ENERGY EFFICIENT TECHNOLOGIES FOR CLIMATE CHANGE MITIGATION:
FUEL BRIQUETTES IN THE RUIRÚ MUNICIPALITY, KIAMBU COUNTY, KENYA.

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N50/CTY/PT/21534/2010

A project report submitted in partial fulfillment of the requirements of the Degree of Master of Environmental Studies (Climate Change & Sustainability) in the School of Environmental Studies Kenyatta University

November, 2013
DECLARATION

This project is my original work and has not been presented for a degree in any other University or any other award.

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Signature ___________________ Date 6/12/2013


Department of Environmental Education.

We confirm that the work reported in this project report was carried out by the candidate under our supervision.

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DEDICATION

I dedicate this to my parents Mr. James Mugo Wanjohi and Mrs. Rosemary Wairimu Wanjohi for their support emotionally and financially, and to my siblings Judy, Philip and Helen for their love and encouragement.
ACKNOWLEDGEMENT

I thank the almighty God for blessing me with health of mind and body throughout the time of this research.

I would like to acknowledge Mr. Peter Thuo of Greentech Company, Ruiru for his technical support during my data collection. I also acknowledge the love and encouragement from my parents and siblings.

This work would not have been possible without the guidance of my academic supervisors Prof. Michael K. Koech and Prof. Caleb Mireri both from the School of Environmental Studies, Kenyatta University. God bless you.
ABSTRACT

Energy is essential for development. It is needed for cooking, providing light, refrigerating food and medicine, supplying fresh water, eliminating household wastes, heating and cooling buildings. Annual total greenhouse gas (GHG) emissions arising from the global energy supply sector continue to increase. Currently, energy-related GHG emissions, mainly from fossil fuel combustion for heat supply, electricity generation and transport, account for around 70% of total emissions including carbon dioxide, methane and some traces of nitrous oxide responsible for climate change. The broad objective of this study was to assess the efficiency of fuel briquettes as an alternative source of fuel in Ruiru Municipality of Kiambu County, Kenya, towards improved energy efficiency. Specifically, the study first sort to determine the levels of adoption of fuel briquettes as an alternative source of energy, secondly it examined the obstacles to adoption of fuel briquettes as an alternative source of energy and finally sort to identify components of municipal solid wastes that can be used in the manufacture of fuel briquettes. The study was guided by the diffusion of innovations theory which is used to understand uptake of new technologies such as the briquettes. The research was conducted using descriptive survey design to gather information from respondents. Quantitative research was used to quantify data and generalize results from the sample to the whole population while qualitative research was used to gain an understanding of underlying reasons and motivations. The sample size was composed of 70 respondents and 4 key respondents. Respondents were sampled from local households in the municipality. Data was analyzed and was presented in graphs, charts, frequency tables and pie-charts. Observations and conclusions drawn from the findings indicated that 30% of the respondents were aware of fuel briquettes as an alternative source of energy. Only 6% of the respondents always used them for cooking and heating in their households. The main obstacles to their adoption are the low awareness levels and unavailability in the market compared to other energy sources prevalently used in the area especially Liquid Petroleum Gas (LPG). Information from the briquette manufacturer indicated the types of municipal solid wastes that can be used in the manufacture of briquettes as charcoal dust, waste paper, sawdust and dried organic waste. The study provided a case for community based energy efficient technologies that can be widely deployed and be of immense benefit in terms of climate change mitigation. The study findings indicated that choice of energy source was determined by levels of income, availability of energy source and cost of energy source. Majority of respondents interviewed did not know about briquettes or their advantages and thus the level of adoption of fuel briquettes in Ruiru was very low. The beneficiaries of the study included the local briquette manufacturer, the government and other policy makers since it provided an understanding of the fuel briquette industry and made recommendations including formulation of policies that encourage uptake and provision of incentives for briquette manufacturers.
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<tbody>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GHG</td>
<td>Green House Gas</td>
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<td>GVEP</td>
<td>Global Village Energy Partnership</td>
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<td>ICC</td>
<td>International Climate Challenge</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<tr>
<td>ITDG</td>
<td>Intermediate Technology Development Group</td>
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<tr>
<td>KCJ</td>
<td>Kenya Ceramic Jiko</td>
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<tr>
<td>KFS</td>
<td>Kenya Forest Service</td>
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<tr>
<td>LPG</td>
<td>Liquid Petroleum Gas</td>
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<tr>
<td>MDGs</td>
<td>Millennium Development Goals</td>
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<tr>
<td>NGO</td>
<td>Non Governmental Organization</td>
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<tr>
<td>SURUDE</td>
<td>Foundation for Sustainable Rural Development</td>
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<tr>
<td>UNEP</td>
<td>United Nations Environment Programme</td>
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<td>UNFPA</td>
<td>United Nations Population Fund</td>
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<td>USD</td>
<td>United States Dollar</td>
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<td>WHO</td>
<td>World Health Organization</td>
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<td>WSSD</td>
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CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Over 3 billion people throughout the world rely on traditional fuels such as wood, charcoal, dung and agricultural residues for cooking and heating (Nigel et al., 2004). The global total production of wood reached approximately 3.9 billion cubic meters of which 2.3 billion cubic meters was used as wood fuels. This means that approximately 60 percent of the world’s total wood removals from forests and trees outside forests are used for energy purposes (FAO, 2008).

