biomass briquette production in Muhoroni Sub-County Kenya; the social, economic and environmental effects it had.

4.4 Environmental Impacts of Briquette production

The respondents were requested to indicate the level of environmental impact caused by the production process of biomass briquettes and the result is as presented in table 4-1**.**

Table 4-2 Environmental effects of Briquette production

	Dumping of Biomass	Noise	Water Use	Land Use	Percentage (%)
Strongly Agree	5	0	0	2	
Agree	6	2	0	11	
Average	9	6	3	26	
Disagree	65	71	80	59	
Strongly Disagree	15	21	17	3	

Source: Field data (2016)

From the study majority of the respondents, 65 percent disagreed that production of briquette resulted in dumping of waste in the environment only 5 percent indicated that they strongly agreed that briquette production resulted in dumping of waste in the environment.

On the effect of noise pollution, majority of the respondents, 71 percent disagreed that biomass briquette production produced noise in the surrounding area. None (Zero percent) strongly agreed, only 2 percent agreed that noise was heard during briquetting.

On water use, 80 percent of the respondents disagreed and 17 percent strongly disagreed that briquette production was putting a strain on water resources in the location. No respondent agreed that briquette production was putting a strain on water resources in their locality. Only 3 percent of the respondents indicated on average that briquette production was putting a strain on water resources.

On Land use, 59 percent of the respondents disagreed and a further 3 percent strongly disagreed that briquette production was putting a strain on water resources in the location. On the other hand 2 percent of the respondents strongly agreed and a further 11 percent of the respondent agreed that briquette production was putting a strain on land resources in their locality. Only 3 percent of the respondents indicated average that briquette production was putting a strain on water resources.

The results imply that production of biomass briquettes relatively do not negatively affect the environment though it has a significant effect on land use. Through key informants and researchers' assessment, land in briquette production is used mainly for sun drying raw materials such as sawdust and bagasse. In general the results confirm that briquette production has positive impact to the environment especially by utilizing waste agromass material.

In a project document written by UNFCC (2012) it was noted that production of briquettes has a positive impact on resource conservation and that such projects utilize biomass wastes that could have been dumped. The document further noted that briquetting prevents solid waste disposal and in turn prevents the release of methane gas generated through anaerobic decomposition of biomass waste this means that briquette manufacturing will not generate any solid waste that would require disposal. Manoj (2015) noted that the use of biomass wastes such as sawdust that has been densified by converting sawdust into briquettes generally has beneficial effects to the environment.

4.5 Climatic Impacts on Biomass Briquette Production

To further understand biomass briquette production, views were sought on the extent to which climatic impacts affect briquette production and transportation. The result is as presented in table 4-2.

Table 4-3 Climatic Impacts on Biomass Briquette Production

	Strongly Agree	Agree	Average	Disagree	Strongly Disagree	Percentage %
Drought	21	24	30	15	9	
Water Scarcity	29	24	17	20	11	
Flooding	38	26	20	8	9	
Rain	12	35	20	18	15	

Source: Field data (2016)

Majority of the respondents, 30 percent affirmed that on average drought had an impact on biomass briquette production. 21 percent strongly agreed and a further 24 percent agreed that drought had an impact on biomass briquette production. 9 percent strongly disagreed while 15 percent disagreed that drought had an impact on biomass briquette production.

On water scarcity, majority of the respondents, 29 percent strongly agreed and a further 24 percent affirmed that water scarcity had an impact on biomass briquette production. 11 percent strongly disagreed and 20 percent disagreed that water scarcity had an impact on biomass briquette production. 17 percent of the respondents indicated that on average water scarcity had a climatic impact on biomass briquette production.

On flooding, 38 percent of the respondents strongly agreed and a further 26 percent agreed that flooding had an impact on biomass briquette production. 9 percent strongly disagreed and 8 percent disagreed that flooding had an impact on biomass briquette production. 20 percent of the respondents indicated average on flooding as a climatic impact on biomass briquette production.

On rain as a climatic factor, 12 percent of the respondents strongly agreed and a further 35 percent affirmed that rain has an impact on biomass briquette production. 15 percent strongly disagreed and 18 percent disagreed that rain had an impact on biomass briquette production. 20 percent of the respondents indicated average on rain as a climatic impact on biomass briquette production.

It can be deduced from the data analysed that climatic aspects do affect production of biomass briquettes. Drought affected the availability of raw materials coming from Muhoroni Sugar factory as wastes such as bagasse reduced whenever farmers experienced poor crop yields. In addition, while rain and floods affected drying of raw materials, flooding was the biggest problem affecting briquette production. Employees at the briquetting factory explained that up to 80% of materials was being sun dried in open fields, therefore whenever the fields were filled with water or soaked, the materials would be washed away or too wet to make briquettes.

Plate1: Raw material for briquette production in Muhoroni Sub-County

Source: Field data (2016)

4.6 Socio-economic benefits of Biomass Briquette Production

Respondents were asked whether biomass briquette production had any socio-economic benefits to the surrounding community the result is as presented below.

Table 4-4 Socio-economic benefits of Biomass Briquette Production

	Strongly Agree	Agree	Average	Disagree	Strongly Disagree	Percentage %
Infrastructure Development	14	14	26	23	24	
Employment Creation	32	33	21	12	2	
Education	9	14	38	21	18	
Health	5	6	26	32	32	

Source: Field data (2016)

From the data collected and analysed majority of the respondents, 24 percent strongly disagreed and a further 23 percent disagreed that biomass briquette production resulted in infrastructural development; improved status of the roads and electricity distribution. Only 14 percent strongly agreed and another 14 percent agreed that biomass briquette production resulted in infrastructural development. However it was noted that the briquette factory had to increase the capacity of the grid transformer to meet its demands which improved the overall local electricity network.

On employment creation, majority of the respondents, 32 percent strongly agreed and a further 33 percent agreed that biomass briquette production was creating employment. Only 2 percent of the respondents strongly disagreed that biomass briquette production was creating employment. It was found that the briquette factory employed 15 people on permanent basis and 103 on casual basis majority coming from the surrounding area.

