

**ADOPTION OF BIOMASS BRIQUETTES AS ALTERNATIVE SOURCE OF  
ENERGY IN MAASAI-MAU REGION, NAROK COUNTY, KENYA**

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**Reg. No.: N50/CE/25160/2012**

**Thesis Submitted in Partial Fulfilment of the Requirements for the Award of the  
Degree of Master of Environmental Studies (Climate Change and Sustainability)  
in the School of Environmental Studies of Kenyatta University**

**NOVEMBER 2020**

## DECLARATION

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## **DEDICATION**

Dedicated to my parents Shadrack Mokaya and Florence Bwari for their educational and moral support, and to my wife Leah Wachinga, son Cephas Mokaya and daughter Flo Moraa for their daily encouragement.

## **ACKNOWLEDGMENT**

Foremost, I am thankful to Almighty God for his protection, love, and blessings. I am also grateful to Mwamonari and Mwamicah Education Groups for financial support that enabled me to pay for this program.

I am greatly indebted to my supervisors, Dr. James Koske and Dr. Cecilia Gichuki, both of School of Environmental Studies, Kenyatta University, for their scholarly advice and guidance that led to the development of this document.

I thank my sisters Zippora, Dinah, Eucabeth and brother Job Mokaya, for the moral and financial support they gave me, without your support, I would not have made it.

Lastly, I will like to thank Mr. Innocent Ngare, and Mr. Amos Atima for their motivation during the whole process of documenting this research paper

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## **LIST OF ABBREVIATIONS AND ACRONYMS**

<b>FAO</b>	Food and Agriculture Organization
<b>GHGs</b>	Greenhouse Gases
<b>GIS</b>	Geographic Information System
<b>ILRI</b>	International Livestock Research Institute
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>KEFRI</b>	Kenya Forest Research Institute
<b>KFS</b>	Kenya Forest Service
<b>KNBS</b>	Kenya National Bureau of Statistics
<b>KFWG</b>	Kenya Forest Working Group
<b>LPG</b>	Liquefied Petroleum Gas
<b>UNEP</b>	United Nations Environmental Program
<b>UNFCCC</b>	United Nation Framework Convention on Climate Change
<b>UN-Habitat</b>	United Nation Human Settlement Program (Habitat)
<b>WHO</b>	World Health Organisation

## ABSTRACT

Climate change phenomenal is a trend that impacts the local communities by affecting their way of life. High demand for wood products to meet the demand of energy supply in Maasai-Mau region has seen the depletion of the forest cover thus increasing carbon dioxide emission and other greenhouse gases into the atmosphere. However, there is no extensive research on the benefits of alternative sources of energy like solar, biogas and biomass briquette in mitigating these impacts. The study investigated the adoption of biomass briquettes as an alternative source of energy in Maasai-Mau, Narok County, Kenya. The study was guided with three objectives (i) to determine the level of adoption of biomass briquette in Maasai-Mau region, (ii) to evaluate the challenges and hindrances Maasai-Mau residents face in the adoption of biomass briquettes in Maasai-Mau region and (iii) to investigate the availability of biomass briquette making materials in Maasai-Mau region. The study used two sampling techniques; systematic and purposive sampling to get information from the key informants and households in the study area with a target sample of 100 respondents. The findings obtained were analysed through Excel and Statistical Package of Social Sciences. Data results were presented in graphs, pie-charts, and tables. From the results, the hypothesis was analysed by Chi-square ( $\chi^2$ ). The study failed to reject the null hypothesis of a relatively low level of education hinders the adoption of biomass briquette, where ( $\chi^2=9.866$ , DF=6, P=0.13). The study concluded that the level of biomass adoption in Maasai-Mau region was relatively low with only 28% of the households using briquettes daily as compared to other sources of energy. The other conclusion from the study was that biomass briquette making materials were readily available with saw dust chippings and charcoal dusts ranking 84.61% and 79.49% respectively. Finally, the study found out that lack of funds and lack of briquette making skills were the highest challenge to adoption of briquette making technology in the region, being ranked as 88% and 77.6% respectively. The primary recommendations were that the Massai-Mau region residents be educated on biomass briquette making skills, and ensuring that their biomass briquette initiatives are funded to solve the challenges they face while adopting this clean energy mechanism as an alternative source of energy.

## INTRODUCTION

### 1.1 Background Information

Climate change is majorly caused by increased heat-trapping gases also known as greenhouses gases in the atmosphere (Kellomaki, 2017). According to the Intergovernmental Panel on Climate Change (IPCC), climate change is any interference to natural climate as a result of natural variability or human-induced over time. On the other hand, United Nations Framework Convention on Climate Change (UNFCCC, 2014) defines it as the change of climate that is attributed directly or indirectly to human activities that alter the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

Climate change impacts are experienced worldwide. Kenya too is experiencing these impacts like prolonged droughts, unpredictable weather patterns, and floods during the short rains, decreased yields of the staple foods and water shortage. In Maasai-Mau region, perennial droughts have led to wildlife animals wander further into the people's farms leading to many cases of human-wildlife conflicts. Wildlife attack pastoralist's cattle and sheep, as a result, the residents kill any wild animal they come into contact with (Chamliho, 2017). This leads to decreasing the number of wild animals thus affecting the tourism sector at large. The other impact of climate change is a socio-impacts in Maasai-Mau region, during the prolonged dry season Maasai men and boys are forced to stay away from their households in search of water and pasture leaving women and children at home for a long time without enough meals as they mostly depend on animals for food. The other socio-economic climate change impact is endangered and reduced number of wild animals, which die due to prolonged droughts and water shortage. This affects the economic gains that directly affects the region which is home to Mara Mara game reserve and the Mara River that attracts tourist during the wildlife migration seasons.

Clearing of the forest resource means that the 50% stored in the forest will find itself way into the atmosphere increasing the number of greenhouse gases that cause climate change (Joseph and Kaswamila, 2017). In Kenya, firewood and charcoal are the main sources of energy. The increasing energy demand is a significant challenge facing the world today. Studies done by Muazu and Stegemann, (2015); and World

Energy Resources (2016), show that an estimated population of 3 billion use wood fuel as their primary source of energy in their households.

Climate change mitigation measures include reducing emission from deforestation and degradation of forest resources otherwise known as REDD+. The REDD+ mitigation measures ensure that forest resources are conserved to conserve carbon stocks, use forest resources sustainably and enhance forest stocks (Sikor *et al.*, 2010; Ireland and Clausen, 2019). Other climate change mitigation measures include adoption of zero-emission power sources like solar energy, installation of light sensors in urban buildings, encouraging carpooling and use of public transport, recycling of waste such as conversion of livestock methane into biogas, production of electricity from landfills and finally adoption of renewable energy and fuels from biomass residues (Melissa *et al.*, 2015). Biomass briquettes fall under the last mitigation measures.

Adoption of biomass briquettes in Maasai-Mau region has a positive impact on Mau Forest ecosystem that is an important water catchment tower not only in the region but also to Kenya as well (Olang and Kundu, 2010; Ndengwa *et al.*, 2020). Mau forest complex benefits both the tourism sector and the agricultural sector. Thus, any mitigation measures that ensure reduction in cutting down of the trees to meet the locals' fuel energy sources demand is good news for the region, Kenya and East Africa (Mutugi and Kiiru, 2015).

The world around us keeps changing and the need for sustainable biomass energy production is important. Woods and agricultural products are the major sources of energy worldwide. In the developed world, wood is used for heating homesteads and as an emergency source of fuel when a homestead is faced with financial difficulties (Ngusale *et al.*, 2014; Orhevba *et al.*, 2016). The contrary is true to the developing world that depends on the wood and agricultural products as the main source of energy. The dependency on wood fuel continues to impact negatively on the environment as desertification rates increase and the top soils are exposed to erosion as we face high cases of deforestation (Muazu and Stegemann, 2015). Scholarly studies done by Sulaiman *et al.*, (2017), and Hamid & Blanchard (2018), have shown that there is a shift of dependency on wood products as the main source of energy in the modern society, towards the use of clean energy like biomass briquettes made

from coconut husks, waste papers, banana peels, corn cobs, and plant residues(Hu *et al.*, 2014).

Biomass briquette is the solution to the efficient source of energy; it transforms waste materials and plant residues to clean fuel. The biomass briquette making process involves the application of pressure on the biomass waste and the binders to produce a high-density solid material. The solid material is called briquette that is used to roast fish, heating houses, cooking, and as a source of energy in homesteads (Ndindeng *et al.*, 2015). However, the need for modern adoption of renewable energy technology will create capacity thus a sustained environment. Creating sufficient biomass production secures energy that enhances economic development and community welfare where the resources are obtained. The global biomass index shares as per 2014 on regional equitable production, indicated that Africa as a continent had 1% compared to Asia that had 10.5%. The two continents combined were less to that of Europe 16.5% and North America 44.1%. The statistics show that the uptake of biomass energy in Africa is still lacking (World Energy Resources, 2016).

Briquette production in Africa facilitates reduction of environmental degradation as the main source of biomass energy. According to Sulaiman *et al.*, 2017 and Jewitt *et al.*, 2020, over 80% of households in the rural settings of the African continent, use wood fuels as the main source of energy for domestic purposes. This has witnessed the rapid decline of forest cover as the demand for charcoal and wood fuel is above the supply from the existing forests that continue to be depleted. Historically, until the middle of 19<sup>th</sup> century, biomass was the leading source of energy supply. However, with the emergence of other sources of energy like coal and oil, biomass energy production was seen of low economic benefit thus leading to negative environmental impact (Van and Fouquet, 2017). With the emerging modern biomass energy production, uptake of briquettes and pellets keep emerging globally.

More pertinently, over 80% of sub-Saharan Africa use wood-based fuels as the primary energy supply (Al-kayiem *et al.*, 2015). In Kenya, biomass is the main source of energy as it accounts for 80% energy provision in the country. However, for Kenya to achieve sustainable development number seven of affordable and clean energy, the household energy sector should shift focus to the development of biomass energy (Weib, 2014). The key environmental impact to consider when assessing the

sustainability of an energy source is the climate impact of the energy life cycle use and supply (FAO, 2018). The solution is adopting biomass briquettes right from the community level to urban centres. Briquettes are small moulded combustible materials formed by compressing raw materials at high pressure to form round, square or triangular pieces that are used as alternative energy (Njenga and Karanja 2014)

The Maasai-Mau region is faced with the challenges of illegal logging, forest encroachment, unemployment and poverty, thus, many poor households will turn to briquette making as a source of income and supply of alternative energy (Hamid and Blanchard, 2018). Charcoal produced from Narok County is preferred since it is from the indigenous trees like acacias that burn for long as opposed to exotic tree (Dato *et al.*, 2019). Charcoal from Maasai Mau region, Narok County is utilized by 90% of the urban residents and 10% is consumed locally (Ndengwa *et al.*, 2020). The amount of charcoal produced from Maasai Mau region has not been quantified, but records from a study done by Taylor *et al.*, 2019, showed that the region has 100 small scale middlemen who buy 30-100 bags of charcoal weekly, and 50 large scale middlemen who buy between 150-300 bags of charcoal weekly. Each bag of charcoal from the region is 50kgs, thus on average, the middlemen buy a minimum of 390 tonnes of charcoal from the region. Although, more studies should be conducted to come up with an in-depth amount of charcoal produced from the region, since the study by Odawa and Seo, 2019, does not include the charcoal sellers who produce and sell directly to the buyers. According Korir, 2019, some of the negative impacts of utilising charcoal and firewood as main source of energy in the region include respiratory diseases, increased cases of lung cancer and chronic obstructive pulmonary diseases due to indoor pollution exposure to women for 5-7 hours per day. The benefits of biomass briquettes present a huge potential for affordable and quality energy that produces quality fuel, a source of income and employment to the youths (Bensh, 2015; Vivek *et al.*, 2019). According to Dinesha *et al.*, 2019, the main aim of briquette making is to provide clean cooking fuel for the women in Maasai-Mau region, Narok County, reduce indoor air pollution, reduce the time wasted in fetching firewood and reduce energy costs as biomass briquettes are cheap and affordable compared to charcoal. The briquettes are used as a substitute for firewood, charcoal and cooking gas. The provision of cooking energy from many sources will meet people's need to afford energy sources that will reduce environmental degradation

(Supas, 2015; Hamzat *et al.*, 2019). It is, therefore, vital to establish briquettes as alternative biomass fuel so as to meet Africa's greatest sustainability challenges; that include energy security (Laurencas, 2016).

## **1.2 Statement of the Problem**

Maasai-Mau region is part of the Mau forest complex, which is made of several forest blocks namely Olposimoru A and B, Olkurto, Ololunga and Naisuya. The forest block are faced with human induced pressure and destruction such rampant charcoal burning, firewood harvesting and illegal logging, which supports the locals as a source of livelihood. The Maasai-Mau region has indigenous trees that are endangered by rampant charcoal burning. The trees in danger include *Juiniperus procera* (Kenya-cedar), *Prunus africana*, *Olea capensis*, *Hagenia abyssinica* and *Podocarpus latifolia*. The high demand for charcoal burning of these slow-growing trees, has reduced the region's forest cover by 6.2% leaving the land exposed to soil erosion, climate change impacts like prolonged drought, rampant floods, low level of rivers and food shortage.

The demand for charcoal from Maasai-Mau region has grown by 2.96% annually. According to Adawa and Seo, 2019, 90% of charcoal produced in Maasai\_Mau region is consumed in peri-urban and urban centers such as Nairobi, Narok, Bomet and Kisii. Cutting of trees for charcoal and firewood production has negative impacts like loss of biodiversity, loss of ecosystem services like food, climate modulation and lower river levels, increased GHGs emission that is a contributor to global warming and climate change (Ndegwa *et al.*, 2020). Charcoal production contributes to 30% of the forest cover loss in Maasai-Mau region, with 15,185 ha of forest lost from the Maasai-Mau forest blocks annually (Kiruki *et al.*, 2019). This situation can be minimized by adoption of alternative source of energy that will fit into the supply chain that is met by charcoal production from the region.

It is against this background that this study seeks to assess the adoption of biomass briquettes as alternative source of energy in the region to ensure that the Maasai-Mau region's forest blocks are not depleted due to cutting down of trees for charcoal production and firewood harvesting for selling to the locals and urban residents.

### **1.3 Research Questions**

The following objectives guided the study

To fully investigate the problem, the study was guided by the following study questions.

1. What is the level of adoption of biomass briquettes in Maasai-Mau region?
2. What challenges and hindrances do Maasai-Mau residents face in the adoption of biomass briquettes as a source of alternative energy in Maasai-Mau region?
3. How available are the biomass briquette making materials in Maasai-Mau region?

### **1.4 Research Objectives**

To fully investigate the problem, the study was guided by the following study questions.

1. To determine the level of adoption of biomass briquette in Maasai-Mau region.
2. To evaluate the challenges and hindrances Maasai-Mau residents face in the adoption of biomass briquettes in Maasai-Mau region.
3. To investigate the availability of biomass briquette making materials in Maasai-Mau region.

### **1.5 Research Hypotheses**

**H<sub>0</sub>:** Relatively low education is the primary hindrance to the adoption of biomass briquettes as alternative energy in Maasai-Mau region.

**H<sub>a</sub>:** Relatively low education is not the primary hindrance to the adoption of biomass briquettes as alternative energy in Maasai-Mau region.

### **1.6 Significance of the Study**

Maasai-Mau region has 80% indigenous trees and shrubs that are under threat due to unsustainable harvesting. This study is important as its findings will help reduce rates of deforestation, improve the economic status of the community, encourage sustainable resource utilization and recycling of biomass wastes. The findings of this study will assist the central and county government to come up with specific

regulations that make the process of biomass briquette adoption smooth for the residents. Data collected will be useful to investigate the penetration of alternative energy in the rural setups and assist stakeholders to start aggressive campaigns towards the adoption of alternative energy to conserve the forest covers in Kenya.

### **1.7 Research Justification**

The demand for wood fuel in Maasai-Mau region's residents and the pre-urban and urban residents has led to degradation of the Maasai-Mau forest that lies in part of the region. The rate of the forest degradation will continue unless the area adopts biomass briquettes as alternative source of energy to conserve the forest and mitigate the climate change.