According to the Intermediate Technology Development Group (ITDG) and Green Peace report (2004), 1.6 billion people in the world have no access to electricity and up to 3 billion people rely on wood fuel or dung as their principle source of energy for cooking and heating. Wood fuel may be available as firewood, charcoal, sawdust and wood chips. When wood fuel is burnt to produce energy for cooking and heating, incomplete combustion leads to the release of heat trapping Green House Gases (GHG) including carbon dioxide (CO₂), Methane (CH₄) and nitrous oxide (N₂O). Fossil fuels such as kerosene and Liquid petroleum gas (LPG) have also gained popularity as household energy sources for the middle and high income end. While these are preferred over the traditional fuels such as wood fuels and dung, they contribute to release of GHG in the atmosphere. Climate change is principally the result of burning of fossil fuels such as coal, oil, and gas (Friedrich, 2006). Global CO₂ emissions continue to increase, reaching 32.1 billion metric tonnes in 2008, an increase of 2.4 percent compared with the previous year and 42% compared with 1990 (UNEP, 2012).

Energy services are an essential input into each of the economic, social and environmental dimensions of human development. They help to facilitate economic development by underpinning industrial growth, enhancing productivity and providing access to global markets and trade. Modern energy services contribute to social development by helping to fulfill the basic human needs of nutrition, warmth
and lighting. In addition to education, public health and environmental conservation, energy services can also protect the local and global environment by helping to control deforestation and by reducing emissions. Energy’s crucial role in enabling development makes the provision of adequate, affordable and reliable energy services absolutely necessary in order to achieve the Millennium Development Goals (MDGs). These goals were adopted by the United Nations Millennium Summit in the year 2000 to focus attention on the most pressing global development needs (UNDP, 2005).

At the World Summit for Sustainable Development (WSSD) which was held in the year 2002 in Johannesburg, South Africa, agreement was reached to significantly advance the attention given to energy; particularly the issue of access to energy services. In an effort to ensure that a lack of energy services does not become an impediment to development (UNDP, 2005). Iwayemi (1998) summarized the fundamental energy problem facing Africa as maintaining widespread access of the population to reliable and affordable supplies of environmentally cleaner energy to meet the requirements of rapid economic growth and improved living standards.

Biomass energy provides 68 percent of Kenya’s national energy requirement and it is expected to remain the main source of energy for the foreseeable future (Kammen et al., 2005). Among the measures taken by the government and Non Governmental Organizations (NGOs) include development and dissemination of improved cooking stoves. When these stoves are efficiently used, they can save 30 to 60 percent of fuel (Helga, 2007). The charcoal ceramic stoves known as Kenya Ceramic Jiko (KCJ) are also energy conserving compared to the metallic charcoal stove since they retain heat within compared to the metallic stove in which heat is lost to the surrounding. The current penetration of improved charcoal stoves as reported by Muchiri (2008) is estimated at 60 percent of rural households and over 80 percent for the urban (UNEP, 2006). Kenya has a rapidly growing population of 38 million (in 2008) and a GDP of USD 25billion. The country has experienced an increase in energy demand which is
linked to the rising population and expanding economy; the latter which grew by 7% in 2007 (Kirai, 2009).