On education access, 38 percent of the respondents who were the majority on average indicated that biomass briquette production had resulted to an increase in education access. Only 9 percent strongly agreed that biomass briquette production had resulted to an increase in education access. However, the respondents noted that the briquetting company had donated books to a local school and was sponsoring two students in a local secondary school.

On health, majority of the respondents, 32 percent strongly disagreed and a further 32 percent of the respondents disagreed that biomass briquette production enhanced access to health facilities in the community. Only 5 strongly agreed and another 6 percent agreed that biomass briquettes had enhanced access to health facilities in the community.

From the responses received employment creation came out as the major socio-economic benefit felt by the residents of Muhoroni sub-county. This was explained in-depth by the plant manager of Lean Energy Solutions Ltd briquette factory who noted that more than 90% of their staff composed of the locals. Apart from employment, roads were maintained regularly by the factory especially during rainy seasons even though the main purpose was to ease transportation of briquettes. It was also noted that the community surrounding the manufacturing plant was organized in groups for purposes of collecting sawdust from the surrounding industries in order to sell to the briquette manufacturing plant.

The key informant further noted that biomass briquette manufacturing had a positive impact on social equity, poverty alleviation and that the project was in line with Kenya's government growth, poverty eradication and job creation strategy which were to aid in the development of local communities.

UNFCC (2012) noted that briquette manufacturing has a positive economic impact in an area where such a project is located. Briquetting contributes to a local economy by creating both direct and in-direct jobs and this is seen by the opportunities generated for technicians, semi-skilled & skilled workers, harvesters, labourers and transporters. Briquetting plants offer the local people an opportunity to collect forest and timber waste from the surrounding industries and sell this to the briquette manufacturing plant.

4.7 Boiler Operations

The data collected study sought to establish the level of adoption of biomass briquettes in boiler operations.

4.7.1 **Results on Respondents' choice of Briquette as the main source of fuel**

Boiler operators were asked whether they used biomass briquettes as their main source of fuel and the responses is as tabulated below.

Table 4-5 Respondents' Choice of Briquette as the main source of Fuel

Responses	**Frequency**	**Proportion %**
Yes	23	76.67%
No	7	23.33%
Totals	30	100%

Source: Field data (2016)

Table 4-4 shows that out of a total number of 30 boiler operations, 76.67 percent preferred to use briquettes as their main source of fuel. Only 23.33% preferred to use fossil fuel as their main source of fuel. The results were used to understand the level of adoption of biomass briquettes in boiler operations.

Plate 2: A Briquette fired boiler in operation at Meru Dairy Co-operative Ltd in Meru County

Source: Field data (2016)

4.7.2 **Impact of Cost of Fuel oil on Biomass Briquette Use**

The research wanted to establish whether cost of fuel influences the type of boiler to run the results is as presented below.

Table 4-6 Impact of Cost of Fuel oil on Boiler Operations

Choice of Boiler to Run	High Cost Of Fossil Fuel	Low Cost Of Fossil Fuel
Biomass Boiler	25	12
Fossil Fuel Boiler	5	18

Source: Field data (2016)

Table 4-5 shows that out of a total number of 30 boiler operators, 25 operators representing 83.33 percent prefer to run biomass boiler when the prices of fuel oil go up. Only 5 boiler operators representing 16.67 % percent indicated that they will still run their fossil fuel boilers. This was explained by the fact that an operator will require full time personnel to run a boiler and a logistics team to arrange for delivery of briquette fuel.

When the prices of fuel oil drop, 40 % of boiler operators indicated that they will continue to run their biomass boilers. Their reasons included environmental consciences and company reputation; they explained that having biomass boilers and making use of wastes to run them was well received by their clients. Secondly the implementation of environmental policy was part of their company/institutional mandate and lastly, it made economic sense to them to run biomass boilers in the long run. They argued that there were no big price shake ups in the pricing of biomass briquettes compared to that of fossil fuel, with fuel oil it was difficult for them to plan properly on their energy budget.

18 respondents representing 60 percent of the boiler operators stated that when the prices of fossil fuels go down they will revert back to fossil operated boilers. They explained that it was easier for them to switch to fossil operated boilers since they operated fossil fuel fired boilers whenever biomass boilers are under maintenance.

According to BTEC (2016) a number of reasons exacerbate price shocks and increased cost of fossil fuels such as carbon legislation, market demands for increased renewable energy portfolio standards, and the inherent supply/demand relationships of finite non-renewable resources, these factors makes biomass more resilient and retains a more stable fuel price.

Carbon Trust, (2009) noted that price volatility is a continuous problem for fossil fuels users; global and regional politics in oil and gas producing countries affect supply chain and may lead to unexpected price changes. On the other hand, price volatility of biomass fuels is less affected by international fossil fuel/commodity prices, and if there are any push factors they are less likely to be extreme compared to those influencing the price of fossil fuels. Furthermore, a change in price of biomass fuel is more predictable when biomass is sourced locally or from a known supplier. In addition, the price difference between biomass fuel and fossil fuel determines the scale of savings to be realized by adopting the former. The net cost of using biomass fuel is usually cheaper than using many of the different forms of fossil fuels used for heating.

The results therefore validate the notion that the cost of fossil fuel or economic considerations affects the adoption of biomass briquette more than any other factor such as environmental consciousness.