### **1.8 Definition of terms**

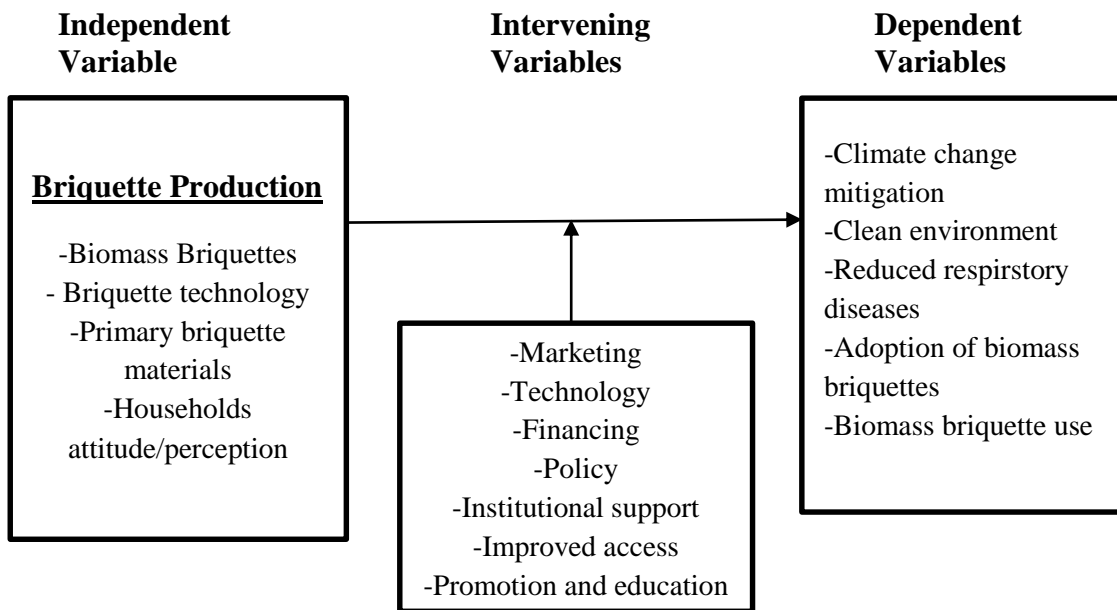
**Climate change** – Change of climate over time due to natural or human induced activities (UNFCCC & IPCC, 2014)

**Climate change mitigation measures** – Efforts to reduce or prevent emissions of greenhouse gases (UNFCCC & IPCC, 2014)

**Adoption** – The decision to acquire a new innovation or idea

**Biomass briquettes** – A high density forms of energy generated from biomass waste; agricultural and forestry waste, with the assistance briquette making machines.

## 1.9 Conceptual Framework



**Figure 1. 1 Conceptual framework. Adapted and modified (Sparrevik *et al.*, 2014).**

Figure 1. 1.1 shows the building blocks and their interaction that guided this study. The figure illustrates that for households to make the decision of adopting biomass briquettes as their alternative source of energy three forms of variables namely independent, dependent and intervening variables have to interact. Intervening variables are a catalyst to dependent variables that are dependent to independent variables. The start point was independent variable of briquette production supported by the sub-sections of biomass briquettes, briquette technology, primary briquette materials, and household attitude or perception towards adoption of biomass briquettes as an alternative energy. The end point was the dependent variables that included climate change mitigation, clean environment, reduced respiratory diseases and adoption of biomass briquettes.

## LITERATURE REVIEW

### 2.1 Briquette History

The briquetting was initially started in the late 70s by the European companies; through the introduction of the briquette making machines. The first recorded case of briquette making was in 1897 by Zwoyer Ellsworth from Pennsylvania. The briquette making was popularized in the 1900s by a businessman known as Orin Stanford, who wanted to come up with an alternative to wood charcoal to help his friend Henry Ford; establish a briquette business to boost his copper smelting business (Guo, Song and Buhain, 2015). During World War II, sawdust briquettes were made popular due to energy shortages in Europe and America (Morgan and Icerman, 2013) and at the end of the war; organic fuel briquette factories were set up in Japan, Scavanian, and United States of America (Zhao, 2011; Garcia *et al.*, 2019).

In Africa, Niger was the first country to embrace and install the briquette making machines and in 1981 Gambia custom made machine at the Kaur plant (Emodi and Boo, 2015). In addition, briquettes were procured from Taiwan by Malawi government to install the machine at sawmills in Zomba, Dedza, Blantyre for making sawdust briquettes. In the year 1983, Kenya had installed two plants that used coffee husks for the production of pellets for industrial boilers and briquettes; and yet there was a unit that produced charcoal from coffee husks, then were convert to briquette by use of molasses as a folder. By 1984, briquette making plants was being adapted in Africa; Zimbabwe installed palletising machine based on cattle feed in Harare. Currently the plant is used to distribute pellets to fertiliser and animal feeds (Bennett and Laurine, 1988) making it the only successful briquette plant in Africa.

Renewable energy in Africa has gained a lot of interest as a result of poor world market prices, a rapid increase in fossil fuel prices, decline volume of product export, and repeated crises faced by power utilities in the region (Surroop and Raghoo, 2018). For example, countries like Kenya, Tanzania Ethiopia are facing extraordinary power rationing, thus affecting their economies. Research studies indicate that biomass energy is the only source of energy utilized by 75% of the population in sub-Saharan Africa (Muenjina, 2013); this is because the sub-Sahara Africa population depend on crops, wood and animal residue to meet household needs such as cooking.

Biomass energy is obtained by converting organic chemical energy into fuels for transportation, heat and electricity. Traditional process such as the use of stoves and carbonization in earth kilns. The methods are inefficient and present unsustainable harvesting practices of charcoal production and wood fuel (Demirbas, *et al.*, 2016). In the recent years, the world bioenergy demand has increased, in 2010 the total approximate bioenergy supply increased by over 50EJ equivalent to 10% of total world major energy supply (Irena, 2014). Additionally, the relative cost of biomass waste disposal highly impacts on the environment as it contributes to greenhouse gas emission resulting to global warming (Emerhi, 2011). Through an appropriate technology, briquette production promotes sustainable development and environmental integrity (Kwofie and Ngadi, 2016).

## **2.2 Characteristics of Biomass Briquettes**

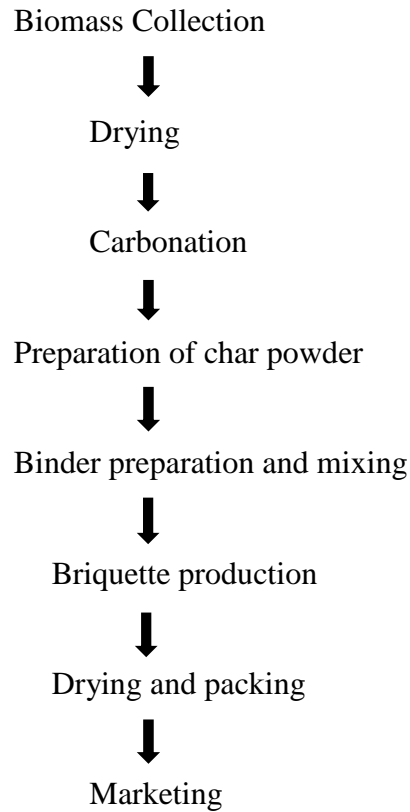
The characteristics of biomass briquette used as an alternative energy source depend on the materials used and the binders. Different regions have different sources of briquette making materials that vary on the components; which are influenced by the geographical setting, climate and agricultural produce (Orhevba *et al.*, 2016). For example, West African countries grow rice and palm, thus the major source of biomass briquette in this region will be rice bran and husk (Hamzat *et al.*, 2019). The briquette made from this region will have 72% of rice, 6% of bran and 22 % husk. This rice by-product is usually piled as waste without any food value. The pile ends up polluting the water bodies and if burnt, polluting the air (Ndindeng *et al.*, 2015). Maize cobs and wheat husk are the major sources of biomass briquette in East Africa, where huge amount of this is left to decompose in the fields and if farmers burn them, they end up causing air pollution (Okoko *et al.*, 2017).

Agricultural wastes are used as energy source thus providing environmental benefits such as habitat for wildlife, climate change mitigation, soil erosion reduction and so on. In developing countries, biomass is significant source of energy for the population; and yet in Africa biomass justifies for 75% Of the energy total consumption (Litvine *et al.*, 2014). For example in Ethiopia and Uganda, biomass accounts for over 80% of the total energy consumed. However, briquette production has transformed the energy system into a sustainable energy system; due to its clean nature and most importantly it can be stored for long duration without degrading.

Studies show that biomass briquettes have higher thermal stability, lower moisture content and high flame temperatures (Muazu and Stegemann, 2015). They also have great combustion properties; less smoke, less soot and high calorific value this is as a result of reduced storage duration and decreased ash content of the briquette (Vivek *et al.*, 2019). The other characteristics include high volatility , high combustion properties and long burning with less ash content (Ndindeng *et al.*, 2015).

### **2.3 The Briquette Production Process**

The briquette making process has five basic processes namely: combustion, anaerobic digestion, fermentation, gasification and pyrolysis the end product is biomass which can be converted into electricity or heat (Suprianto *et al.*, 2018). The named processes involve three important stages for a briquettes to be made, that is; milling stage where the raw material are cut into smaller particles, carbonation stage where the collected biomass is converted to char through slow burning in low oxygen, then the char is mixed with binders and fed into the briqueeting machine machine before they are dried and transported for usage. (Damien *et al.*, 2009; Suprianto *et al.*, 2018).



**Figure 2. 1 Biomass briquette production processes (Source:Author)**

Briquetting process is where the agricultural and forestry raw materials are processed through compressing and compacting. To obtain compactness; raw materials are compressed under high temperatures thus increasing the temperature of the raw materials forming a scorched kind of a surface with silky appearance. During compressing stage, high temperatures are gained by using lignocellulosic materials thus producing soft lignin which plays the role of binding agent (Shyamalee *et al.*, 2015). The briquette making process requires a machine to exert pressure so as to bind the organic matter into a component that will be dried to make a briquette. Some machines currently in the market include piston press, pellet press, manual press, roller press, and other homemade pressers (Kaosol, 2011; Aliyu *et al.*, 2020).



**Plate 1. 1: Piston press machine (Source: Maa-briquette Narok)**

The piston press machine above uses electricity to run and produces briquettes equivalent of 50 sacks per day. The best amongst them is the roller press as it helps reduce the volume of the mixed material by ten times; from normal  $100\text{kgm}^{-3}$  to a range of  $1000\text{kgm}^{-3}$  to  $1100\text{kgm}^{-3}$  thus burn with the efficiency of 2 to 3 hours (Nyakeru, 2013). In the roller press, a mixture of charcoal and binder is fed to the peripheral pocket of the two rollers to produced briquettes. The roller press work through the principle of pressure and agglomeration (where powder particles are glued together to increase the size of a particles). Pressure is applied in the two counter-rotating rolls when passing agricultural residue in the two-part; where they are pressed into smaller pocket forming the densified product (Jaya *et al.*, 2010; Vivek *et al.*, 2019).

Briquette raw materials are readily available in Kenya, considering it is an agricultural based country. The raw materials for biomass briquettes making include maize cobs, bagasse, coconut husks, and rice husks; saw dust chippings, groundnut shells, sisal

fiber, vineyard wastes, bean straws, and cotton straws. The briquettes making process include binders mixed in a 2 % ratio to the organic matter of 85% and 8% water. The binders include charcoal dust, molasses, gum arabic, the water swelled clay, and other locally available materials like cow dung and maize starch that is readily available from local posho-mills (Mugo, 2013; Ndengwa *et al.*, 2020).

One or two binders can be used to get a more compact briquette, with the molasses and cornstarch most favoured; the raw material compactness are dependent on variation between the moisture content and the capacity of the briquette production machine. (Guo, Song and Buhain, 2015). The steps of making briquettes include drying all raw materials to 13% moisture content to allow the cutting of the mixture into small chips (Amer, 2014). Some materials like coconut and coffee husk need special machines to reduce them to chips that can be mixed with binders (Nyakeru, 2013). According to FAO, 2018, a ratio of 3:1; three parts of raw materials to one part of binders, and 3:1 for water to raw materials is needed. The mixture is then fed into one of the machine types; pellet press, piston press to name but a few. This machine pressurizes the mix into a compacted matter then pass it through the exit chamber letting out briquettes of about 35-40grams (Shyamalee *et al.*, 2015). The briquettes are then dried in the sun for 1-2 days during the sunny days and can take up to 6 days during the rainy seasons (Petrov, 2011; Korir, 2019).

Biomass briquettes is used in the United States of America as a source of energy for outdoor cooking, the source of heat during winter seasons and barbecue cooking (Murari, 2012; Perea-Moreno *et al.*, 2019). The USA uses corn starch as a sole binder which means no tree is cut to provide charcoal dust to act as a binder (Vilas, 2012; Jewitt *et al.*, 2020). In Africa, Zambia and Malawi has successfully embraced the briquette technology as alternative source of energy (Gatis, 2014; Pirelli *et al.*, 2020).

### **2.3.1 Biomass Energy Sources**

Biomass is an organic matter in the form of wood, crops, animal waste; that is used as a source of energy if well utilized. Biomass obtains the energy majority on Sun, this because organic materials absorb energy from the sun through the process of photosynthesis; which convert the stored energy into carbohydrate and sugars (Kumar *et al.*, 2015). Biomass raw materials are commonly obtained from the forests that

serve as the leading biomass fuel source across all continents. Communities, factories, and learning institutions in developing countries, Asia, and Latin America for centuries; have utilized forests for biomass production (Amer, 2014).

There are five types of biomass energy sources; wood and agricultural products, solid waste, landfill gas, alcohol fuel, and biogas (Srirangan *et al.*, 2012). Globally, large quantities of agricultural residues produced per year, and they are tremendously underutilized; for example, straw and husk at the processing factory which if utilized, can be converted into energy. Significantly, more quantities of biomass is left in the fields. However, farming by ploughing the residue back to the soil and burning the leftover instead of leaving them to decompose causes more emissions of greenhouse gases (Thierfelder *et al.*, 2013). If this residue could be collected and processed into fuel or energy, it will have a great impact on the energy sector.

In 2010, in United States 4% of the energy consumed was obtained from biomass fuel, 46% was produced from wood and agricultural products, biofuel that is alcohol account for 43% and 11% of the energy used was from municipal wastes (Walpole *et al.*, 2012). Their level of biomass utilization towards environmental quality varies due to the benefits of biomass use to the environment. For instance, the demand of factory harvest on wood fuel if not sustainable, leads to loss of forest cover and environmental depletion skyrocket, affecting the existing indigenous communities (Kaosol, 2011). Biomass materials that are mostly used to produce energy are known as feedstock that is wood, plants and wastes. For energy to be obtained, direct means is used for example burning of biomass and conversion of biomass to electricity and indirect means is used for example processing of biomass into biofuel such as biogas.

#### **2.4 Biomass Towns in Japan**

Annually, Japan biomass production is 322 million tons (Manzano *et al.*, 2013). The biomass recycling is 76% whereas the 24% of the biomass is not recycled and yet Japan has the largest forested country in the world and only 1% of the recycled biomass account for forest residue. However, 80% of the wood in Japan is imported. Currently the biomass power plant operating in Japan has an output of 100MW. Japan is working on tripling the megawatts for biomass power plant by year 2024 or 2025 and will have an output of 300 megawatts enough to meet demand of about 700,000 households (Gates *et al.*, 2017). Japan has towns known as "Biomass Town" where

biomass is used efficiently with no wastage. These towns have solar energy, wind energy and other forms of renewable energy that reduce air pollution in the region.

Demand for dependable source of renewable energy in Japan, is mostly on the business world. However, solar power being readily available form of renewable energy, it's unstable due to fluctuation of weather condition in Japan and other parts of the world. Therefore, biomass plant will be more stable and a better alternative to the population. The biomass energy in this town is low in sulphur, nitrogen content and CO<sub>2</sub> neutral. Biomass is converted into gases, solid and liquid energy that drives the economy in the areas (Balasubramani *et al.*, 2016).