Over-reliance on primary biomass energy has led to the widespread exploitation of forest resources with adverse environmental impacts. Forest cover in Kenya has diminished to 6%, substantially below the minimum recommended coverage of 10%. As a result, there has been a reduction in water levels in rivers and dams leading to inconsistent power supply and frequent power outages. The use of petroleum for power generation does not offer a lasting solution due to fluctuations in global market prices of crude oil, and the climate impacts of increased GHG emissions. Transportation of petroleum over long distances is also risky and contributes to increase in GHG emissions (GVEP, 2006).

Following the expiry of the Economic Recovery Strategy (2003-2007), Kenya’s Development Agenda is now anchored on the Kenya Vision 2030, which aims to transform Kenya into “a newly –industrialized, middle-income country providing a high quality of life to all its citizens in a clean and secure environment”. The Vision is anchored on three key pillars: economic, social and political. Environmental issues are addressed in the social pillar which seeks to achieve a just, cohesive and equitable social development in a clean and secure environment. The Kenya Vision 2030 has identified Energy as a key foundation and one of the infrastructural “enablers” upon which the economic, social and political pillars of this long-term development strategy will be built. The Ministry of Energy will play its contributory role towards achievement of Kenya Vision 2030 by; Enhancing power generation capacity; Increasing access to Electricity; Development of new and renewable sources of Energy; Ensuring security of fossil fuel resources; and Capacity building of the Energy sector. Kenya must, therefore, generate more energy at a lower cost and increase efficiency in energy consumption (GoK, 2007).

The constitution of Kenya 2010 addresses important aspects of the relationship between humans and nature in article 42 of its bill of rights. It dedicates Chapter V on
“Land and the Environment” and states the rights of citizens and responsibilities of the government on environmental matters in articles 69 and 70. Article 42 establishes, among others, the right to a clean and healthy environment including protection for present and future generations through legislative and other measures. Article 69 establishes, among others, the obligations of the state in respect of the environment, including the sustainable exploitation, utilization, management and conservation of natural resources and the equitable sharing of the accruing benefits. Article 70 establishes, among others, the enforcement of environmental rights, including legislative measures and the ability of individuals to petition to courts in cases when a right to a clean and healthy environment has been violated.

Kenya’s new devolved form of government will have a significant effect on the way energy policy and regulations are developed and applied. Under the new constitution National Government shall be responsible for energy policy including electricity and gas reticulation and energy regulation while county governments shall be responsible for county level planning and development including electricity and gas reticulation and energy regulation. It is difficult to foresee the implications of this but the process of reviewing the Energy policy to address this is underway.

A number of initiatives to regulate the energy sector have already been undertaken; The Solar PV (Solar electric systems that capture the sun’s rays using photovoltaic cells) and solar water heating regulations have recently been gazetted with operators issued with licenses by the energy regulatory commission; A Feed-in Tariff policy (FiT) covering wind, small hydro and biomass sources, for plants with capacities not exceeding 50MW, 10MW, and 40MW respectively was established in 2008. This was reviewed in 2010 to facilitate accelerated investment in generation from renewable sources, as well as incorporate other renewable energy resources namely, geothermal, biogas and solar. A draft National Energy Policy and Energy Bill (2012) which recognizes nuclear energy as a potential source of energy for electricity has also been developed.
Iwayemi (1998) observes that energy affects environmental quality through deforestation associated with unsustainable biomass energy dependence and greenhouse gas emission from fossil fuel use resulting in global warming. Various factors affect demand, consumption and choices of energy sources that households make. In addition to levels of income and ability by the buyer to pay for energy promptly, a number of other factors like energy constitution, levels of household energy consumption and relevant appliances to access the service could influence the choice of household energy.