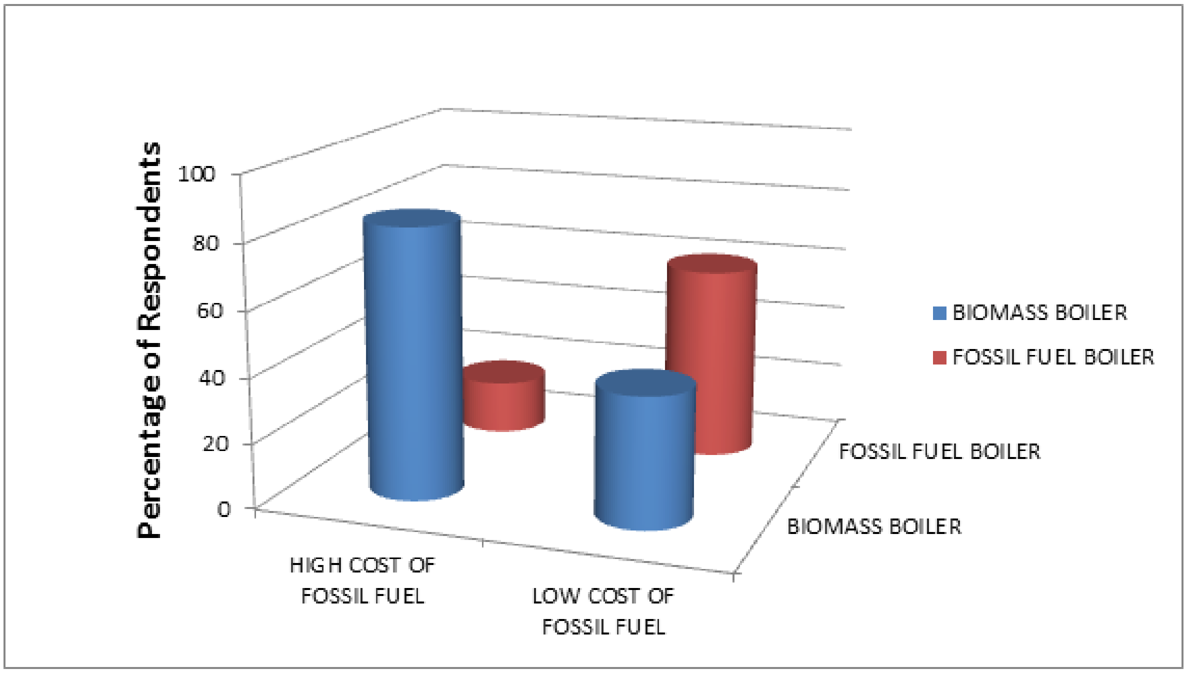


Figure 4-8 Impact of Cost of Fuel on Boiler Operation

Source: Field data (2016)

4.7.3 Measures of relationship between cost of fuel oil and tonnes of briquettes consumed

4.7.3.1 Simple Regression Analysis

In trying to understand the statistical relationship between briquette use and fossil fuel, simple regression was used. The cost of fuel oil defined as independent variable and tonnes of briquette consumed defined as the dependent variable. Regression only interprets what exists physically for instance there must be a physical way in which independent variable X can affect dependent variable Y.

Findings in Figure 1-21 indicate that the cost of fuel oil per liter strongly affects the use of biomass briquettes. Key informants explained that when the prices of fuel oil go down they at time switch off or scale down biomass boiler operations.

The equation Y=63.174x+1561.9 shows that the coefficient for cost of fuel oil per liter is 1,561.9 tonnes of briquettes. The coefficient indicates that for every additional 20 Kenya shillings in cost of fuel one should expect tonnes of briquettes consumed to increase by an average of 1,561.9 tonnes.

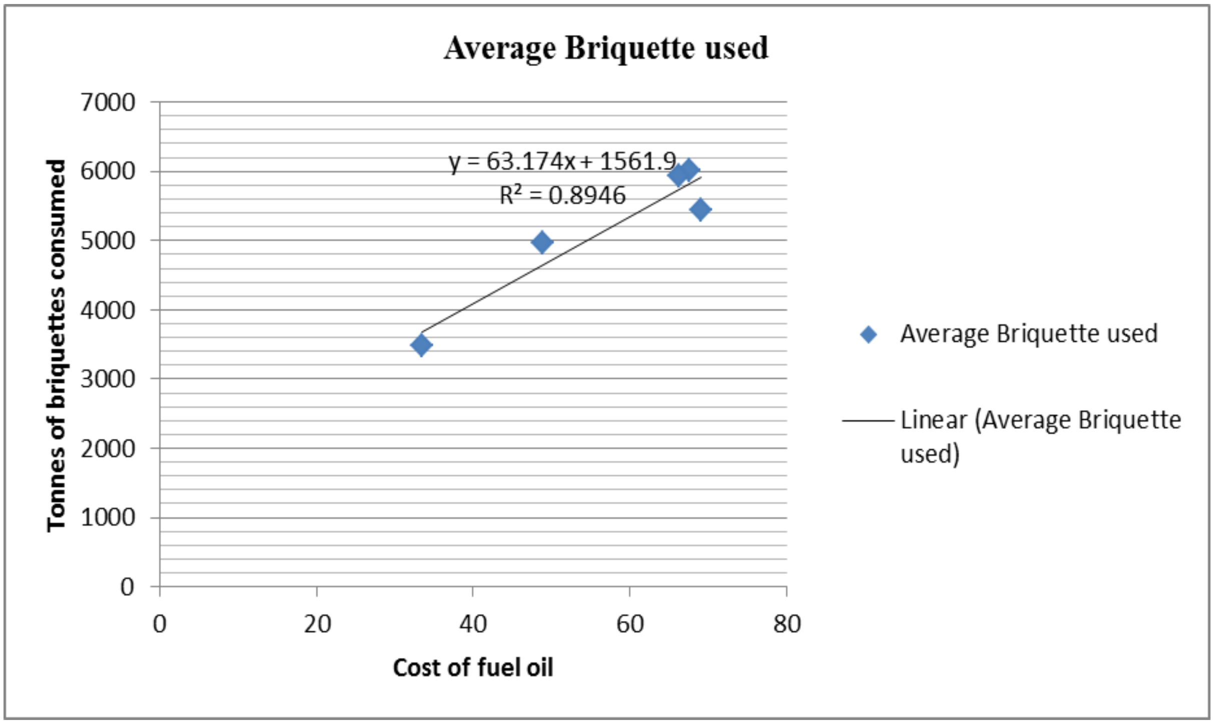


Figure 4-9 Regression Graph between cost of fuel oil and average tonnes of briquettes consumed

Source: Field data (2016)

4.7.3.2 Karl Pearson's coefficient of correlation analysis

The study sought to establish how the cost of fuel influences the adoption of biomass briquettes. Karl Pearson's coefficient of correlation analysis was chosen to quantify the strength of the relationship between the variables: briquette use and cost of fossil fuel. The Pearson product-moment correlation coefficient (or Pearson correlation coefficient in short) is a measure of the strength of a linear association between two variables and is denoted by *r*.