Biomass in Japan is popularly being used in power plants as a fuel, especially after the tragic accidents in a nuclear power plant at Fukushima in 2011. Japan has embrace palm kernel shell in biomass-based power plants; where it is used as its source of energy. In 2015 japan constructed more biomass power plant to promote cleaner and green energy while minimizing on the fossil fuel used.

In Japan, fuel shortage has reveals alternative source of energy that is biomass energy. Over 800 projects have been approved by government offering an output of 12.4 gigawatts capacity that is equivalent to 12 nuclear reactors (Sahoo,2013). However , the projects has raised a number of question on how to find sufficient fuel to keep on shipping the fuel to Vietnam and Canada and other countries. According to Aikawa and Hayase ,2013, the projects will require an equivalent wood pellets about 60 million tons as related to the global output of 24 million tons in 2014. An area where there is ample use of biomass system, is recognised and run with help of stakeholder cooperation is known as biomass town.

## **2.5 Briquette in Indonesia**

Indonesia is made up of 60% of farmers who depend solely on agriculture for economic benefits. In Indonesia, coconut shell charcoal briquettes are obtained from matured and quality coconut shells collected from different part of the country; as most Indonesians from Northern provinces depend on coconut as their main crop (Zhang, 2014). They sell the produce to oil industries, but the coconut shell used to litter their farms and urban centers until they started to use it in making coconut briquettes. The briquettes are used for purifying drinking water from various water sources, cooking in the homesteads, and local restaurants (Pagsuyoin *et al.*, 2015).

Energy demand is aggregating globally, due to the intense requirement for daily activities, business, and industrial sector. Indonesia is highly rich in biomass energy, however, the sector is infertile; this is because of lack of knowledge, climate change, and geographical location to utilize the energy. (Hata *et al.*, 2009). Due to high poverty level and low income for rural Indonesians, biomass is directly burn to satisfy their household needs and on extreme the industrial processes. For instance, Indonesia has a high production of durian fruit was about 759,055 tons in year 2013 (Pagsuyoin *et al.*, 2015). Durian depletion engender about 70% of unconsumable waste in form of seeds and shells. Durian fruit wastes is used to make briquette due to its chemical properties like amylose and amylopectin; which acts as good binding agent (Wahyono, 2009).

In Indonesia, coconut shell charcoal briquettes are obtained through the use of matured and quality coconut shell collected from various part of the country. Ruby factory in Indonesia is the leading manufacturer and exporter of coconut shell charcoal briquettes. These coconut shells are gathered from coconut harvesting regions such as Java, Sulawesi, and Sumatra (Demirbas *et al.*, 2009). The United Nations Development Programme (UNDP) introduced biochar project to farmers in East Nusa Tenggara and central Sulawesi provinces Indonesia; to promote their crop yield and clean energy for cooking with briquettes. The project aimed at empowering women, to boost and earn extra income to improve their living standards. It is also a way of mitigating and adapting to climate change and its impact (UNDP, 2013). As energy demand increase in remote areas and islands, Indonesia energy demand will have tripled by the year 2030. However, over 10% of the Indonesia population lack access to electricity; although the government is aiming at 100% electrification by 2026 (Irena, 2017).

## **2.6 Challenges of Biomass Briquettes Adoption in the Philippines**

Agricultural wastes in the Philippines has made the country to be among the countries that studies show has great potential in renewable energy adoption. The Philippines is an agricultural country that has huge wastes of rice husks, rice straws, sugarcane bagasse, coconut wastes and urban wastes (Romallosa, 2017). The country has one of the best mechanisms of converting these wastes into biomass briquettes by the use of compacting machines that is jack-driven. The Philippines use this improved briquette

making by use of jack-driven machine that has a hole in the middle to allow fast drying of the briquettes. The jack-driven machine is made of hydraulic pistons, car jack presser, wooden compound levers and solar powered pedals. This machine has made it easy for the innovative youths to convert the readily available agricultural wastes and urban wastes into the environmentally friendly biomass briquettes (Romallosa and Kraft, 2017).

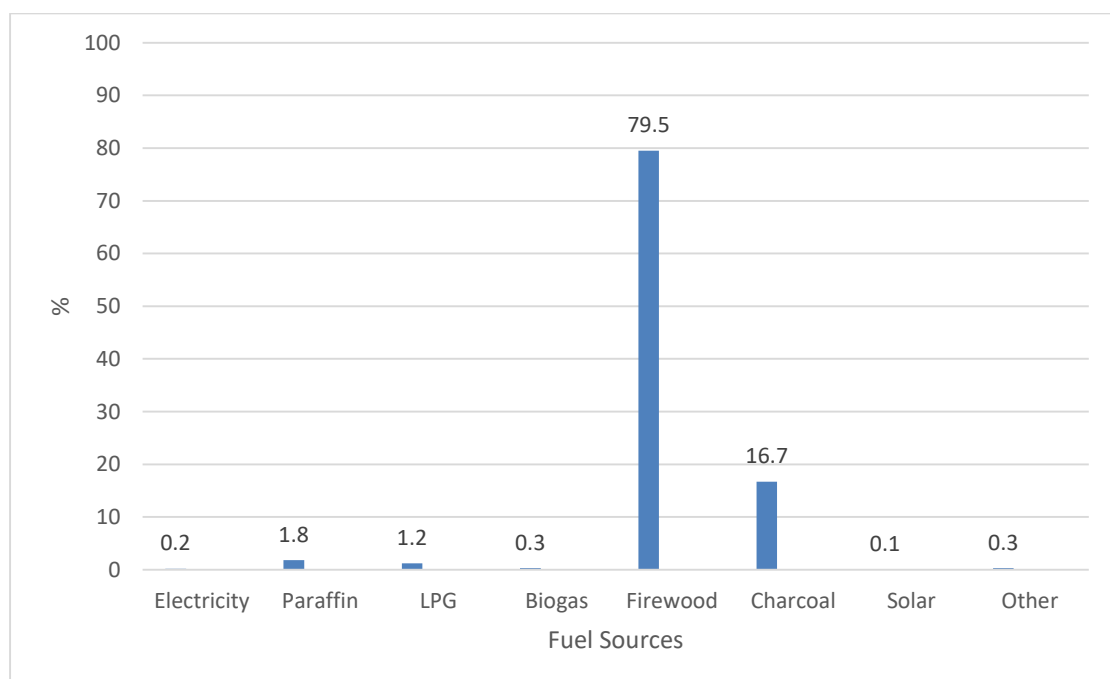
The Challenges the youths face in the Philippines include lack of funding to enhance the jack-machines to produce more briquettes per day, the inefficient machines that are prone to rust and lack of goodwill from the local government to educate them on the ways of improving these machines to be efficient and produce more briquettes. The available machine can only produce ten briquettes per processing, that makes the process of briquette making tedious as an improved machine can produce up to 30 briquettes per press with reduced wastage of raw materials (Olsen, 2007), improved machines produce high-quality biomass briquettes with high volatile matter that burns with less smoke and less ash, as opposed to the briquettes produced by the jack-machine that have inefficient briquettes. Another challenge facing the youths in this country include the high cost of machines, lack of funding to market the biomass briquettes to the local community and urban residents most of whom are dependent on woody and petroleum fuels (Balasubramani *et al.*, 2016).

## **2.7 Challenges of Biomass Briquette Adoption in Africa**

Briquette making projects from Africa has been in single trials that later failed to take off due to lack of funding, stakeholder involvement, and lack of aggressive awareness campaigns on the continent (FAO, 2018). Other reasons for failure include high machine maintenance, poor planning of the projects, and lack of trained experts to drive community briquette adoption (Vilas, 2012). According to Nyakeru (2013), several briquettes doing projects have been implemented in Kenya with sawdust and coffee husks as the primary raw materials. The projects failed to take off due to early donor withdrawal leaving the projects with no funds to sustain themselves. The few projects that have taken off has seen local forest covers being conserved, with 80% non-dependency on wood fuel noted (Njenga and Karanja, 2014).

## 2.8 Energy Sources

Maasai-Mau region has less than 6% electricity coverage (KNBS, 2009), but the residents depend on charcoal and firewood for cooking, lighting and warming themselves during the cold seasons (Sainepo *et al.*, 2018). As per figure 2.2 below, 96.2% of the energy used by the region's household originates from wood-fuel (NEMA, 2013). The study by NEMA,2013, found out that charcoal burning is not only used as a source of energy in the region but also as a source of income as most youths are unemployed and live below the poverty line, hence turn to charcoal burning as their source of income.



**Figure 2. 2 Distribution of household fuel source in Maasai-Mau Region**

## 2.9 Briquettes Use in Kenya

Since the 1970s, Kenya has been producing briquettes in small scale. However, the Kenyan population has not fully embraced the use of briquettes because of the traditional fuels, for example, charcoal, lack of knowledge and lack of appropriate equipment. In the early 1980s the government ban the transportation and production of charcoal due to extreme deforestation in the forestry sector in Kenya; and yet there has been little response to the law to embrace environmentally friendly fuels and renewable energy source such as biomass energy, solar energy, and wind energy and so on (Ngusale and Kiplagat , 2014). Creation of awareness, distribution of energy efficient equipment and enforcement of 2006 energy act, lead to lessening of

dependency on charcoal as a source of energy. Penetration of briquettes as a source of energy in Kenya is gaining momentum.

In some part in Kenya such as Kitui and Mwingi, produces charcoal; therefore, the demand for charcoal use is high regardless of the energy act 2006. Briquettes are clean energy, which is environmentally friendly. According to the 2013 ministry of energy report on briquette making, Kenyans have taken this as an enterprise business, especially in the Coast, Kisii, Kisumu, and other places (Deignan and Hoffman, 2013). Several projects have previously been commissioned. According to Andrienzen, 2013, one such project that was commissioned in Nakuru County by the Global Environmental project trained youths on energy saving stoves and briquette making in the year 2012, and saw eleven production units established in the county. These production units employed 30 youths to offer services in the briquette making chain right from waste management, raw material drying to final stage of transporting the briquettes to end users (Andrienzen, 2014).

In Kenya, wood fuel is the primary fuel because it accounts for 70% of energy production, 21% of the petroleum and about 9% electricity on the energy sector (Leach and Mearns, 2013; Aliyu *et al.*, 2020). Due to rapid population growth wood fuel demand is increasing at a higher rate leading to rural-urban migration and setting up more industries to accommodate the population through the creation of employment. By 2020, the demand for wood fuel is predicted to rise by about 54 million tonnes annually in Kenya. And yet, fuelwood is unsustainable energy due to Kenya's forest cover is about 6% and the growth of wood fuel demand is about 4.7 million tonnes per year relative to sustainable supply which has increased by 0.6% annually. The survey has revealed that Kenya produces charcoal about 1.6 million tonnes per year and on a daily basis, Kenya produces 700 tonnes of charcoal. Therefore, regardless of the presence of the energy act 2006, Kenya is still highly dependent on charcoal to meet their daily needs.

### ***2.9.1 Briquettes usage in Kenya***

Briquettes projects have been adopted in Ruiru Township of Kiambu County although the residents favour the primary energy sources of charcoal, paraffin, liquefied gas, and firewood. This is based on the traditional practices with no other preference (Ferguson, 2012). In Nairobi County, a group of women from Kahawa, Kayole,

Soweto, Kibera and Mathare slums started briquette making as a simple process of solving the energy problem that was facing them in 2010, and also, they decided to sell to neighbours. According to Trac *et al.*, 2013, they are making an income of up to 2000 USD per annum. Women groups affirm that briquette making is an important venture Kenyans can explore to realize their environmental goals and economic development (Omer, 2014; Suryaningsih and Nurhilal, 2018).

In Dandora Nairobi, the residents have been collecting coffee husks and rice husks from the nearby industry in industrial area Nairobi; where the machine was malfunctioning. They made the briquette manually to satisfy their household energy requirement. In Uthiru Nairobi, the yard collects the maize straws at Gikomba market to make briquettes. For example in Kikuyu area in Kenya, a women entrepreneur produces briquettes from municipal waste; this is due to the energy crisis felt in 2009, where the power supply was unpredictable and rationing in some part of the country was introduced. To help promote energy conservation because of the low level of water in dams to generate hydroelectric power.



**Plate 2. 1: Briquette packed for transportation to Nairobi estates (Source: Maa-Briquettes Narok)**

In Kenya, urban and semi-urban areas are more encouraging in briquette making and expansion of briquette business due to its relatively low smoke fabrication and also use of biomass briquette can replace charcoal consumption by 5- 10%. Research done by Ferguson, 2012; Suprianto *et al.*, 2018, revealed that in recent year briquette technologies have been introduced in Kenya such as machines for making briquettes. The industry remains untapped due to challenges faced by Kenyan such as poor access to finance, lack of awareness and knowledge about the global market of the

briquettes. Kenyan in the briquettes making regions make briquette for export where this will help the producer financially thus leading to the undeveloped area due to lack of introduction of local standards (Ferguson, 2012).

### ***2.9.2 Kenyan perception on briquette use***

Kenya's forest cover has decreased drastically as a result of forest depletion. Research reveals that in the 60s the forest land has declined from about 360 hectares to 90 hectares in 1999 (Trac *et al.*, 2013). In Kenya, the main factor leading to forest depletion is agricultural production and settlement and wood misuse during log conversion. For example extreme logging and encroachment for agriculture in Mau forest. However, in order to achieve wood demand both external and internal and for timber industries sustainability; people are required to conserve and protect our forest against crisis such as deforestation, desertification, encroachment of forest land and also provide efficient ways of utilization of wood in harvesting and processing stage to avoid and minimize wastage hence lessening the pressure on forest.



**Plate 2. 2: Earth mould site after charcoal production in Ololung'a Narok**  
(Source: Author)

The level of perception in Kenya is mostly dependent on awareness and knowledge of the briquette use. Research by Omer (2014), shows that 96% of the population in

Kenya disagree that briquettes are cheap and it is not readily available in local markets and also it lacks local standardisation; this makes it more difficult to access the product). Also lack of information on the technology and fear to embrace new technology due to little knowledge on the benefits and risks of the technology. However, 80% agreed that briquettes are easy to use and handle with regard to the availability of raw materials. The level of perception of briquette is dependent on socio-economic status of the consumer; thus persons with high socio economic status will embrace the technology without the second thought while the person with low socioeconomic status will tend to be more conservatives on traditional and unsustainable ways of energy sources.

### ***2.9.3 Awareness information on briquettes in Kenya***

Most of the population are not aware of the existence of briquette (about 98%). Therefore, they are only aware of the firewood used for lighting, fuel and cooking; and yet around 4.5 million tonnes of biomass wastes are available annually in Kenya (Mutugi and Kiiru, 2015). However, regardless of the research done earlier on biomass waste availability, little has been prepared to value the best way to use biomass waste economically. Recent research done by WHO (2016), emphasis on improving already existing technology (for example stove, *jikos*) rather than sustainable fuels in order to satisfy household needs. In Nairobi urban and its peripherals, they support briquette as it provide dais to recognize environmental and sustainable element for modern energy requirement.



**Plate 2.3: Airing of briquettes (Source; Author)**

Fuel market in Kenya is of three essential types, these are petroleum, electricity and wood fuel that is 21%, 9% and 70% respectively books for accumulated energy consumed. In Kenya, wood fuel remains a major energy source where 90% of household in rural areas are accounted for by fuelwood and 85% in urban areas for requisite energy. However, the briquettes utilization in Kenya is relatively low compared to liquid petroleum gas (LPG) use which has rapidly expanded in both rural and urban markets. The wood value chain in other word is economic significant of forestry. This is because of the help forestry has in the achievement of sustainable development goals through the production process of wood as a renewable raw material (Schmithusen *et al.*, 2014).