To meet socio-economic development goals, people and countries must have adequate energy services to meet household needs of their populations as well as the needs of their productive and service sectors. Increases in economic output, population and urbanization in developing countries mean that energy services requirements will inevitably increase. Briquette making exemplifies the potential of appropriate technology. It saves trees and prevents problems like soil erosion and desertification by providing an alternative to burning wood for heating and cooking. It substitutes agricultural waste like hulls, husks, corn stocks, grass, leaves, food and animal garbage for a valuable resource. It improves health by providing a cleaner burning fuel (Stanley, 2003).

Adoption and continued (sustained) use of energy efficient technologies in developing countries is therefore an important sustainability strategy which should be adopted by as many households as possible (Worldwatch Institute, 2009). There is need to study the usage of fuel briquettes as well as the obstacles to their adoption as an energy efficient technology that can be used for climate change mitigation. There is also need to identify locally available materials that can be used in the manufacture of quality fuel briquettes with high economic, environmental and health benefits.

1.2 Problem statement

Wood fuel shortage is becoming a problem in many countries of the South. Fuel shortage in these countries is not only a problem of the rural areas but also of the
densely populated poor margins of medium and large cities. While the traditional types of fuel (firewood and charcoal) become more and more exhausted, modern fuels (paraffin, coal, LPG, electricity) are not affordable for the majority of the poor (Kirai, 2009).

The acquisition and use of wood fuel energy conservation technologies is very important for Kenya to be able to decrease demand on wood fuel and tackle the problem of deforestation. Traditional fuels, normally available at low or no cost are characterized by low combustion efficiency. Low combustion efficiency leads to emission of Carbon dioxide, Methane and Nitrous oxide causing an increase in greenhouse gases when the rate of consumption is higher than its replacement (Sanga and Jannuzi, 2005).

On average, 5,000 ha of forest cover are lost every year through illegal logging, encroachment, excision for settlement of people and cultivation (GoK, 2010b). A great concern in the energy sector is that demand for wood fuel exceeds supply. The scarcity of fuel wood and the impact of its escalating prices are more acute at the household level because of poverty and limited alternatives. These impacts are more felt by women, who are responsible for household cooking (King’uyu, 2002).

The reduction of wood fuel demand from forests can assist in forest conservation which is important because of the ecosystem services from forests such as; carbon sequestration and subsequent mitigation of climate change, water catchment, habitat for living organisms as well as the aesthetic value. There has been a shortage of wood fuel in many parts of Kenya. This high demand causes people to turn to nearby forests for firewood and charcoal leading to deforestation and subsequent soil erosion (Wanambwa, 2005).

The generation of organic waste in urban areas poses a growing challenge to the local waste management system. Organic waste (30-50% of the total waste) is not only a problem because of its large volume but also because it causes bio-chemical reactions
on landfill sites leading to the formation of landfill gas (methane) and leachates that 
pollute atmosphere and groundwater. In rural areas, agricultural residues (straw, rice 
and coffee husks, coconut and groundnut shells, bagasse, coir dust, etc.) are generated 
in large volumes and often not utilized at all (Vest, 2003). These pressures cause 
severe impacts on the environment in terms of pollution of land, natural resources 
depletion, public health and costs to the local economy. Research is therefore needed 
in order to appreciate and mainstream the integrated solid waste management 
approach which enhances economic, environmental and social benefits into Kenya’s 
development policies and strategies.

This study provided a case for fuel briquettes made from municipal solid waste as an 
alternative, affordable and sustainable energy efficient technology that can be used to 
replace the conventional sources of energy and play a role in climate change 
mitigation through reduced GHG emissions.

1.3 Research questions

The following questions guided the study;

1. What are the levels of adoption of fuel briquettes as an alternative source of 
   energy by Ruiru Municipality residents?
2. What are the obstacles to adoption of fuel briquettes as an alternative source of 
   energy in Ruiru Municipality?
3. What components of municipal solid wastes can be used in the manufacture of 
   fuel briquettes in Ruiru Municipality?

1.4 Objectives of the study

The broad objective of this study was to assess the adoption levels of fuel briquettes 
as an alternative source of fuel in Ruiru Municipality of Kiambu County, Kenya, 
towards improved energy efficiency.