Table 4-7 Data Set on Average Cost of Fuel Oil and Average Tonnage Briquette Used Per Factory.

Years	Average Cost of Fossil Fuel	Average tonnage of Briquette used
2012	69.05	5438
2013	67.595	6005
2014	66.21875	5943
2015	48.81166667	4967
2016	33.54625	3475

Source: Field data (2016)

X Values

$\sum = 285.222$

Mean = 57.044

$\sum(X - Mx)^2 = SSx = 959.559$

Y Values

$\sum = 25828$

Mean = 5165.6

$\sum(Y - My)^2 = SSy = 4280715.2$

X and Y Combined

N = 5

$\sum(X - Mx)(Y - My) = 60619.632$

R Calculation

$r = \sum((X - My)(Y - Mx)) / \sqrt{((SSx)(SSy))}$

$r = 60619.632 / \sqrt{((959.559)(4280715.2))} = 0.9458$

r = 0.9458

According to Kothari C.R (2004) for values between 0 and 1 the following is a rough guide for interpretation of results:

r = 0.10 to 0.29/ r = -0.10 to -0.29 =small relationship

r = 0.30 to 0.49/ r = -0.30 to -0.49 =medium relationship

r = 0.50 to 1.0/ r = -0.50 to -1.0 =large relationship

The value of r^2 (0.8945) is the linear relationship while $1-r^2$ (0.1055) is the residual unexplained variability.

The value of R is 0.9458. This is a strong positive correlation, which means that the cost of fossil fuel scores go with increase in tonnage of Briquette used (and vice versa). The value of R^2, the coefficient of determination, is 0.8945.

The value of "r" is 0.9458 depicts a strong linear relationship between Cost of Fossil Fuel and tonnage of Briquette used (and vice versa).

The value of r^2, the coefficient of determination, is 0.8945.

4.8 Factors Affecting Biomass Briquette Adoption in Boilers in Kenya

The study sought to establish the level of influence of other factors affecting briquette use in boiler operations in Kenya, the result is as presented in figure 4-11.

It was found that the level of adoption of biomass briquettes use is dependent on the availability of biomass fired boilers. It was also discovered that fossil fired boilers could be converted to biomass fired ones by mechanically changing the furnace. However the costs were a deterrent to 93% of the boiler operators interviewed.

16 respondents representing 53.3 percent agreed that maintenance cost was the biggest deterrent in using biomass briquettes. However, according to one of the respondents who was operating a biomass fired boiler operator, most companies are skeptical adopting briquette fired boilers because of misinformation and lack of exposure in the use of briquette use.

The research also found out that there is no shortage of boiler operators. 11 respondents disagreed and a further 5 percent strongly disagreed that there is a lack of trained operators.

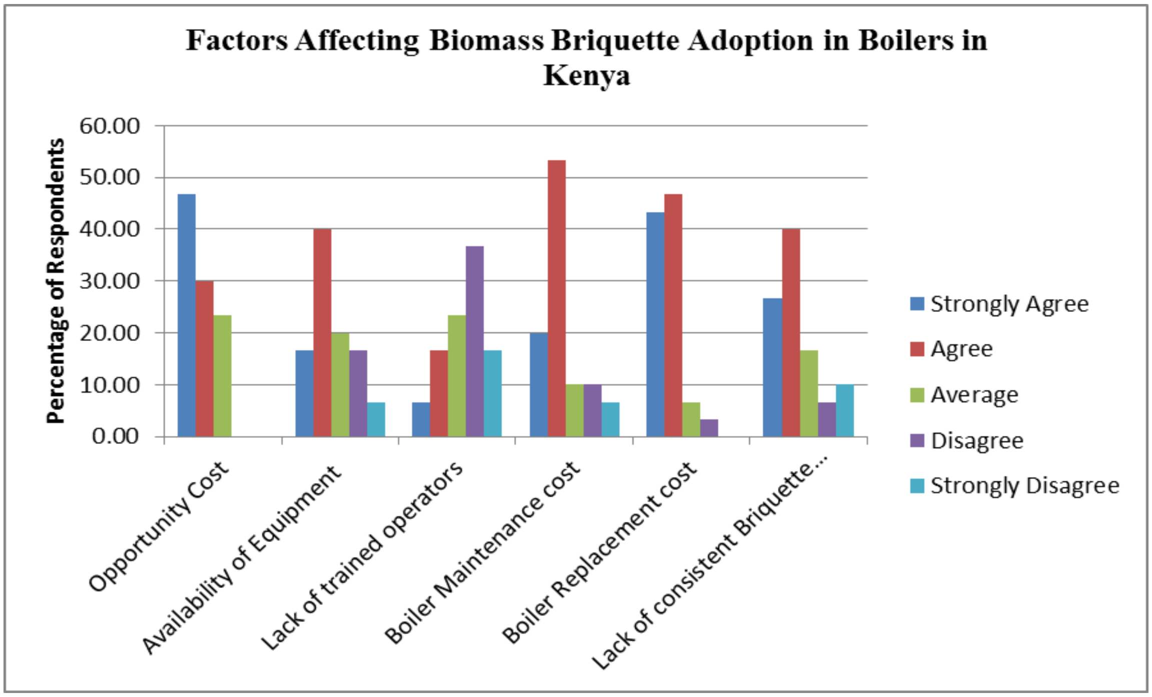


Figure 4-10 Factors affecting biomass briquette adoption in boilers in Kenya

Source: Field data (2016)

4.9 Environmental Impact of biomass briquettes in Boiler Operations

The respondents were asked whether the use of biomass briquettes in boiler operations had any significant negative environmental impact. The result is as presented below.