According to Stolarski *et al.*, (2013), the cost involved in the production and manufacturing of briquettes revolve around raw materials, operation cost, preparation and cost of machine maintenance. According to Ferguon (2012), usage of biomass

waste residue is more effective in the minimization of pollution levels. In North America and Europe, the uptake and adoption of the briquettes as a major source of energy to meet their household and commercial needs. Sweden leads by a million tonnes annually in the manufacturing and processing of briquette use and pellet production (Young and Khennas, 2018)

In developing countries, particularly in Kenya, briquettes business stocks briquettes in market regionally, few in the local market and few briquettes for export purposes. However, due to lack of local standardization of briquettes thus making it difficult to access them in the local market and also the price tag on them is not favourable to low and middle-income earners. Globally especially in East Africa, adoption of briquette use and technology is relatively low as compared to the traditional source of energy use. This is as a result of lack of awareness, cost-effective, and easy access and availability of traditional sources such as firewood and charcoal (Ferguson, 2012; ). Therefore, the market sector, particularly in Kenya, is single-minded on decisions of customer with respect to price relationship between traditional fuels and biomass briquettes.

Introduction of briquette production has contributed to employment and capital creation therefore, reduce poverty levels and environmental stress for those country dependent on extractive industry such as Kenya. For example, Kibera, Kayole, Soweto, Kahawa and other low-income areas have benefited on the production. Research done by Mutugi and Kiiru (2015), revealed that by 2010 the people in this region were making around USD 2000 per month through the selling of charcoal briquettes. Therefore, minimizing the cooking fuel cost by about 10%.

#### ***2.9.4 Briquette use and environmental conservation***

Globally, environmental problems have called for collective action and in other words, it has taken wide viewpoints. In recent year's knowledge and awareness on environmental issues has rapidly increased with the introduction of advocacy institution, environmental bodies and multilateral environmental agreements (MEAs), and protocol; to guiding people on ways of handling environmental problem facing those (Harper *et al.*, 2017). These organisations have acquainted with terms such as environmental conservation, deforestation, and environmental protection and so on. Briquette utilization in Kenya has led to lessened pollution levels, reduced emission,

and regulation of waste generation through policy formulation like the 3rs; reduce, reuse and recycle. Briquette producer and manufacturer use the biomass waste to produce the briquette that is later used as a source of energy.

Demand for energy has enlarged considerably due to the fast population growth rate worldwide (Shaaban and Petinrin, 2014). Use of fossil fuel and coal as source energy has a severe impact on the environment, as it contributes greatly to the emission of GHGs that lead to the adverse effects of climate change felt in the world. Therefore, adoption of alternative energy source, especially biomass energy, will minimize the impact on the environment as compared to the non-renewable energy such as coal. Prolonged exposure to indoor air pollution as a result of the use of traditional fuels like firewood and charcoal causes severe pneumonia and other respiratory tract diseases. Research done by Kumar *et al.*, (2010), found out that, in developing countries, over 3 million people are still dependent on kerosene stove for cooking. This is a clear indication that briquette technology is not fully adopted in these countries.

Utilization of briquette as compared to fossil fuel and burning of coal leads to reduced amount of pollutant emission to the environment in developing countries, wood industry generate residue that has potential to eradicate poverty; through provision of alternative cooking fuels as illustrated in Cuba, Nigeria and partly in Kenya (Gominho *et al.*, 2012). However, adoption of briquette fuel and its technology is thinning out in both rural and urban areas; this is because the briquette production is dependent on raw materials that are locally available. Therefore, government engagement toward briquette production and technology is very vital; this is through policies formulation, provision of tax incentives to sole proprietor, private parastatals and most importantly formation and implementation of regulation especially on forest harvest and forest residue (that are used on briquette making) to enhance achievement of 10% target of forest cover and still have sufficient fuel supply.

#### ***2.9.5 Adoption of Briquettes in climate change mitigation***

Climate change mitigation is an important step towards meeting the future generation's energy demand. Biomass briquettes adoption, as other clean energy sources, has several benefits. Biomass briquettes adoption reduces greenhouse gases

emissions and reduces air pollution that is associated with other energy sources like coal, charcoal and use of fossil fuel in the industries.

A study was done by Owusu and Sarkodie (2016), found out that there was a reduction of 14% of emissions in 33 European countries that adopted biogas energy in the period from 1990 to 2010. This initiative had a positive result in Turkey's forest cover. Biomass briquettes being one of the clean sources of energy, like biogas, is projected to have a similar impact if adopted.

### **2.10 Benefits of Biomass Briquettes**

There are many biomass wastes available in the country that includes coffee husks, maize stalks, rice husks, maize cobs, sisal fibres among others. The biomass waste can be turned into briquettes so as to provide an alternative, sustainable energy and curb forest degradation (Rapoza, 2013; De Jong *et al.*, 2017). The briquettes burn with less smoke and have been proven to burn up to 98% efficiency if the stove is energy-saving one and up to 76% if the stove is not an improved stove (Otieno and Awange, 2014; Ali *et al.*, 2019). This is a higher efficiency as compared to charcoal and firewood that have an efficiency range of between 60-68%. They produce a low ash content because they only burn by 5% less of their original weight (Maungo and Tengnas, 2011; Mitchell *et al.*, 2020). Moreover, they are odourless as they contain a minimum evaporative gaseous substance. They leave no soot on pots and reduce household air pollution with carbon monoxide and fine particulate (Njenga and Karanja, 2014; Maneechot *et al.*, 2020). The briquettes are cheaper when cooking traditional meals like dry maize and beans, where it costs Ksh 3 to prepare a meal for a family of three as opposed to the usual cost of the smallest locally available charcoal tin at Ksh 26-50 (Liyama, 2014; Ndegwa *et al.*, 2020).



**Plate 2. 4: Biomass briquettes in a cooking stove (Source: Author)**

According to Wang *et al.*, (2016), briquette ash has soil amendment benefits. The areas that receive acid rain, due to sulfur dioxide emission from industrial activities, leads to acidification of the soils. The briquette ash has components of calcium and magnesium that neutralizes the acid (Wang *et al.*, 2016). Studies of the biomass briquettes made by the jack-machine in the Philippines produced less smoke with reduced NO<sub>x</sub> and SO<sub>x</sub> gases that are harmful to the human health and are a pollutant to the environment, the briquettes are burnt longer compared to charcoal and firewood thus, biomass briquettes are economical to charcoal and firewood (Romallosa, 2017).

#### ***2.10.1 Use of Biomass Briquettes as Mosquito Control***

Briquettes have several uses other than the usual source of energy. A study conducted by Nyakeru, 2013, in Kiambu County, found out that briquettes made from jatropha seed husks, cow dung as a binder and pyrethrin had a 100% mosquito's knockdown in indoor uses. The ratio used in that study was 3g:0.5ml:2g, a mixture of jatropha to cow dung to pyrethrin (Nyakeru, 2013; Mainali *et al.*, 2017). This shows that briquettes can benefit locals with energy and provide malaria prevention. Thus, adoption of briquettes in our community encourages environmental conservation as well as other benefits for the community embracing it.

## **2.11 Knowledge Gaps**

The review has shown that dependency on wood fuel energy has a direct impact on forest degradation and reduction of the forest cover in the country. However, from the review, there is a gap in rigorous research on the benefits of adopting alternative sources of energy on the environment and as an alternative source of income to the residents or households who are in the business of selling firewood and charcoal. It is of great importance to research the availability of alternative sources of energy and the availability of materials for making them. The research should also address the level of adoption of the alternative sources of energy and challenges the residents face in the process of adopting the alternative sources of energy as compared to the main sources of energy like charcoal.

In conclusion, the benefits of alternative energy should be researched and the households made aware that the benefits of alternative sources of energy are better than wood fuel and the socio-economic benefits are similar to the conventional sources of energy. The following chapter describes the location where the study was carried out, different features like study design, target population, sampling procedures, and how data was collected and analysed.

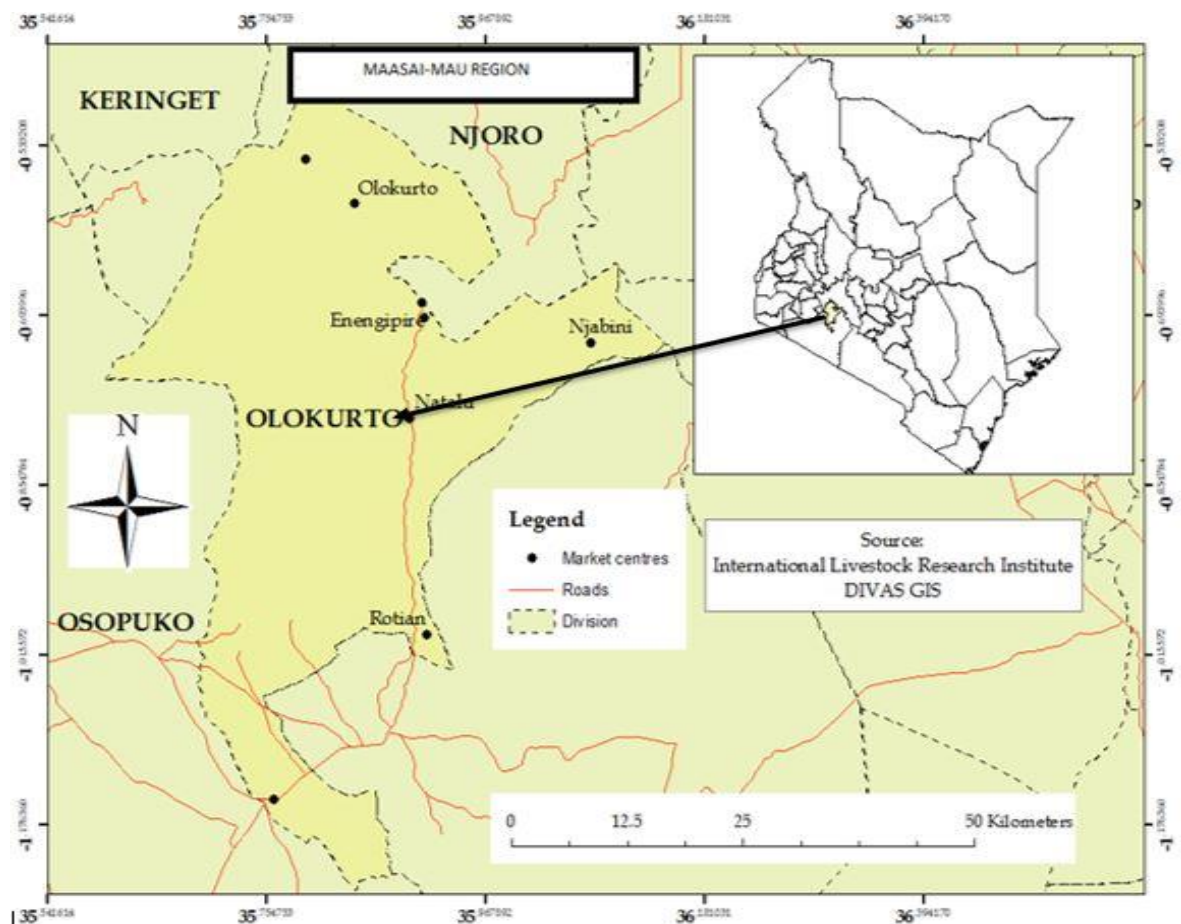
## METHODOLOGY

### 3.1 Study Area

This section is divided into the population size, location, and size of the study area, the climatic condition, and socio-economic activities of the residents.

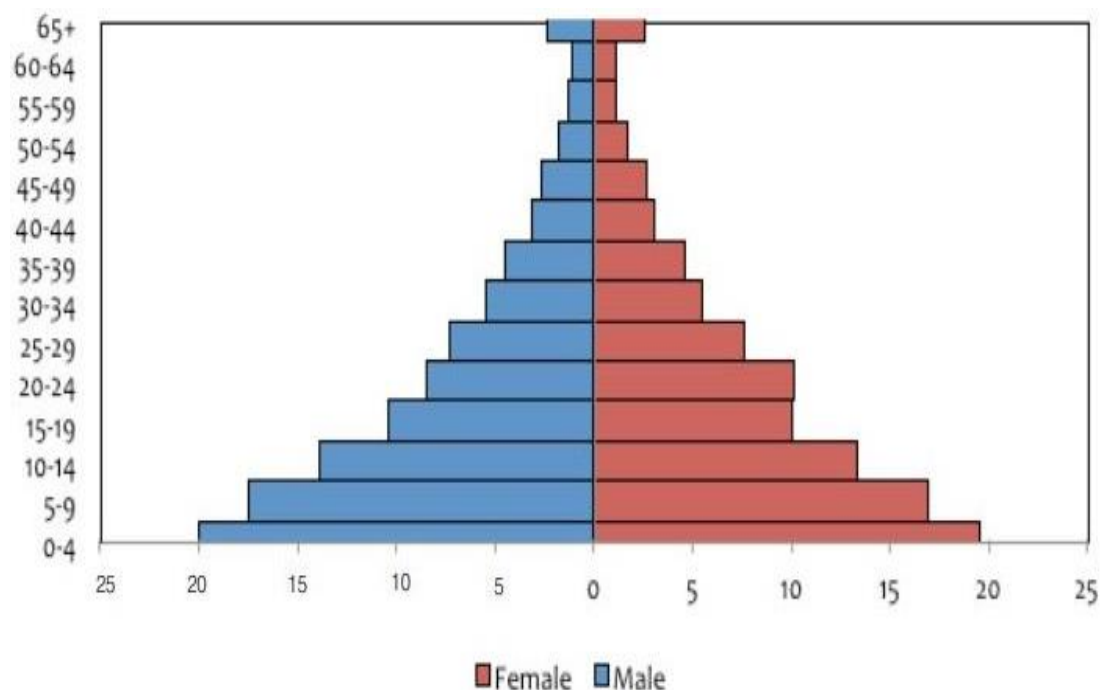
#### 3.1.2 Population, Location and Size

Maasai-Mau region is located to the North of Narok County, South of the Mau complex with 808.7ha of Mau forest falling in this region. The region covers an area of 14,154 km<sup>2</sup>. The area extends from 0°37' 01.19" S to 36°00' 59.23" E and 0° 41'09.66" E to 35° 55' 34.97" E. Maasai Mau's altitude ranges from 2000m and 2700m above sea level, with dense indigenous woodland, riverine forests and highland grasslands. The region is home to former division namely, Olokurto that is made up of three sub-locations namely Natalu, Rotian, and Enengipiri.



**Figure 3. 1** Maasai-Mau region in Narok County (*Source: ILRI DIVAS GIS, 2015*)

The region has a targeted population of 5,800 households (KNBS, 2009) and most residents are from the Maasai and Ogiek communities. According to KNBS, 2009, the census found that most households had four family members and 51% of the population composed of children aged between 0-14 years, as shown in figure 3.1 below.



**Figure 3. 2 Narok County Population Pyramid (KNBS, 2009)**

According to KNBS (2009), the total population of the study area and subsequent households is as per table 3.1 below. A similar study conducted by NEMA, 2013; and Langat *et al.*, 2016, found out that male headed households represented 63% of the total households as opposed to 37% of households headed by a female. The study found out that in Maasai-Mau region, households headed by male was 78% as opposed to 22% that was headed by female.

**Table 3. 1 Population and household size; Maasai-Mau Region, Narok**

	Total Population	Male	Female	Total Households	Female-Headed Households	Male-headed Households
Olokurto	21,033	10,586	10,447	5,800	1,276	4,524
%	100	50.33	49.67	100	22	78

According to Kenya Integrated Household Budget Survey (KIHBS), 2008, more than 33% of Maasai-Mau region's population live in poverty, although the region is home

to abundant natural resources like forests and a huge number of tourists to Mara River and Maasai Mara game reserve.

### 3.1.2 Agricultural and Economic Activities

According to the Narok County Development Plan, 2017, the county's land are divided into four, namely; agricultural land, urban land, forested land, and conservancies. Urban land encompasses towns like Ololung' a Narok and Lolgorian to name but a few, while fall under the Mara game reserve and Maasai Mara ecosystem. Forested land fall under the Mau forest and part of the Maasai-Mau region where this study was based. Some of the agricultural activities areas include livestock rearing and crop farming. Table 3.2 shows data of agricultural activities for the Narok county as KNBS, 2009.

**Table 3. 2 Livestock population in Narok County, KNBS 2009, census**

Sheep	Cow	Goats	Donkeys	Poultry	Camel
1.2 million	1.4 million	0.8million	98,196	0.5million	608

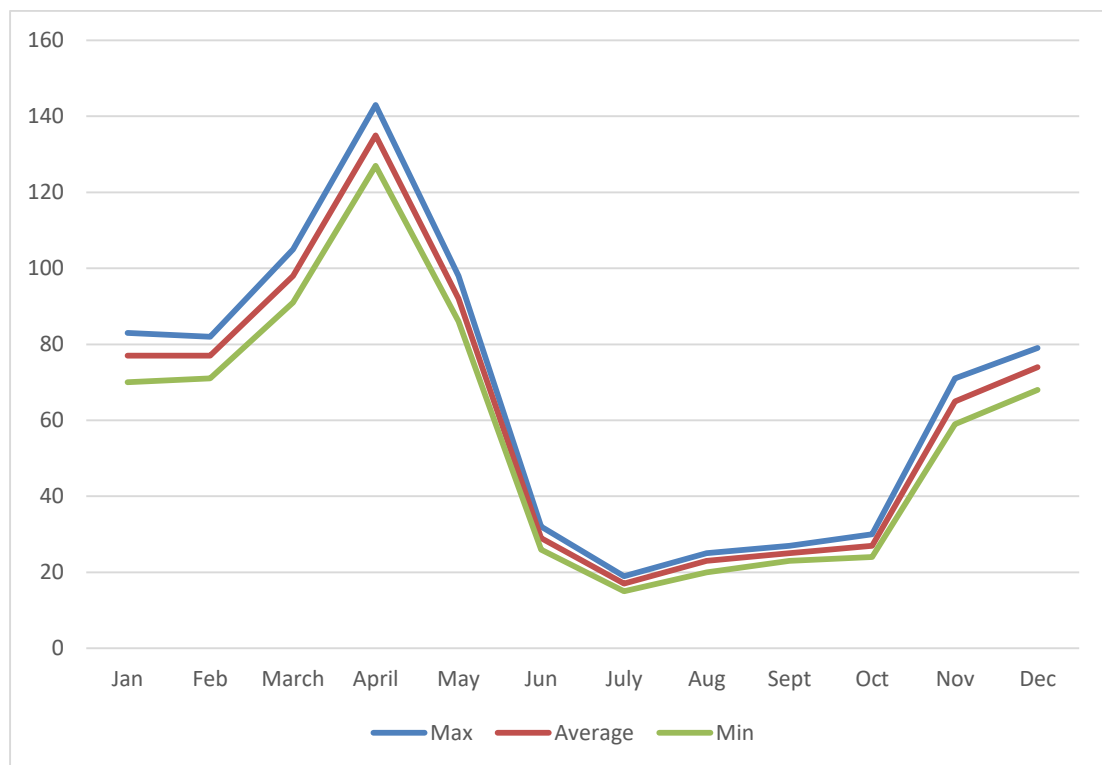
The type of crops grown in the study area include wheat, maize, barley, Irish potatoes, beans, and other horticultural crops (Sainepo *et al.*, 2018). Livestock keeping and crop farming is the major source of employment in the region (Mashara, 2018).

Tourism activities is another type of economic activity in the region as the region is home to Mara game reserve and Mara river. Mara game reserve is home to wild animals like lions, elephants, buffaloes, cheaters, leopards, antelopes among others. While Mara river attracts vast numbers of local and international tourist, who come to view the migration of wildebeest into Serengeti game reserves (Sainepo *et al.*, 2018). These tourism activities contributes highly to the self-employment of youths and women in the region who have curio shops, hotel industry and showcasing of the cultural activities in the region (Mashara, 2018).

### 3.1.3 Climate

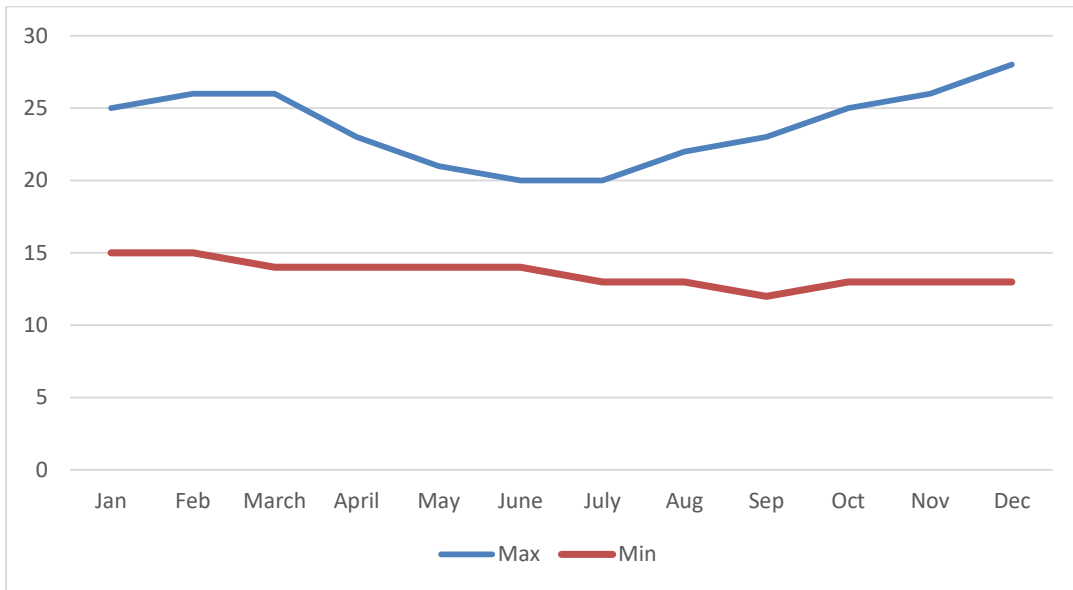
The Maasai-Mau region has four agro-climatic zones, namely; semi-arid, semi-humid, sub-humid, and humid zones. The average annual rainfall for the region ranges from 2,500mm for the long rainy season in the months between February to June and 500mm during the short rainy season in August to December.

This region is an important water catchment area forming the upper catchment for Ewaso-Nyiro and western catchment for Mara River. This area is part of the Mau ranges that are among the major water towers in Kenya. Table 3.3 below shows maximum, average, and minimum rainfall as per the study conducted by FAO, 2018, for the years between 1965 to 2015.



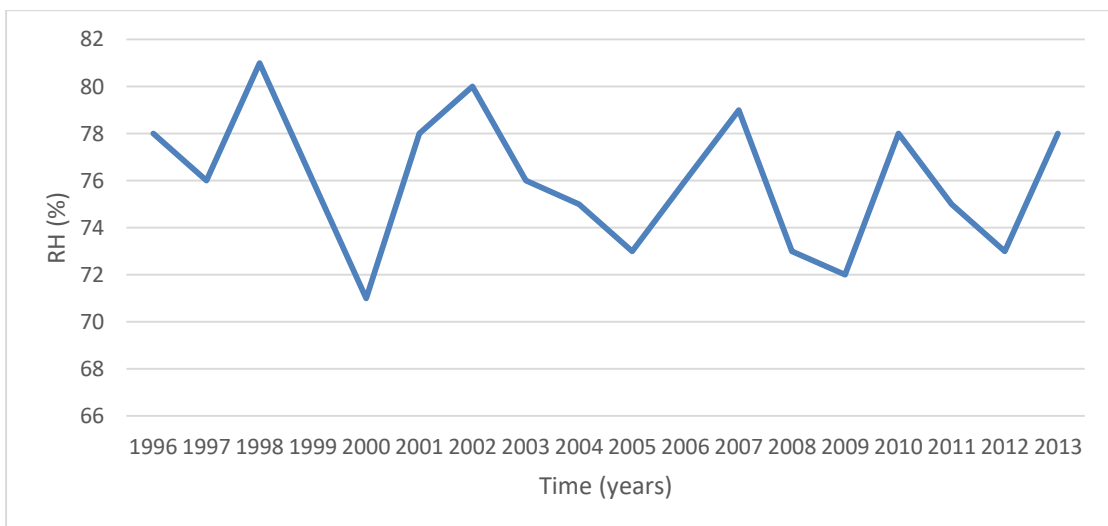
**Figure 3. 3 Maasai-Mau max., average and min. rainfall (Source: FAO, 2018)**

According to FAO (2018), the average temperature for the study area has had an increasing trend over the past decades with a minimum of 8°C and a maximum of 28°C as shown in figure 3.4 below.



**Figure 3. 4 Max and Min. temperature (°C) in Maasai-Mau region (Source: Mutugi & Kiiru, 2015)**

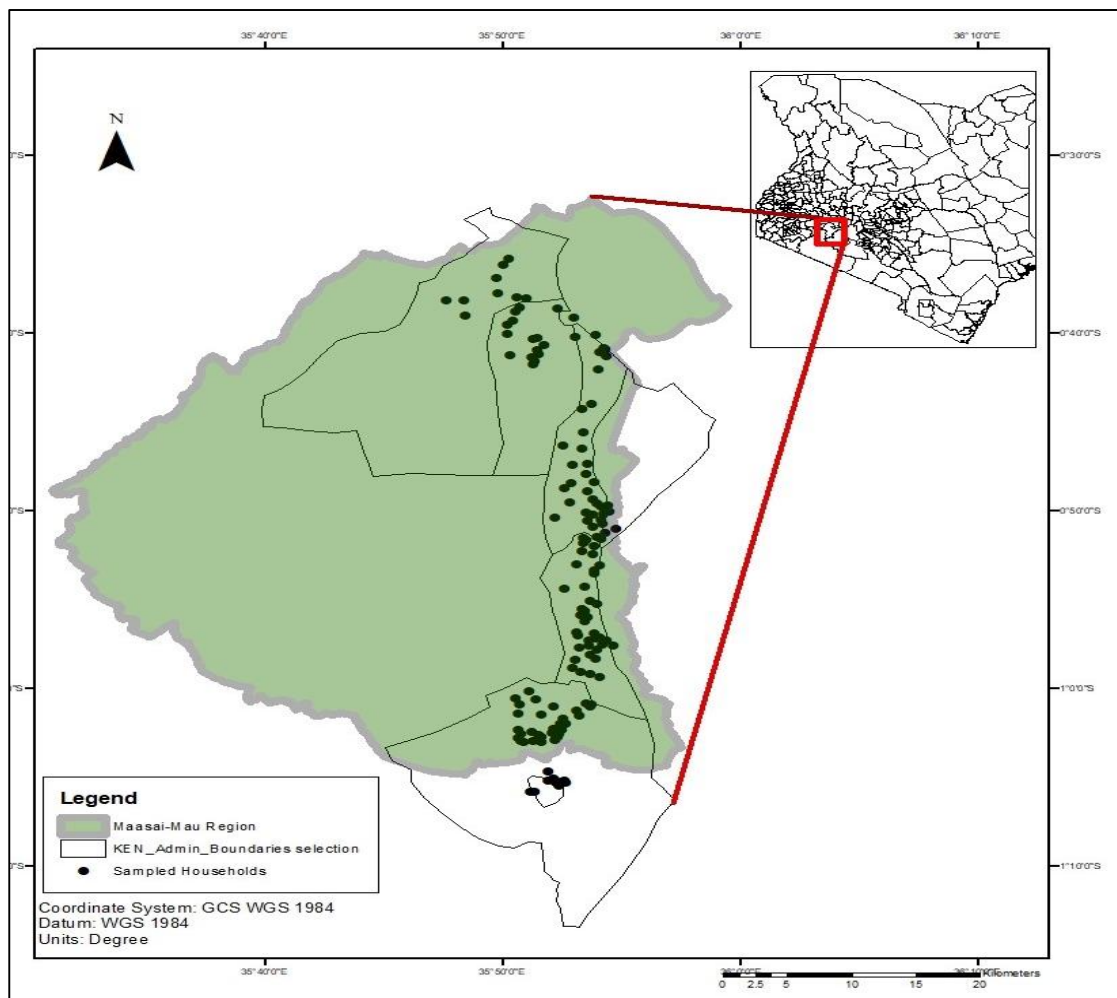
According to Mutugi and Kiiru, 2015; Williams, 2020, the relative humidity (RH) of the study area has been decreasing over the last decades with the highest recorded at 81% in 1998 and lowest at 71% in 2000. The relative humidity trend for the period 1996 to 2013, for the study area, is as per figure 3.5 below.



**Figure 3. 5 RH (%) of the Study area for 1996-2013 (Source: Mutugi & Kiiru, 2015)**

### 3.2 Research Design

An exploratory survey was conducted and information on demographics of adults in each homestead, sources of energy and economic livelihood collected. Use of stratified sampling technique was used to stratify the area into six residential blocks as per administrative sub-locations and major villages. Cluster and simple random sampling were used to select the ward used in the study. Urban and suburban areas were grouped to form a cluster. For urban and sub-urban cluster, purposive random sampling was employed to collect information from it, this agrees with a study carried out by FAO, 2018, that states that urban centers are the highest consumer of wood-fuel energy. Also, purposive random sampling techniques were used to collect data from key informants found within the study area.



**Figure 3. 6 Sampled households from the study area (Source: Author, 2020)**

### **3.3 Target Population**

The targeted population involved a total household of 5,800 as per (KNBS, 2009) within the Maasai-Mau region that lies in Olokurto Ward of Narok County. Majority of the households use woody fuel as the main source of energy. The woody fuel that includes firewood and charcoal is gotten from the Maasai-Mau region forest that lies in the study area. The ward that was randomly sampled for this study was Olokurto ward that comprises of six villages namely; Olokurto, Entiyani, Naituyupaki, Iltuati, Ilkeremisho, and Ilmolelian.

### **3.4 Sampling Procedure**

The study engaged two sampling procedures:

- a) Systematic random sampling- this method was used to collect data from households within the study area. Every household was given equal opportunity with the head of the family responding to one questionnaire, and if one household declined to be interviewed, the next household was given that opportunity. According to Farhat and Robb, 2018, systematic random sampling is spread more uniformly over the entire population, and it provides more information as opposed to simple random sampling.
- b) Purposive sampling- this method was used to collect data from the main key informants in the study area. The main vital informants interviewed were from the briquette making groups, officials from the non-governmental organizations with clean energy projects in the area, and managers of Narok hotels that use briquettes as their primary source of energy.

Structured questionnaires were administered to collect data from households and key informants. Both open-ended and close-ended questions were used. Questionnaires had two sections; the first section targeted the respondents' profile data while the second section sought a specific response from the respondents.



**Plate 3. 1: Maa-Briquette organization in Narok County (Source: Author, 2019)**

Structured interviews used to get data from key informants, namely Kenya Forest Service officials working in the study area, the National Environmental Authority (NEMA) officials, and employees of relevant Non-Governmental Organization working in Maasai-Mau region like the Kenya Working Group (KFWG), Ogiek Community Briquette Makers and Maa-Briquettes leaders.

### 3.5 Sample Size

The sample size was determined using the formula recommended by Nassiuma (2000) as follows;

$$n = \frac{NCv^2}{(Cv^2 + (N - 1)e^2)}$$

Where;            n=Sample size  
                      N=Population of households in the study area  
                      Cv=Coefficient of variation (at 0.5)  
                      e=Tolerance of the desired level of confidence, take 0.05% at 95% confidence level.

Therefore; using the equation above, one gets

$$n = \frac{5,800(0.5)^2}{(0.5^2 + (5,800 - 1)0.05^2)}$$

$$n = 98.32$$

(Nassiuma, 2000)

Therefore, as per the formula, a rounded figure of 100 households was selected for this study.

### 3.6 Data Collection Instruments

The study employed different methods to collect data. The questionnaires were administered to household heads in the study area. Interviews were conducted on the key informants from the county ministry of environment and energy, NEMA officials in the region, officials of relevant NGOs such as briquette making initiatives and groups that work with the Maasai-Mau region community in adopting of alternative sources of energy in the study area. Key observations made by the researcher were crucial in this study too. Lastly, relevant secondary information was obtained aimed at answering the research questions.

### 3.7 Data Collection Procedure

The research was approved by Kenyatta University graduate school, giving the researcher permission to carry out field data collection. At the county level, the study was approved by Ward heads and the village administrators, as the data and information was to be collected from the household heads in their area of jurisdiction. The researcher carried early pre-site visit two months earlier to be conversant to the study area. Lastly, the key informants and the household heads were assured of the

information confidence and that the information provided was for academic purpose only.