Table 4-8 Environmental Impact of Biomass briquettes in boiler operations

	Strongly Agree	Agree	Average	Disagree	Strongly Disagree	Percentage %
Ash Production	56.7	36.7	6.7	0.0	0.0	
Fly Ash	20.0	33.3	23.3	16.7	6.7	
Water use	0.0	6.7	20.0	30.0	43.3	
Smoke	20.0	23.3	43.3	13.3	0.0	

Source: Field data (2016)

From the data collected and analysed the majority, representing 56.7 percent strongly agreed and a further 36.7 percent agreed that ash from burning biomass briquette is an environmental problem. None of the respondents disagreed though they all noted that they had disposal mechanisms. It was discovered that some boiler operators packed ash in sacks before transporting to dumpsites.

On the production of fly ash, 20 percent of the respondents strongly agreed and in addition 33.3 percent agreed that fly ash was an environmental problem for them. 6.7 percent of the respondents strongly disagreed and a further 16.7 disagreed that fly ash was an environmental hazard to them. This was explained by the maintenance regime of the boilers and the design of the boilers. Boilers fitted with equipments designed to capture and filter fly ash had a higher probability of not releasing fly ash to the environment.

On water use none of the respondents strongly agreed that biomass boilers over utilized water. Only 6.7 percent of the respondents agreed that water use was an environmental problem. 43.3 percent of the respondents strongly disagreed and in addition 30 percent of the respondents disagreed that water use is an environmental problem in running biomass boilers. This is explained by the fact that water used in boilers is usually recycled within the system.

On smoke emissions, 20 percent of the respondents strongly agreed and a further 23.3 percent agreed that smoke is emitted during the burning of briquettes though they also noted that the levels of smoke emissions are minimal. Majority of the respondents representing 43.3 percent indicated average while only 13.3 percent disagreed. Respondents who disagreed seemed to have either newer biomass boilers or old ones retrofitted with modern dust filters. According to the Chief Engineer of Meru Dairy Factory, a boiler operating factory, by ensuring that there is complete combustion in the furnace and that the boiler dust collector is functioning properly it can reduce smoke emissions and volatile matter up to 98 percent.

On the impact of briquetting on water pollution UNFCC (2012) noted that there is no significant impact as there is neither release of any toxic gases, fumes or chemicals and compounds nor releases of any hazardous solid or liquid effluents which can cause water pollution. UNFCC (2012) further noted that biomass briquette use has no significant impact on noise, safety, visual impacts, or traffic. The report insisted that the process does not create any noise pollution that can be heard outside of factory premises nor cause any underground pollution or contamination.

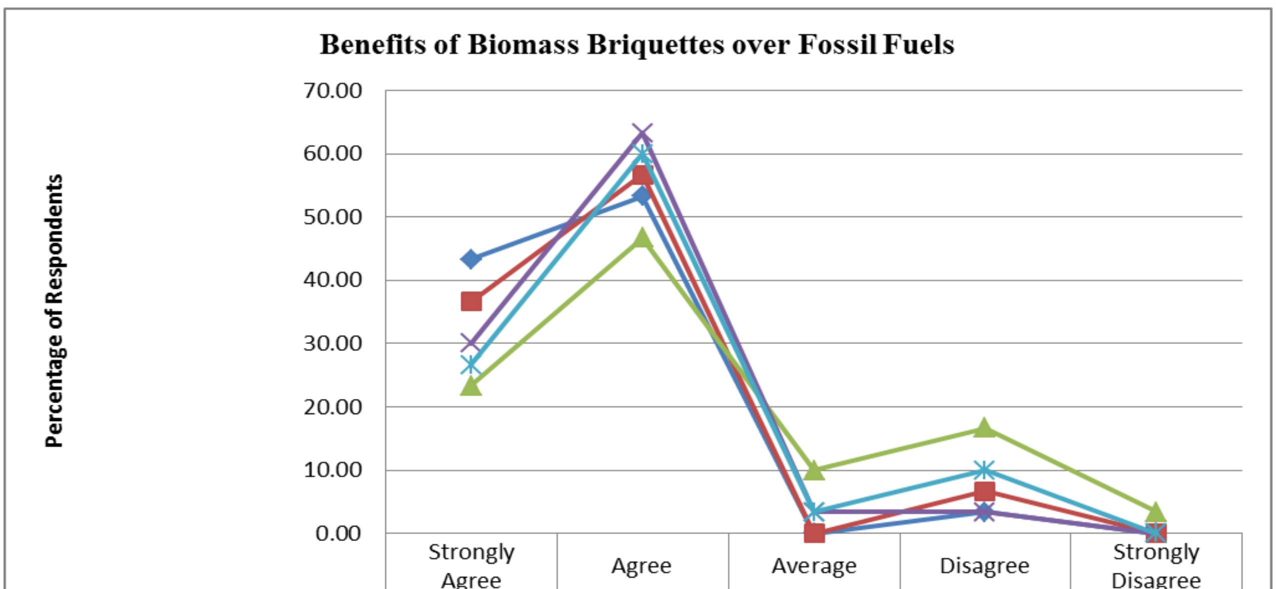
Manoj (2015) noted that any source of energy that involves the burning process will generate pollutants with negative effects to the environment and on biological systems. Burning of biomass fuels for instance will generate pollutants such as ash which is the unburnt remnant of the combustion process while the gaseous pollutants may include: carbon monoxide (CO), volatile organic compounds (VOCs), sulfur oxides (SOx) and particular emissions (PE).

According to Saidur (2016) ash from briquettes disposed in landfills has a higher surface area and poses a health risk because it may be inhaled or rainwater may leach out the toxins from the ash contaminating soil or underground waters more readily than if the waste use to make the briquette is left unburned.

From the responses analysed it was observed that though operating biomass boilers using briquettes is environmentally friendly in comparison to use fossil fuels, biomass boilers have some negative impacts to the environment and particularly emissions and residues that are a result of the burning process. According to the respondents at the dumpsites ash was being blown away as there were no arresting mechanisms that were being employed. Ash residue if not properly managed is one of the biggest environmental problems.