### **3.8 Pre-testing Research Instruments**

Pilot study was carried in the study area to randomly selected key informants and heads of household, where their response was analysed to check on the suitability and relevance of the questionnaires and interviews, and if the instruments needed any adjustment and make the instruments better.

### **3.9 Data Analysis**

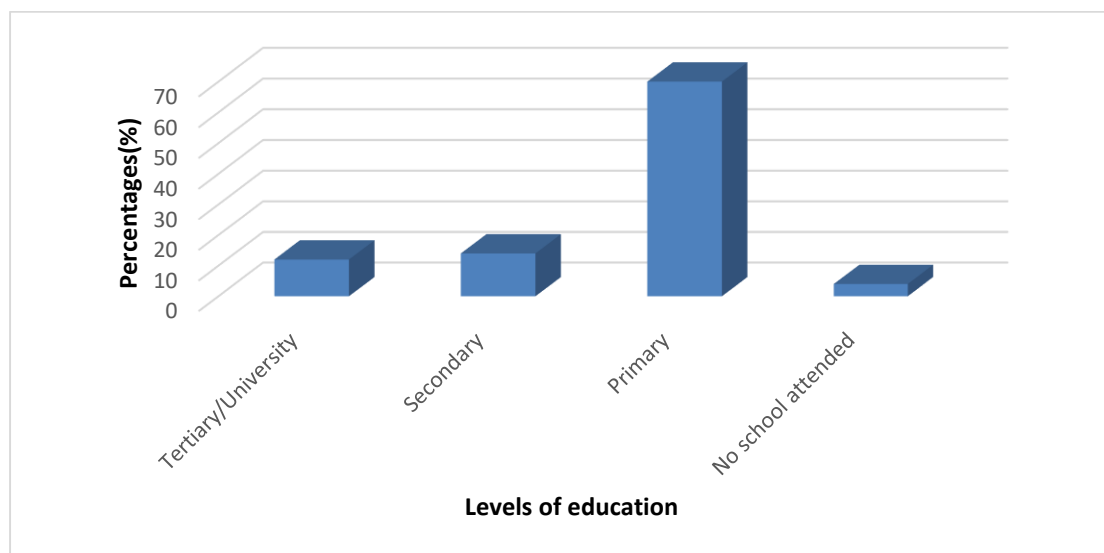
Data collected was summarized and analysed on excel spreadsheets and presented in the Chi-square format. The data analysis included both descriptive statistics and analytical components with the use of several statistical tools to present data from the study area. Descriptive statistics were used to analyse qualitative and quantitative data obtained from closed and open-ended questions. The study used means, standard deviation, relative frequencies, and percentages to interpret the quantitative data. The respondents' information that required them to rank was coded and by the use of Likert scale, where the magnitude was determined by the weighted means (W.M). According to Yamene, 1967, weighted mean is calculated by multiplying each weight by matching value, the results are summed up then divided by sum weights. Qualitative data collected was coded and clustered into common themes for subsequent statistical analysis. The Statistical Package for Social Sciences (SPSS) computer software was used for quantitative analysis to generate data used for subsequent data analysis. Additionally, the significant differences between any two means were tested by the significant difference of means. The actual results were analysed by Chi-Square at 0.05 confidence level.

## RESULTS AND DISCUSSION

### 4.1 Respondents Profile

The study was conducted in Maasai-Mau region, Narok County, Kenya. A total of 100 respondents were interviewed, where 90 were household heads, and 10 were key informants who included leaders from non-governmental organizations that deal with energy issues in the region, ministry of environment and natural resources representatives, heads of the forest block, heads of local briquette making group and local hotels that use of briquettes as their main source of energy. The response rate represents 100% acceptance ratio, which is above the 65% level set by Dolsen and Machlis (1991). Out of the total household respondents, N=100, 47% were male, and 53% were female.

The gender difference is acceptable, considering that Maasai-Mau region is a livestock keeping area where the male population has the duty of grazing the animals in the field. Also, according to KNBS, 2009, male from the region were found to have moved to the urban areas in search of employment, leaving the women and their children in the homesteads.



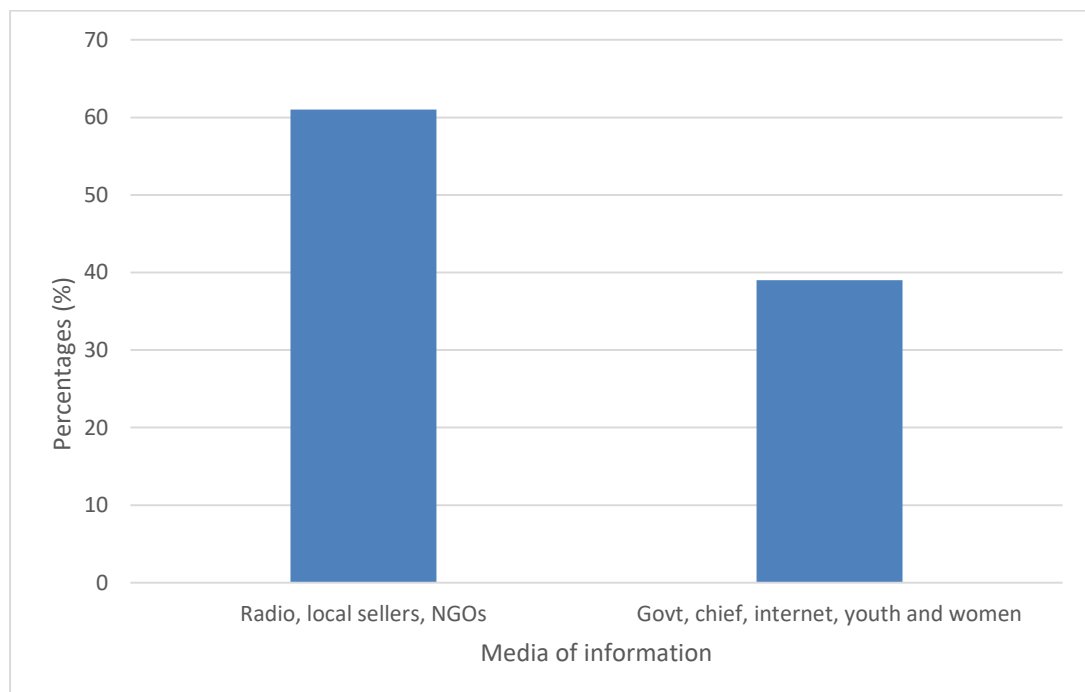
**Figure 4. 1 Respondents' education level**

Figure 4.1 shows that among the household heads who responded, n=100, 12% had tertiary and university education, 14% of the respondents had secondary education, 70% of the respondents had primary education and 4% of the respondents had no formal education. From the study it indicated that 96% (n=96) of the respondents had

primary education and above, implying that education had a role in the response being given for each question responded in the research tools applied.

The education level was important to the study as the study's hypothesis was analysing the relationship between relative low education and the challenges of adopting biomass briquette as alternative source of energy. They study found out that education level of the household heads had no statistical evidence to adoption levels of alternative source of energy in the study area. However according to Mutune & Nunow, 2018, a study done in Eburu and Sururu forests, found out that level of education had direct impact on the forest, as relatively low level of education meant that the respondents depended on the forests for economic reasons, as they rate of formal employment was low.

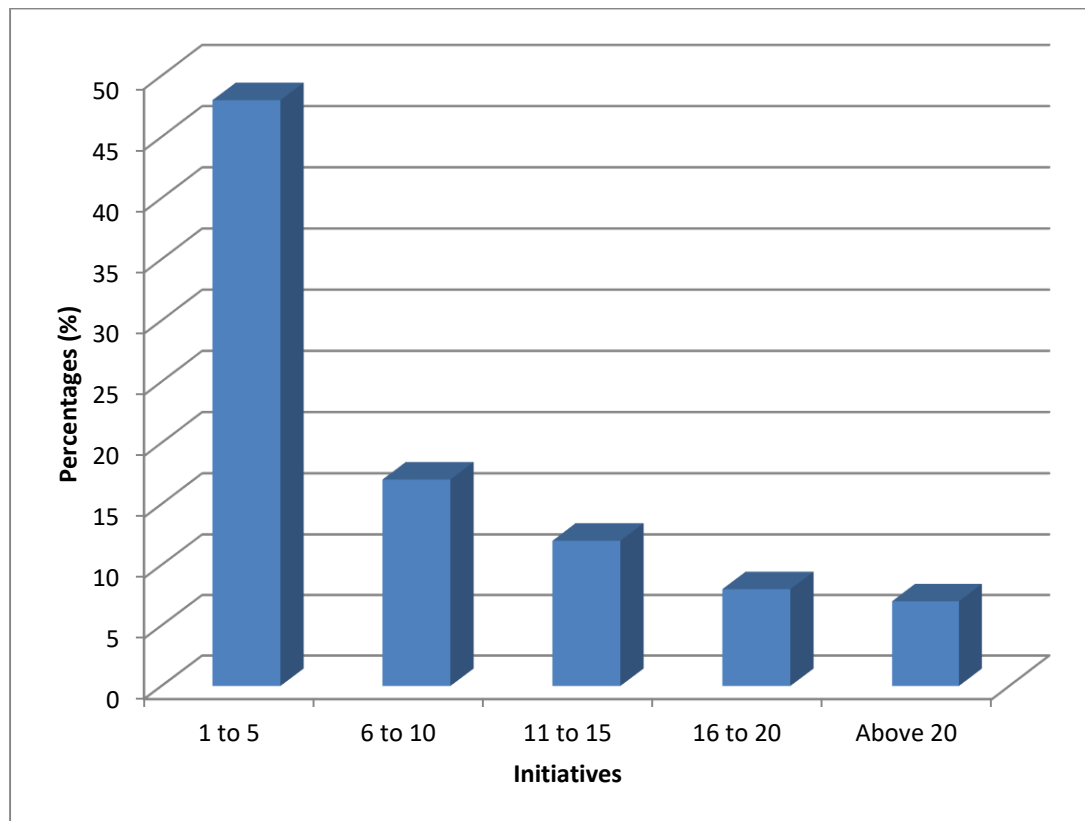
From figure 4.2 below, the respondents (N=100) said a combination of radio, local briquette sellers, and local NGOs were the main sources of information on briquette making and adoption in Maasai-Mau region representing 61% (n=61) of the respondents, and 39% (n=39) said they learnt about briquettes from the local government authorities, youth and women groups, chiefs and the internet.



**Figure 4. 2 Media used by respondents to learn of briquettes technology and usage.**

#### 4.2 The level of adoption of biomass briquette in Maasai-Mau region

The study found out that the number of known briquette makers and sellers; known as briquette initiatives, in Maasai-Mau region were ranging from 1 to 15, whereby 48% of the respondents (N=100) said there are 1 to 5 initiative in their locality, while 17% of the respondents said they know of 6 to 10 initiatives in their locality, with 8% of the respondents stated that they knew of 16-20 briquette making initiatives in their locality with 7% saying over 20 initiatives are found in Maasai-Mau region.



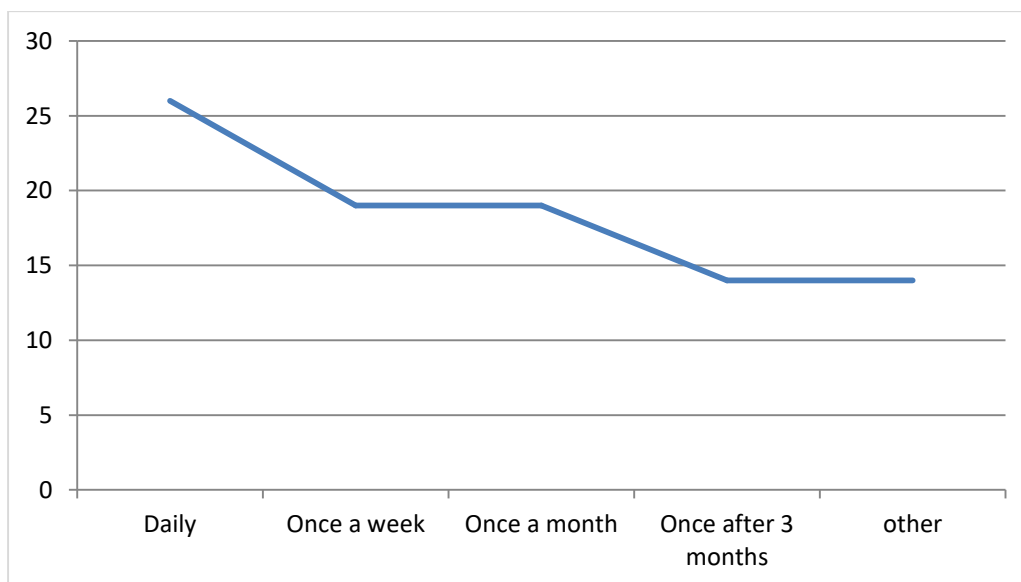
**Figure 4. 3 Maasai-Mau region briquette initiatives**

According to Egeru (2016), briquette makers and sellers are not known to the respondents and local residents, as they lack funds to market their initiative and some of them produce the briquettes for domestic use only. The study affirms that in a rural setup, the active briquette initiatives were 1 to 5, this is as per the research conducted by Mugo (2013), in Ruriu region Kiambu County. Where he found out that the active briquette making initiatives were 3 in number, with small scale and noncommercial initiatives existed too.

Another study by Karanja *et al.*, (2013), in Soweto slum Nairobi found out that most briquette initiatives were done by self-help groups. The study found out that a total of

seven self-help groups, that came together to create employment, revenue, and source of energy, was in Soweto area. According to Mwampamba *et al.*, 2013; Lohri *et al.*, 2019, they argue that in the larger East Africa region, there are three major industry leaders in the briquettes making, namely; Chardust Ltd of Nairobi, Kenya, Cassandra Ltd of Rwanda and East Africa Briquetting Co of Tanga Tanzania. Though he argues that there may be several initiatives in the market who produce briquettes in small scale or produce with the aim of serving local population, similar to Wild Living Resources projects along the Kenyan coastal and Western Uganda Charcoal Briquetting Project, Mwampamba *et al.*, (2013), that assist the local communities to meet their household energy demands and the surplus is sold for economic purposes. The scholar argues that the briquette industry has the potential of creating employment for the youth and women, as per figure 4.4 below outlines.

This relatively low level of briquette adoption cuts across several studies done by (Mwampamba *et al.*, 2013, Njanga *et al.*, 2013, Mugo, 2013 and Ndengwa *et al.*, 2020), who agree that briquette adoption in Africa, East Africa, and Kenya has not penetrated as expected as the major making and distributors of the same range between 5 to 10 in Africa and 1 to 5 in East Africa. This is as opposed to 75 in India by 1997, Kathuria and Sonia (2012).



**Figure 4. 4 Briquette household usage in Maasai-Mau Region**

Figure 4.4 above shows the household usage of briquette in Maasai-Mau region, Narok County, Kenya. The study found out that 28% of the respondents, n=100, use biomass briquettes daily as their main source of energy, while 22% of the respondents

said they use them once a week. While 20% of the respondent's briquettes once a month and 14% of the respondents use the briquettes more than three months in their households and 16% of the respondents said they have never used the briquettes in their homesteads. This shows that briquette technology has not penetrated the study area.



**Plate 4. 1: Biomass briquette use in a hotel in Ololung'a Narok (Source: Author, 2020)**

A study conducted by Ngusale *et al.*, 2014, found out that 78% consumers who attended a series of informal conferences in 2011, lacked knowledge of briquette making and were confused between a briquette and charcoal. The research argued that more education campaigns and issuing of free briquettes to residents to enable them to have first-hand experience on benefits of briquettes. Kiruki *et al.*, 2019, also argued that county government should set up one stop shops to champion briquette adoption, education and supplying briquettes to the consumers was to ensure the technology and encourage adoption of the same in the local area. Another study by Okaka and Apil, 2013; Korir, 2019, agree that with most respondents, 88.5% of the respondents, were unaware that charcoal dust can be used in making briquettes, where 85.2% of the charcoal dealers dispose the charcoal dust, 11.1% take it home and 3.7% share it with neighbors.