4.10 Benefits of Biomass Briquettes over Fossil Fuels

The study tried to identify benefits that accrue when using biomass briquettes other than fuel oil in boiler operations and the results is as presented in figure 4-5.



	Strongly Agree	Agree	Average	Disagree	Strongly Disagree
Pollution Reduction	43.33	53.33	0.00	3.33	0.00
Employment Creation	36.67	56.67	0.00	6.67	0.00
Health and Safety	23.33	46.67	10.00	16.67	3.33
Foreign exchange savings	30.00	63.33	3.33	3.33	0.00
Cost Effectiveness	26.67	60.00	3.33	10.00	0.00

Figure 4-11 Benefits of biomass briquettes over fossil fuels

Source: Field data (2016)

From the data collected and analysed majority of the respondents, 53.3 percent, were in agreement and 43.3 percent strongly agreed that biomass briquettes reduce pollution in comparison to fossil fuels. Only 3.33 percent disagreed. From the responses analysed it is evident that the use of biomass briquettes has a number of advantages over fossil fuels. Boiler operators explained that they were required by law to carryout stack emissions tests annually; when they used biomass briquettes and regularly maintained their boilers, they had a better chance of getting approvals because of the low registered levels of pollutants.

On employment creation, majority of the respondents, those who strongly agreed and those that agreed representing 93.34 percent indicated that the biomass briquettes create employment in its chain process. It was also established that running biomass briquette fired boilers was still cost effective when compared with fossil fuel fired ones even when the management of running one was outsourced.

4.11 Proximate analysis of the biomass briquette

Briquette sampled had: 40 % sawdust and 60% bagasse.

Plate 3: Biomass briquettes in a production store at Lean Energy Factory in Muhoroni Sub-County

Source: Field data (2016)

Table 4-9: Proximate analysis results

Sample	Percentage moisture content	Percentage volatile matter	Percentage fixed carbon	Percentage ash content
Briquette	8.96	74.1	20.21	6.73

Source: Field data (2016)

Volatile matter refers to the component of biomass briquette that is expelled when the briquette is heated (up to 400 to 550°C). During this heating process the biomass decomposes into volatile gases and solid char. It is usual for biomass materials to have high volatile matter content of up to 80 percent (Efomah. *et al*., 2015). From the biomass briquette tested, a volatile content of 74.1% was recorded. According to Loo (2008) this range is high and signifies easy ignition of the briquette and proportionate increase in flame length (Efomah. *et al*., 2015).

High Volatile matter content signifies that during combustion, most of the formed biomass briquettes will volatilize and burn as gas in combustion chambers. Ash, which is the inorganic matter left out after complete combustion of the biomass was found to be 6.73%. Ash is an impurity that does not burn during and after combustion. The low ash content indicated that the briquette was suitable for thermal utilisation. Higher ash content affects the calorific value of biomass briquette (Adekunle, 2015).

The fixed carbon of a fuel is the percentage of carbon available for char combustion. For the formed briquettes, it was found to be 20.21%. The low fixed content means that the burning process can be prolonged because of its low heat release. As such the fixed carbon gives a rough estimate of the heating value of a fuel.

The moisture content of the sawdust and bagasse briquette was 8.96%. This result was within the limits of 15% recommended by Wilaipon in 2008 for briquetting of agro-residues (Efomah, *et al*., 2015).

4.12 Hypothesis Testing

The researcher formulated three hypotheses that have been analyzed in this section. From the analysis of the responses provided by the respondents, the following results were obtained.

4.12.1 **Hypothesis One:**

H_0 There is no significant socio-economic benefit in the production and use of biomass briquettes.

To test this hypothesis, community respondents were asked whether they thought production of biomass briquette is beneficial to the community.

Table 4-10 Responses to whether the production of biomass briquettes is beneficial to the community.

Responses	**Yes**	**No**
Number of Respondents	45	21
Proportion of Respondents	0.68	0.32

Source: Field data (2016)

A z-test for the difference between two proportions was carried out using the formula below.

$$Z = \frac{P-\pi}{\sqrt{\pi(1-\pi)n}} \qquad \text{[Equation 11]}$$

$$= \frac{0.68-0.50}{\sqrt{0.50(1-0.50)/66}}$$

$$= \frac{0.18}{0.06155}$$

$$= 2.924$$

In the formula, *p* is the proportion of the sample choosing one of the options in the survey (e.g., “yes”), *π* is the null hypothesis value and *n* is the sample size.

The 95% confidence interval is an estimate of the range of these possible values (more precisely, 95% of this range). In the case of the z-test, the normal distribution and our estimate of standard error are used to construct the interval using the following formula.

$$P \pm (Z_{Critical})(S\_(x\ ))_1 \qquad \text{[Equation 12]}$$

Where the Z_{Critical} is the critical value, which is 1.96 whenever the normal distribution is used. The following values for the lower confidence limit (LCL) and the upper confidence limit (UCL):

$$LCL=0.68-(1.96)\ (0.06155) = 0.68-0.12=0.56$$

$$UCL=0.68+\ (1.96)\ (0.06155) = 0.68+0.12=0.8$$

Thus, the 95% confidence interval is 0.56-0.80

The computed value of 2.924 exceeds 1.96 cut off value at 95% confidence interval hence the null hypothesis is rejected and the alternative hypothesis accepted. That is, statistically there is significant evidence that there are socio-economic benefits in the production and use of biomass briquettes.

4.12.2 **Hypothesis Two:**

H_0There are no significant potential negative environmental impacts in adopting the use of fossil fuels as opposed to biomass briquette fuels in boiler operations.

Table 4-11 Results on environmental impacts

	Observed N	**Expected N**
Strongly Agree	18	6
Agree	9	6
Average	2	6
Diagree	1	6
Strongly Disagree	0	6
Total	30	

Source: Field data (2016)

Table 4- 12 Test Statistic

Chi Square	38.333
Df.	4
Asymp. Sig.	.000

Source: Field data (2016)

The calculated Chi-square ($\chi 2$) is 38.333 while the critical value at 0.05 significance level is 9.488, hence null hypothesis is rejected and the alternative hypothesis accepted. That is, there are significant potential negative environmental impacts in adopting the use fossil fuels as opposed to biomass briquette fuels in boiler operations.