According to Kathuria and Sonia (2012) in 1997 only 75 briquette making initiatives were in India but by 2007, the initiatives had increased to 250 as the locals understood the technology behind briquette making and the government increased awareness to the local communities on the benefits of briquettes as opposed to wood products. According to Shukla and Vyas, 2015, the global alternative energy production by 2014 was 58% from the wind, 25% solar photovoltaic, 16% biomass fuel and 1% from concentrated solar power.

#### **4.3 The challenges and hindrances do Maasai-Mau residents face in the adoption of biomass briquettes as a source of alternative energy in Maasai-Mau region**

This objective is divided into two sections namely the challenges and hindrances that the residents of Maasai-Mau region face in the process of adopting to biomass briquette technology. Even though the challenges and hindrances have a close similarity, for the purpose of this research, the sections were separated as the two were captured and analysed separately, as discussed below. The study researched on the challenges youths and women face in the process of adopting this technology as the youths are the majority in the charcoal burning business in the region and the women are the most affected in the consumption of the wood fuel like charcoal. Women are also majority small scale charcoal sellers within the local community and the nearby towns like Narok and Olulunga centres (KNBS, 2009; FAO, 2018).

##### ***4.3.1 The challenges Maasai-Mau residents face in adoption of biomass briquettes***

Table 4.1 shows the ranking of the challenges youths and women face in the study area that hinders them from adopting the biomass briquettes as their main source of energy and as a source of employment. From a weighted mean of 351.29, 66.67%, n=26, of the respondents said that lack of funds was the highest challenge youths and women face in the adoption of biomass briquettes as their source of alternative energy in Maasai-Mau region. From a weighted mean of 348.72, 56.41% and 35.90% rating it as highest and moderate challenge respectively, agreeing that monopoly in combination with unfair competition from already established briquettes making enterprises and individuals. They argued that the established individuals are not ready to accept new entrant into the business and they work hard to destabilize the prices so as they dominate the already market.

The weighted mean of 341.02%, 58.97% and 28.21%, for highest and moderate challenges respectively, agreed that lack of experts and mentors was the second highest challenge. The respondents ranked education level the third highest challenge with 341.01 weighted mean with 61.54%, n=24, of the respondents ranking highest challenge. They argued that education forums assist in unlocking the potential of the youths and women and lack of it leaves them unaware of the process of adopting briquette technology or the market. These findings agree with several scholars who have studied challenges Africa faces in the adoption of briquette technologies, according to Nyakeru, 2013, several youth projects on briquettes have been started in Kenya, but 60% of them have failed due to donor withdrawal. He argues that the 40% is sustained by good leadership that ensures that any revenue is infested back until the projects stabilize, agreeing with Mwampamba *et al.*, (2013), who found out those major organizations in East Africa, that makes briquettes, employs 974; casual and permanent, thus adoption of this technology in Maasai-Mau region will be a source of employment.

Another study by Otieno and Awange (2014), argues that challenges that face youths and women in Kenya include high machine maintenance, poor planning of the projects and lack of trained experts to drive community briquette adoption. He states that briquette producers in Kenya lack a common forum in which they can voice their agendas and boost their industry. A study by FAO (2018), found out that several briquette making projects were initiated in Africa in period 2007-2011, with the aim of creating employment for youths and women. The study found out that 68% of the projects failed to take off due to national governments failing to disburse funds for training and buying of machines. The rest were in their initial phases due to lack of stakeholder involvement, community participation and lack of aggressive awareness campaigns to educate the youths and women on the benefits of such projects.

Table 4.1 shows the analysed data from the Likert scale where the respondents ranked the challenges they face in the process of biomass briquette adoption in Maasai-mau region, where the highest challenge was ranked as 4, moderate challenge ranked as 3, slight challenge ranked as 2 and least challenge ranked as 1. The magnitude was measured by the use of weighted mean (W.M) that gives better relative importance of

the rankings as opposed to relying on percentages and simple averages (Yamene, 1967).

**Table 4. 1 Challenges youths and women face in adoption of biomass briquettes**

Challenges of adoption for youths and women										
	4		3		2		1		%	
	n	%	n	%	n	%	n	%		W.M
Lack of government support	13	33.33	15	38.46	8	20.51	3	7.69	100	297.41
Lack of practical training	22	56.41	12	30.77	3	7.69	2	5.13	100	338.46
Limited access of information	22	56.41	12	30.77	3	7.69	2	5.13	100	338.46
Lack of funds	26	66.67	8	20.51	4	10.26	1	2.56	100	351.29
Lack of mentors and experts	23	58.97	11	28.21	3	7.69	2	5.13	100	341.02
Traditional segregation	11	28.21	14	35.90	9	23.08	5	12.82	100	279.52
Restriction in adoption regulations/policies	13	33.33	15	38.46	8	20.51	3	7.69	100	296.81
Lack of a common association	20	51.28	9	23.08	8	20.51	2	5.13	100	320.51
Relatively low education forum	24	61.54	8	20.51	6	15.38	1	2.56	100	341.01
Limited market	18	46.15	13	33.33	4	10.26	4	10.26	100	315.37
Limited involvement in policy making	19	48.72	14	35.90	4	10.26	2	5.13	100	328.23
Monopoly/unfair competition	22	56.41	14	35.90	3	7.69	0	0.00	100	348.72

NOTE: N=100, 4=highest challenge 3=moderate challenge 2=slight challenge 1=Least challenge

This study agrees with a study conducted by (Okaka and Apil, 2013) that found out that the challenges the youth and women face in East Africa were lack of access to policy information 30.8%, lack of market opportunity 30.8%, lack of finance for new technology 11.5% and lack of skills training 26.9%. Most respondents 57.7% were unaware of the biomass energy, technology and resources policies, the finding that agrees with this study where 71.99% of the respondents said they were faced with the challenge of harsh policies and regulation relating to biomass briquette adoption in

Kenya that are not clear and does not guide them to meet the required international standards. A study by Mutugi and Kiiru (2015), conducted in Kenya, found out that one briquette producer in Nairobi uses South African regulations in order to meet the exportation standards. The same situation, according to Otieno and Awange (2014), is in Uganda that has adopted the South African briquette standards while exporting their briquettes. This presents a bureaucratic challenge to small scale briquette producers as they cannot afford certification costs.

According to Otieno and Awange (2014), briquette producers lack a forum in which they can voice their common agenda so as to boost their industry. The scholar argues that Kenya lack a briquette owners association, that supports the needs of the existing producers and education forums for those willing to start producing the briquettes. This agrees with the study conducted by Mutugi and Kiiru (2015), that found out that major producers were fighting to form a board that was to come up with strict rules and regulations to secure the market and stops the briquettes from flooding the market.

#### ***4.3.2 The hindrances Maasai-Mau residents face in adoption of biomass briquettes***

Table 4.2 shows sources of hindrances to adoption in Maasai-Mau region, Narok County, Kenya. From the table, six statements were sampled, and their perception was determined through the magnitude of the respondents' response represented as 4 for highest hindrance, 3 for moderate hindrance, 2 for slight hindrance and 1 for least hindrance. From a weighted mean of 374.33, lack of briquette making skills with 76.92% and 20.51%, for highest hindrance and moderate hindrance respectively. From a weighted mean of 369.03, lack of awareness with 82.05% and 10.26% for highest and moderate hindrance respectively.

**Table 4. 2 Source of a hindrance to adoption in Maasai-Mau region, Narok.**

Hindrance to adoption										
	4		3		2		1			
	n	%	n	%	n	%	n	%	Total %	W.M
Poverty	17	43.59	13	33.33	8	20.51	1	2.56	100	317.93
Education level	24	61.54	8	20.51	2	5.13	5	12.82	100	330.77
Lack of awareness	32	82.05	4	10.26	1	2.56	2	5.13	100	369.03
Lack of briquette making skills	30	76.92	8	20.51	1	2.56	0	0.00	100	374.33
Briquette availability	15	38.46	14	35.90	8	20.51	2	5.13	100	307.69
Stereotype to briquette making materials	9	23.08	17	43.59	8	20.51	5	12.82	100	276.93

Note: N=100, 4=Highest hindrance, 3=moderate hindrance, 2=slight hindrance, 1=least hindrance

Education level was the third rated with a weighted mean of 330.77, where 61.54% of the respondents agreed that it was the highest hindrance. The respondents agreed that poverty; briquette availability and stereotype to briquette making materials were not highest hindrances with 317.93, 307.69 and 276.93 weighted mean respectively. From the table, 43.59% of the respondents felt that poverty was the highest hindrance, with 38.46% agreeing that briquette availability was the highest hindrance and 23.08% rating stereotype to briquette making materials as the highest hindrance to briquette adoption in Maasai-Mau region.



**Plate 5. 1: Mixing of sawdust and charcoal dust (Source: Maa-Briquettes Narok)**

Some of the stereotypes captured from the study was that briquettes are associated with poverty and the process of making them was a dirty one as shown by plate 7 above.

These findings agree with a study done by Mugo (2013) that reveals that level of awareness affected the uptake of briquette technology in Ruiru County, Kenya, with 70% of the respondents saying they were not aware of the briquette. Also, a study by Ngusale *et al.*, 2014, agrees that most consumers, 78%, lacked knowledge of briquette making and were confused between a briquette and charcoal.

#### **4.4 The availability of biomass briquette making materials in Maasai-Mau region**

The availability of biomass briquette making materials was measured using six materials, namely, molasses; saw dust chippings, charcoal dust, maize cobs, bean straws and potato waste. The respondents were asked to rank the materials in a three rate scale of readily available, moderately available and least available. The means of all the items in table 4.3 were within 1.89 and 1.38.

The majority of the respondents agreed that saw dust chippings were readily available 84.61% and 10.26% moderately available. With a mean score of 1.56, maize cobs

were rated to be available in the region with 69.23% of the respondents saying it was readily available and 25.64% saying it was moderately available. Since the region still ranks charcoal, see table 4.3 below, as the main source of energy, most of the respondents 79.49% readily available, said charcoal dust was available in the region. Most respondents, readily available 53.85% and moderately available 30.77% with a mean score of 1.68, agreed that potato wastes are also available in the region. Bean straws with a mean of 1.89 were evenly ranked across all the ratings with 20.51% saying it was readily available, 51.28% saying it was moderately available and 28.21% saying it was the least available material in the region.

**Table 4. 3 Availability of biomass briquette making materials in Maasai-Mau region**

Item Statistics					
	Rank in %				
	Mean	S.D	3	2	1
Molasses	1.76	.722	46.16	38.46	15.38
Saw dust chippings	1.38	.659	84.61	10.26	5.13
Charcoal Dust	1.56	.803	79.49	7.69	12.82
Maize cobs	1.46	.649	69.23	25.64	5.13
Beans Straws	1.89	.761	20.51	51.28	28.21
Potato waste	1.68	.784	53.85	30.77	15.38

N=100, 3=readily available, 2=moderately available, 1=Least available

This findings agrees with a study done by Mutugi and Kiiru (2015), who tested calorific energy, the length of cooking a mixture of 1kg maize and beans and time to fully burn to ashes. This research found out that biomass briquettes made of charcoal, waste paper, and potato wastes were the best. It took 11minutes to fully ignite and 3 hours 09minutes to fully burn into ash, as compared to charcoal that takes 11 minutes to fully ignite but burns 1hour 57 minutes to fully burn to ash and, briquette made from saw dust chippings and maize cobs that took 15 minutes to fully ignite. The author concluded that using charcoal requires one to keep on adding more charcoal

until the meal is completely cooked as opposed to biomass briquettes. Another study done by Mugo (2013), who conducted a study Ruiru County on the awareness of biomass briquettes, found out that 70% of the respondents were not aware of the briquette and those aware thought briquettes were a poor man's source of energy due to the low pricing to charcoal.

#### 4.4.1 Sources of household energy in Maasai-Mau Region

Table 4.4 shows the ranking of the source of energy as rated by household heads, n=92, in the region. From the weighted mean of 370.65, 83.68% felt that charcoal was the main source of energy in the households from the rates of moderate, frequent and always usage of charcoal.

**Table 4. 4 Ranking of the household source of energy in Maasai-Mau region.**

Household energy usage												
	5*		4*		3*		2*		1*			
	n	%	n	%	n	%	n	%	n	%	n	W.M
Charcoal	32	34.78	20	21.74	25	27.17	11	11.96	4	4.35	92	370.65
Firewood	35	38.04	21	22.83	15	16.30	11	11.96	10	10.87	92	365.22
Briquettes	20	21.74	11	11.96	16	17.39	19	20.65	26	28.26	92	278.26
Paraffin	6	6.52	14	15.22	13	14.13	32	34.78	27	29.35	92	234.78
LPG(Gas)	16	17.39	9	9.78	17	18.48	21	22.83	29	31.52	92	258.70
Electricity	11	12.09	15	16.48	8	8.79	24	26.37	33	36.26	91	241.76
Crop residues	14	15.22	17	18.48	17	18.48	22	23.91	22	23.91	92	277.17
others	3	3.26	4	4.35	4	4.35	2	2.17	4	4.35	92	55.43

5\* Always use, 4\* frequently use 3\* moderate use, 2\* rarely use and 1\* do not use

This was opposed to second ranked source of firewood with 77.17% from a weighted mean of 365.22, from moderate, frequent and always used in their households. Firewood was the most preferred in households in the remote areas of the study area, where girls the duty of collecting was left to girls. The results also indicate that briquettes were average, with 51.09%, from 278.26, the rating for moderate, frequent and always used in the region.



**Plate 6. 1: Sacks of charcoal at Olokurto centre. (Source: Author)**

The respondents who adopted briquettes as an alternative source of energy, were mostly based in town setting and adjacent areas. Most respondents (77%) said, they preferred briquettes because of the cost, burns longer compared to charcoal and paraffin and produces less smoke.



**Plate 6. 2: Briquettes in drying racks and sacks (Source: Author)**

Paraffin was the least, ranked among the major sources with a weighted mean of 234.78 with 35.87% agreeing usage was always, frequent and moderate. Even though the majority ranked charcoal as the main household energy source, when asked about the merits and demerits of their choice of energy, 34%, n=34, said charcoal is expensive, 23%, n=23, said charcoal was smoky, 17%, n=17, said it burnt with a lot of ash, with 26%, n=26, saying it burns with a lot of soot and one needs more to cook food for a family of four.



**Plate 7. 1: Burning briquettes on a *jiko* in Ololunga CFA. (Source: Safi Charcoal)**

This is as opposed to 12%, n=12, who said briquettes are expensive, 1%, n=1, who said briquettes burn with a lot of smoke, 30%, n=30, said briquettes are affordable, 28%, n=28, saying briquettes burn with less ash and 27% said briquettes burn longer and 14% agreed that briquettes burn with less or no soot as compared to charcoal and firewood.

#### 4.5 Hypotheses Testing

*Ho: Relatively low education is the primary hindrance to the adoption of biomass briquettes as an alternative energy in Maasai-Mau region*

Table 4.5 shows a cross tabulation of education level and briquette usage in Maasai-Mau region, Narok County, Kenya. The table shows a chi-square test at 6 degree of freedom and the critical chi square is  $\chi_6^2 = 9.866$  at 0.05 level of significance.

#### Descriptive Statistics

	N	Mean	S.D
<b>Education level</b>	100	1.90	1.106
<b>Poverty</b>	100	1.84	1.089
<b>Stereotype to briquette making materials</b>	100	1.96	.994
<b>Lack of briquette making skills</b>	100	1.58	.945
<b>Briquette availability</b>	100	1.60	.932

The above descriptive statistics were used to investigate the Ho that relatively low education is the primary hindrance to the adoption of biomass briquettes as an alternative energy in Maasai-Mau region. After performing the test; table 4.5 below, it was revealed that the p value was 0.13.

**Table 4. 5 the chi-square results for the contingency table**

<b>Chi-Square Tests</b>			
	Value	Degrees of freedom	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.866 <sup>a</sup>	6	.130
Likelihood Ratio	10.830	6	.094
Linear-by-Linear Association	.082	1	.775

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.76.

Since the p value 0.13 is greater than the significance level 0.05, there is a strong statistical evidence to accept the null hypothesis. Thus, the study concludes that relative low level of education hinders adoption of biomass briquette as an alternative energy in Maasai-Mau region. Table 4.6 below shows that households with heads of relative low level of education have not adopted briquettes usage as opposed to their counter part of relative high level of education.

**Table 4. 6 Education level versus how often do you use briquette in Cross tabulation**

	How often do you use briquette in								Total	%
	Daily		Once a week		Once a month		More than three months			
	n	%	n	%	n	%	n	%		
Tertiary/ University	11	33.3	9	27.3	9	27.3	4	12.1	33	100
Secondary	7	21.9	6	18.8	12	37.5	7	21.9	32	100
Primary	13	37.1	12	34.3	3	8.6	7	20	35	100

Note: N=100, the degrees of freedom are (4-1) X (3-1) and the computed chi-squared,  $\chi^2_6 = 9.866$

***Ho Briquette making materials are readily available in Maasai-Mau region.***

Table 4.7 shows item statistics of six briquette making materials in Maasai-Mau Region, Narok County, Kenya.

Table 4. 7 Item Statistics for six briquette making materials in Maasai-Mau Region

	Item Statistics			Availability score		
	N	Mean	S.D	3	2	1
Molasses	72	1.76	.722	46.16	38.46	15.38
Saw dust chippings	72	1.38	.659	84.61	10.26	5.13
Charcoal Dust	72	1.56	.803	79.49	7.69	12.82
Maize cobs	72	1.46	.649	69.23	25.64	5.13
Beans Straws	72	1.89	.761	20.51	51.28	28.21
Potato waste	72	1.68	.784	53.85	30.77	15.38

NOTE: 3 readily available, 2 moderately available, 1 least available.

The table 4.7 above agrees with a study done by Aya *et al*, (2015), that found out that in Kibera slum, readily available raw material for briquette making was saw dust chippings, followed by charcoal dust which was a by-product of charcoal, and molasses. The same study found out that households headed by women tended to prefer briquettes as they gave less smoke and burnt for long. They found out that 1.75 kgs of briquettes burnt for 4 hours and produced 96.6 ppm of CO<sub>2</sub> compared to charcoal of the same quantity that produced 240.6 ppm of CO<sub>2</sub>. Table 4.7 above was used to test Ho test of briquette making materials are readily available in Maasai-Mau Region through ANOVA and the results were as shown in table 4.8 below.

**Table 4. 8 ANOVA results for test of availability of raw materials in table 4.7**

	Sum of Squares	df	Mean Square	F	Sig
Between People	69.074	71	.973		
Between Items	13.463	5	2.693	6.004	.0001
Within People					
Residual	159.204	355	.448		
Total	172.667	360	.480		
Total	241.741	431	.561		

Grand Mean = 1.62

After investigating, the ANOVA significance value is 0.0001 which is less than the significance value 0.05. In this case, there is very strong evidence to reject the null hypothesis. Thus, we can conclude that Maasai-Mau region, Narok County, has readily available briquette making materials, namely, molasses, saw dust chippings, charcoal dust, maize cobs, bean straws and potato waste.

## **SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS**

### **5.1 Summary**

This study was aimed at investigating the adoption of biomass briquettes as alternative energy in Maasai-Mau region, Narok County, Kenya. The study was guided by four objectives which will be summarized under conclusion and then a recommendation to the local and national governments and, a section for further studies will conclude this chapter.

### **5.2 Conclusions**

The study concludes that the level of adoption and penetration of biomass briquette usage in the households in Maasai-Mau region was relatively low compared to the high level of firewood and charcoal usage as their main source of energy. From the study, only 28% of the respondents use briquettes daily, this is a relatively low level of adoption considering that 79.5% and 16.7% of the households in Maasai-Mau region utilise firewood and charcoal respectively as their main source of energy.

The study also concludes that lack of funds and lack of briquette making skills were the highest challenges the youths and women of Maasai-Mau region face in the biomass briquette making process. Lack of funds, with a weighted mean of 341.29 and 66.67%, of the respondents ranking it as the highest challenge to adoption of biomass briquette technology as their alternative source of energy. On the other hand, lack of briquette making skills with a weighted mean of 374.33 and a 76.92% of the respondents ranking it as the highest hindrance to the adoption of biomass briquette technology in the study area.

Finally, the study concludes that briquette making materials were readily available with sawdust chipping being ranked as readily available at 84.61%, followed closely with charcoal dust at 79.49%. This implies that, the adoption of biomass briquette technology as an alternative source of energy has all the raw materials to make it a success in the region, if the households get funding to support the initiative.

### **5.3 Recommendations**

This section will cover recommendations and areas of further studies as per the findings of the study.

#### **5.3.1 Recommendations**

Based on this study's findings, the following recommendations are proposed to all stakeholders to ensure our forests and natural resources are secured for the future generations.

1. The residents of the Maasai-Mau region be educated on the biomass briquette making skills and given the funds to support them in adopting the briquette making technology, thus promoting briquettes as alternative sources of energy and increase the utilization of the same in the households in the areas.
2. The youth and women from the region should be educated on the benefits of adopting biomass briquettes as their main source of energy and income to conserve the Mau forest that lies in the part of the region. This is due to the study findings of all the raw materials needed in making briquettes being readily available in the region.
3. Lastly, this study recommends that already established briquette making groups in Narok county, be utilized to mentor the youths and women in the charcoal burning business, so as they educated them on the relatively high demand of biomass briquettes in the hotels and users who adopt this form of energy in support of conserving the region's forests.

#### **5.3.2 Areas for Further Research**

1. Further studies should be carried out on the potential of biomass briquette in controlling municipal wastes.
2. Researchers should document how GIS and remote sensing can be applied to map all the alternative energy initiatives in the region.
3. Further study should be carried out on the country's awareness of biomass briquettes as an alternative energy.
4. Further study on the pollution levels of biomass briquettes in comparison to other energy sources.

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## APPENDICES

### Appendix I: Questionnaire to Households in Maasai-Mau

#### Introduction

I am a student at Kenyatta University pursuing a Masters of Environmental Studies, Climate Change and Sustainability and doing a thesis titled “Adoption of Biomass Briquettes as alternative source of Energy in Maasai-Mau region, Narok County, Kenya” The results will assist in environmental conservation, protection of forest cover, economic gains for youths and community members and will give county and national government an opportunity to roll out climate change projects to ensure biomass briquette technologies are adopted in Kenya. Your answers will be highly appreciated and will be handled with utmost confidentiality.

Instructions: Kindly tick against your preference or write on the space provided.

#### Section A: Background information

1.	Gender (Tick where appropriate)	<input type="checkbox"/> Male <input type="checkbox"/> Female
2.	Age in years	<input type="checkbox"/> 18-27 <input type="checkbox"/> 28-37 <input type="checkbox"/> 38-47 <input type="checkbox"/> 48-57 <input type="checkbox"/> 58 and above
3.	Education level	<input type="checkbox"/> Tertiary/University <input type="checkbox"/> Secondary <input type="checkbox"/> Primary

a) Do you know what a briquette is?  Yes       No

b) If YES, kindly explain how available briquette making materials are

.....

c) How often do you use briquettes in your homestead?

Daily       Once a week       Once a month

Once after 3 months       Others.....

c) Will you recommend briquette usage as a source of energy in our community, kindly give reasons why

.....

d) If using briquettes, how did you learn about them, kindly explain

.....

1. a) In a scale of 1-5, please tick (√) your preferred source of energy.

1. Least preferred 2 Little preferred 3 moderate preference 4 fairly preferred 5 most preferred

	Least preferred	← Moderate preferred →			most preferred
	1	2	3	4	5
Charcoal					
Solar					
Firewood					
Paraffin					
Electricity					
Biogas					
Briquettes					
Maize cobs					
Crop residues					

Kindly rate what determines the choice of your preferred energy source

A) Cheap       b) Availability       c) Burns longer

d) Less smoke       e) Lights easily       f) friendly to the environment

g) Any other.....

b) What is the daily cost of your most preferred energy choice, kindly give a cost per smallest available unit in the local market?

.....

C) Kindly rate the following energy sources as per your household usage.

	Never used	Rarely used	Moderate use	Frequently used	Always used	
Charcoal						
Firewood						
Briquettes						
Paraffin						
LPG (Gas)						
Electricity						
Crop residues						
Others						

5) a) How many briquettes making initiates are there in your locality and technologies used?

.....

b) Do you know advantages of briquettes as opposed to other energy sources? Kindly mark an (X) as the advantages or disadvantages for each.

	Smoky	Expensive	Less ash	More ash	Lasts longer	Burns with a lot of soot
Charcoal						
Solar						
Firewood						
Paraffin						
Electricity						
Biogas						
Briquettes						
Maize cobs						
Biofuel						

6) What hinders adoption of briquette usage as a household primary source of energy?

.....  
8) Based on your own assessment, can briquettes sustain your homestead energy demand? Kindly give a short explanation for your answer

.....  
.....

9) Do you think briquette energy adoption can solve the problem of forest destruction in this region? Kindly elaborate

.....

Thank you for taking your time to answer this questionnaire.

**Appendix II: Questionnaire for Briquette Making Groups and Relevant Stakeholders**

I am a student at Kenyatta University pursuing a Masters of Environmental Studies, Climate Change and Sustainability and doing a thesis titled “Adoption of Biomass Briquettes as alternative source of Energy in Maasai-Mau region, Narok County, Kenya” The results will assist in environmental conservation, protection of forest cover, economic gains for youths and community members and will give county and national government an opportunity to roll out climate change projects to ensure biomass briquette technologies are adopted in Kenya. Your answers will be highly appreciated and will be handled with utmost confidentiality.

Instructions: Kindly tick against your preference or write on the space provided.

- 1. Background information
  - a) Organization (optional)
  - b) .....
  - c) Position.....
  - d) Organization’s major activity in the region

2) According to available records and self-assessment, has briquette making penetrate Maasai-Mau and Narok County  
.....

3) What hinders adoption of briquette usage as aprimary source of energy?  
.....  
.....

4) a) Is briquette adoption process easy for the youths and women in the region?  
Kindly give short explanation for your answer  
.....

5. a) According to your own/organization's assessment, what is the most preferred energy source in the region? Number them as per preference

- |    |    |
|----|----|
| 1. | 2. |
| 3. | 4. |
| 5. | 6. |

7. Any other.....

b) What are the costs of briquette making and available technologies in the region and county?.....

.....

c) What is the cost of other energy alternatives? Kindly justify your answer

.....  
.....

8. a) How available are the briquette making materials?

.....

b) Name the available materials, starting from the most available to the least?

- |    |    |
|----|----|
| 1. | 2. |
| 3. | 4. |
| 5. | 6. |

Others.....

9) As per your own assessment, is the community aware of briquettes and briquette making process?.....

Thank you for taking your time to answer this questionnaire.

### **Appendix III: Briquette Material Checklists**

This checklist will enable the researcher to note the briquette making materials in preference in the region, briquette making initiatives in the region

1. What are the briquette making materials available in the region?

a) .....

b) .....

c) .....

d) .....

Others.....

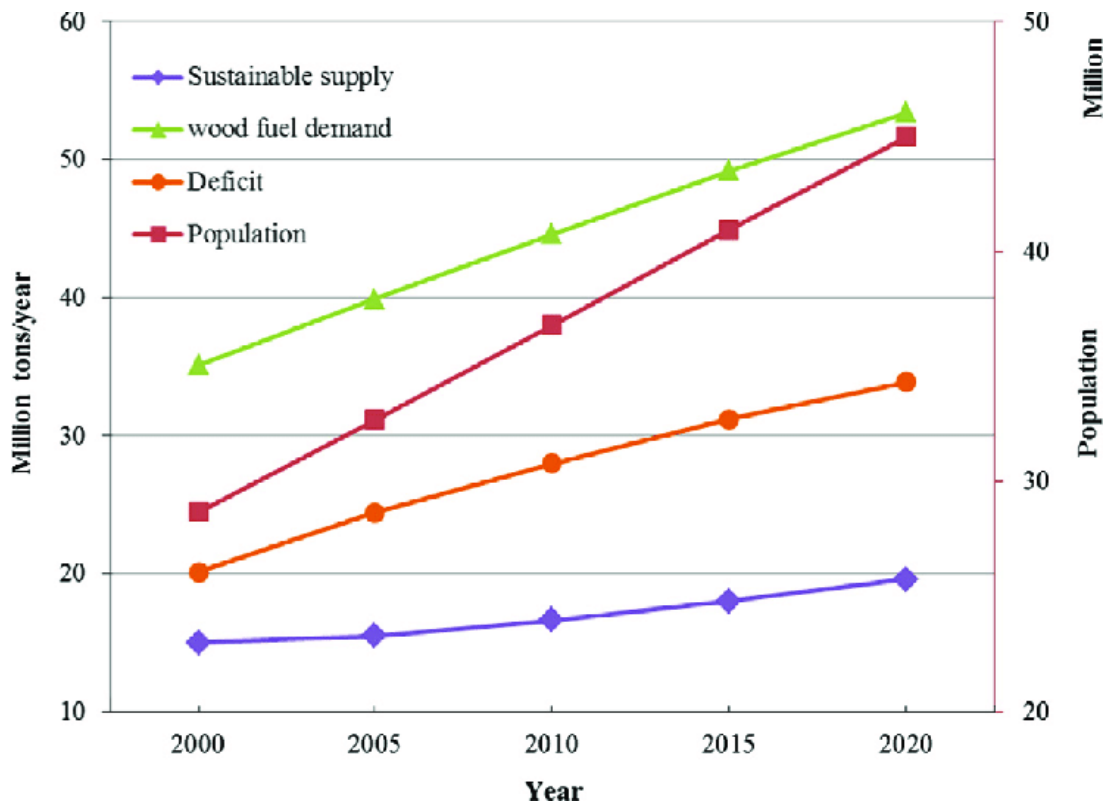
2. How many briquettes making initiatives are there in Narok town?

.....

3. What is the cost of briquettes in the region?

.....

## Appendix IV: Fuel demand projection by 2020



Fuel projection by 2020 by Ngusale *et al*, 2014



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Our Ref: N50/CE/25160/12

DATE: 10<sup>th</sup> August 2015

Director General,  
National Commission for Science, Technology  
& Innovation  
P.O. Box 30623-00100,  
**NAIROBI**

Dear Sir/Madam,

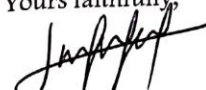
**RE: RESEARCH AUTHORIZATION FOR MOKAYA DENNIS CHWEYA- REG. NO.  
N50/CE/25160/2012**

I write to introduce Mr. Mokaya Dennis Chweya who is a Postgraduate Student of this University. He is registered for M.Env Degree programme in the Department of Environmental Education.

Mr. Mokaya intends to conduct research for an M.Env. Proposal entitled, "Adoption of Biomass Briquettes as Alternative Source of Energy in Maasai-Mau Region, Narok County, Kenya".

Any assistance given will be highly appreciated.

Yours faithfully,

  
**MRS. LUCY N. MBAABU  
FOR: DEAN, GRADUATE SCHOOL**

EO/mn



2

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**Internal Memo**

**FROM:** Dean, Graduate School

**DATE:** 11<sup>th</sup> August, 2015

**TO:** Mokaya Dennis Chweya  
C/o Environmental Health.

**REF:** N50/CE/25160/12

**SUBJECT:** APPROVAL OF RESEARCH PROPOSAL

=====

This is to inform you that Graduate School Board, at its meeting of 29<sup>th</sup> July, 2015, approved your Research Proposal for the M.Env Degree Entitled, "Adoption of Biomass Briquettes as Alternative Source of Energy in Maasai-Mau Region, Narok County, Kenya".

You may now proceed with data collection, subject to clearance with the Director General, National Commission for Science, Technology and Innovation

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking forms per semester. The form has been developed to replace the progress report forms. The supervision Tracking Forms are available at the University's website under Graduate School webpage downloads.

Thank you.

**EDWIN OBUNGU**  
**FOR: DEAN, GRADUATE SCHOOL**

c.c. Chairman, Department of Environmental Education

Supervisors:

1. Dr. Cecilia Gichuki  
C/o Department of Environmental Education  
Kenyatta University
2. Mr. James Koske  
C/o Department of Environmental Education  
Kenyatta University

ED/mn