4.12.3 **Hypothesis Three:**

H_0The price of fossil fuel does not significantly influence the adoption of biomass briquette use in boiler operations.

Table 4-13 Responses on whether the cost of Heavy Fuel oil determine the type of boiler to run biomass or HFO

Responses	**Yes**	**No**
Number of Respondents	28	2

Source: Field data (2016)

Table 4-14 Test statistics

Chi Square	22.533
Df.	1
Asymp. Sig.	.000

Source: Field data (2016)

In this case, the calculated chi square value is 22.533 this value is greater than the critical value of 3.841 at (0.05) significance level. Therefore the null hypothesis is rejected and the alternative hypothesis accepted. That is, there is sufficient evidence to conclude that price of fossil fuel significantly influences the adoption of biomass briquette use in boiler operations.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the findings, conclusions deduced from the study and also the recommendations based on the study objectives.

5.2 Summary of findings

The study set out to carry out an evaluation of renewable energy adoption in Kenya. The case study was biomass briquette production and its use in industrial boiler operations. From the findings, majority of the respondents 65.15% were female while 34.85% were male. 56% of the respondents had acquired secondary education, 24% had primary level education, and 18% had tertiary level education while 1.5% had no education at all.

The study sought to establish the level of environmental impact caused by the production process of biomass briquettes and focused on four environmental impacts namely: dumping of biomass materials, noise emissions, water use and land use. The study revealed that majority of the respondents in respective order of 43%, 47%, 53% and 39% disagreed that briquette production was affecting the environment.

The study established that biomass briquette production had many socio-economic benefits to the community and focused on four aspects namely: infrastructure development, employment creation, access to education and health. The study found out that employment creation was the most notable benefit accruing from biomass briquette production with 32% of the respondents strongly agreeing and only 2% strongly disagreed.

The study further established that the cost of fossil fuel influenced the adoption of biomass briquettes and used Karl Pearson's coefficient of correlation analysis to quantify the strength of the relationship between the variables: briquette use and fossil fuel, the cost of fossil fuel was used as the predictor variable. From the formulae generated (Y=63.174x+1561.9) the coefficient indicated that for every additional 20 Kenya shillings in cost of fuel oil the tonnes of briquettes consumed increased by an average of 1,561.9 tonnes. Therefore the study found out that the cost of fuel oil is an important factor that affects the adoption of biomass briquettes. When the prices of fossil fuels go down boiler operators will tend to stop their biomass boilers in preference of fossil fuel operated boilers reducing the uptake of biomass briquettes.

Proximate analysis on the biomass briquettes produced in Muhoroni was carried out and it was found that the briquettes contained 8.96% moisture content, 74.1% volatile matter, 20.21% fixed Carbon and 6.73% ash content. According to Loo (2008) the high volatile matter and signifies easy ignition of the briquette and proportionate increase in flame length (Efomah, *et al.*, 2015).

The study further found that production of briquettes plays a major role in employment creation and women empowerment. The key informant indicated that the company has employed 76 permanent staff and 398 casual laborers. 68 percent of them being women of which 22 percent are widows. 32 percent of the respondents strongly agreed and another 33 percent agreed that briquette production created employment opportunities in their community.

The study also found that the biomass briquette production and its adoption in boiler operations reduce emission of pollutants to the environment. When boiler operators were asked if they thought that there are more negative environmental impacts related to the adoption of biomass briquettes as opposed to the use of fuel oil majority (80%) of them were in favour of biomass briquettes.

5.3 Conclusions

The study concludes that the contribution of biomass briquette production and its use in boiler operations is considerable since it has socio-economic benefits to the community such as job creation. The project‘s contribution to local economic development is through direct and indirect income generation activities, directly working at the production factory, at the boiler site or in between the process such as transportation.

The study found that biomass briquette production and use in boiler operations has a marginal negative impact to the environment and it contributes to the replacement of fossil fuels in boiler operations. However the cost of fossil fuels hampers the stability and growth of biomass briquettes as a fuel in boiler operations as cost supersedes environmental concerns when choosing which fuel to use.

5.4 Recommendations

Based on this study, the most effective approach of promoting the adoption of briquettes is by policy action and giving incentives to industries utilising biomass briquettes. Therefore the study recommends the following:

a) The government of Kenya should regulate the price of Heavy Industrial Oil as its' constant unpredictable price change destabilizes the growth of biomass briquette industry.

b) Policies that promote the use biomass wastes for the production of briquettes should be formulated and adopted.

5.4.1 Suggestion for further studies

Further research is necessary to understand the future of the industry with increasing lack of consistent supply of raw materials such as bagasse due to increased demand for briquettes and other competing uses.

Research should be carried out on the potential of non-carbonized briquettes use at household level.

More research is also required on variety of biomass wastes with briquetting potential, materials that have low volatile matter, low moisture content, low ash content and high fixed carbon content.

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APPENDICES

QUESTIONNAIRE FOR COMMUNITY MEMBERS

The questionnaire will assist to analyze the impact of renewable adoption in Kenya using a case study of non-carbonized briquette use in industrial boiler operations. Do not write your name on the questionnaire since the information you shall give will be treated confidentially and will only be used for the purpose of this research.

Instructions

Please respond to each item by putting a tick next to the response applicable as you deem necessary.

i.e. [√]

SECTION ONE: GENERAL INFORMATION

Date……………………………………………….Questionnaire number…………………… ………….

Sub Location…………………………………Location………………………………......

County…………………………………………….

I. What is your gender
    i. Male [ ]
    ii. Female [ ]
II. What is your highest academic qualification?
    i. None [ ]
    ii. primary [ ]
    iii. Secondary level [ ]
    iv. Tertiary [ ]

SECTION TWO: NON-CARBONIZED BRIQUETTE PRODUCTION

1. In your opinion what options would you recommend for bagasse disposal or use?

2. On the following environmental influences on non-carbonized briquette production, which one has the most impact on your locality? Use a tick

	Strongly Agree	Agree	Average	Disagree	Strongly Disagree
Dumping of biomass materials	[ ]	[ ]	[ ]	[ ]	[ ]
Noise	[ ]	[ ]	[ ]	[ ]	[ ]
Water Use	[ ]	[ ]	[ ]	[ ]	[ ]
Land Use	[ ]	[ ]	[ ]	[ ]	[ ]

3. Using the following climatic impacts, to what extent do you feel they impact non-carbonized briquette production? Use a scale provided to rate them.

	Strongly Agree	Agree	Average	Disagree	Strongly Disagree
Drought	[ ]	[ ]	[ ]	[ ]	[ ]
Water Scarcity	[ ]	[ ]	[ ]	[ ]	[ ]
Flooding	[ ]	[ ]	[ ]	[ ]	[ ]
Land Use	[ ]	[ ]	[ ]	[ ]	[ ]

4.

(a)Would you say that the production of Briquettes is beneficial to the community?

Yes [ ]   No [ ]

(b) In your opinion, how is non carbonized briquette production beneficial to the community?

	Strongly Agree	Agree	Average	Disagree	Strongly Disagree

a) Employment creation	[ ]	[ ]	[ ]	[ ]	[ ]
b) Infrastructure development	[ ]	[ ]	[ ]	[ ]	[ ]
c) Health access	[ ]	[ ]	[ ]	[ ]	[ ]
d) Education	[ ]	[ ]	[ ]	[ ]	[ ]

5. What are some of the Advantages and disadvantages of producing briquettes?

Advantages:

a) …………………………………………………………………………………

b) …………………………………………………………………………………

c) ……………………………………………………………………. ……………..

Disadvantages:

a) …………………………………………………………………………………

b) …………………………………………………………………………………

c) …………………………………………………………………………………

BOILER OWNERS AND OPERATORS

The questionnaire will assist to analyze the impact of renewable adoption in Kenya using a case study of non-carbonized briquette use in industrial boiler operations. Do not write your name on the questionnaire since the information you shall give will be treated confidentially and will only be used for the purpose of this research.

1.

a). Do you use biomass briquettes as your main source of energy for boiler operations?

Yes [ ] No [ ]

2. If yes, please rate the efficiency of using biomass briquettes; Use a scale of 1 – 5, where 5 is the highest impact and 1 no impact (indicate using a tick)

SCALE	1	2	3	4	5
TICK					

3. If no, would you like to install a biomass boiler and use non-carbonized briquettes?

Yes [ ]   No [ ]

4. Does the cost of Heavy Fuel Oil determine which boiler to run Biomass or HFO boiler?

Yes [ ]   No [ ]

5. On the following environmental influences on non-carbonized briquette use, which one has the most impact on your locality? [Use a tick]

	Strongly Agree	Agree	Average	Disagree	Strongly Disagree
Ash production	[ ]	[ ]	[ ]	[ ]	[ ]
Fly Ash	[ ]	[ ]	[ ]	[ ]	[ ]
Water Use	[ ]	[ ]	[ ]	[ ]	[ ]
Smoke	[ ]	[ ]	[ ]	[ ]	[ ]

7. Would you say that there are more negative environmental impacts related to the adoption of biomass briquettes when compared to the use of Fuel Oil in boiler operations?

Strongly Agree	Agree	Average	Disagree	Strongly Disagree
[ ]	[ ]	[ ]	[ ]	[ ]

8. According to your knowledge, how have the following factors led to the slow pace of non-carbonized briquette adoption in boiler operations in Kenya?

	Strongly Agree	Agree	Average	Disagree	Strongly Disagree
a) Opportunity cost	[ ]	[ ]	[ ]	[ ]	[ ]
b) Equipment	[ ]	[ ]	[ ]	[ ]	[ ]
c) Labour	[ ]	[ ]	[ ]	[ ]	[ ]
d) Boiler Maintenance cost	[ ]	[ ]	[ ]	[ ]	[ ]

e) Replacement cost	[ ]	[ ]	[ ]	[ ]	[ ]
f) Capacity building	[ ]	[ ]	[ ]	[ ]	[ ]
g) Transportation cost	[ ]	[ ]	[ ]	[ ]	[ ]
h) Consultancy cost	[ ]	[ ]	[ ]	[ ]	[ ]
i) Professional valuation	[ ]	[ ]	[ ]	[ ]	[ ]
j)Government Policy	[ ]	[ ]	[ ]	[ ]	[ ]

8. In your opinion, how is non carbonized briquette use in boiler operations beneficial over Fuel Oil?

	Strongly Agree	Agree	Average	Disagree	Strongly Disagree
e) Pollution reduction	[ ]	[ ]	[ ]	[ ]	[ ]
f) Employment creation	[ ]	[ ]	[ ]	[ ]	[ ]
g) Health and Safety	[ ]	[ ]	[ ]	[ ]	[ ]
h) Foreign exchange savings	[ ]	[ ]	[ ]	[ ]	[ ]
i) Cost effectives	[ ]	[ ]	[ ]	[ ]	[ ]

Appendix 2: Questionnaire for key informants

1. Employment

a. How many employees does the project have?

b. Apart from direct employment in the project, are there indirect employment/income generation activities in the project?

c. How does the Project ensure inclusion of local community members?

d. What is the criteria for employment especially semi and non-skilled labour?

e. Are there job opportunities reserved for the local community?

2. Infrastructure Improvement

a. Are there initiatives by the Project to improve local infrastructure for the community?

b. Give a list of above

i. …….
ii. …….
iii. …….
iv. …….
v. ……..

c. How often does the Project implement community development projects?

d. What is the criterion used to decide which community development projects to implement?

3. Women Empowerment

a. Are there initiatives by the Project to empower women in the local community?

b. What are these initiatives?

4. Environmental Development Initiatives

a. Are there environmental sustainability gains by the Project?

b. Give a listing of these in a. above

c. Does the Project involve the local community in environmental management and improvement?

d. What is the mode of operation?

e. What are these initiatives that the Project employs in involving the community in environmental development?

f. How does the Project counter the negative environmental activities of its activities?