Specific objectives were to:
1. Determine the levels of adoption of fuel briquettes as an alternative source of energy.
2. Examine the obstacles to adoption of fuel briquettes as an alternative source of energy.
3. Identify components of municipal solid wastes that can be used in the manufacture of fuel briquettes.

1.5 Hypotheses of the study

The hypotheses of the study were;

1. The levels of adoption of fuel briquettes as an alternative source of energy in Ruiru Municipality are significantly low.
2. Low awareness levels of Briquettes have led to their poor adoption as viable alternative energy source.
3. No components of municipal solid wastes can be used in the manufacture of fuel briquettes.

1.6 Justification of the study

This study provides a case for energy efficient fuel briquettes that contribute towards the preservation of the existing forests so that they continually capture and store carbon dioxide while counteracting on-going land degradation processes which threaten food and water security and jeopardize the livelihood of future generations.

This study serves as a step towards realization of the first Millennium Development Goal to eradicate extreme poverty and hunger. The adoption of this energy saving technology will release the women and children from the burden of spending many hours in search of wood fuel and be involved in productive activities such as farming and small enterprises. There will also be improvement in maternal health and reduction in infant mortality due to the improvement of the indoor air conditions. Studies have shown that although many poor people accept indoor air pollution as a ‘fact of life’, it is, in truth a very significant health problem especially for women and children and adoption of relatively simple solutions such as briquettes and the use of...
clean fuels, such as biogas, can reduce levels of indoor air pollution and significantly improve people's health (Krishna, 2008).

This study aimed to collect and analyze data to fill the gaps of knowledge on perceptions, adoption levels as well as the challenges and obstacles facing the fuel briquettes manufacture from Municipal solid waste in Ruiru Municipality, Kiambu County. This advanced knowledge will lead to performance improvements and future cost reductions in integrating the energy efficient technology into the market.

The study will inform policy reforms and development within the Energy sector in Kenya especially now when the new devolved system of governance is takes shape. The Constitution of Kenya (2010) provides for a two-tier structure of government consisting of National and County Governments. In regard to the energy sector in particular, the Constitution, in part 1 of the Fourth Schedule provides that the National Government shall be responsible for energy policy formulation including electricity and gas reticulation and energy regulation. This knowledge can be used by policy makers to develop policy, institutional and financial mechanisms to enable cost-effective deployment of the briquette technology in a wide variety of contexts. Findings about its climate change mitigation potential will add to the existing scientific knowledge and may be used to facilitate crucial decision-making and cheap processes nationally and regionally.

1.7 Significance of the study
Energy and environmental issues are intimately linked such as air and water pollution from the eradication and use of fossil fuels and biomass fuels. Although the potential of global climate change resulting from the excessive use of fossil fuels is the most dramatic and obvious of such concerns, the environmental impacts of energy use are broader. In developing countries, poor urban air quality linked to inefficient combustion processes and dirty fuels is often a concern. The availability of energy resources can determine how much food is grown and cooked, how living spaces are heated, and how much time is needed to 'produce' household energy. The
implications of insufficient energy choices in the face of abject poverty are immediate and pressing. Developing nations, particularly the poorest ones, consume far less energy than developed nations.

This study is important to fill the knowledge gap relating to the current level of adoption of energy efficient briquettes in Kenya’s urban areas. Briquettes provide a highly sustainable energy efficient fuel source. They generate fewer GHG emissions; reduced indoor and urban air pollution; burn longer and hotter than traditional fuels (charcoal, agricultural residue and firewood); and the technology does not require change of equipments e.g jikos.

Briquettes contribute to improvement in women and children's health, energy and time use. Improved indoor air quality in homes reduces exposure to smoke and dangerous fumes responsible for many respiratory diseases and illnesses. Using fuel briquettes means less firewood to chop and charcoal to buy, saving time and money and putting less pressure on natural resources. The briquette industry also provides a viable enterprise due to utilization of locally available wastes as raw materials.

This study provides an effective guide to policy making processes for the energy sector. It highlights the benefits of briquettes over the conventional fuels (including charcoal and fuel) and examines the various obstacles to adoption of the technology. This study also gives recommendations to policy makers on the promotion of briquettes as an alternative source of energy

1.8 Theoretical framework

In the context of environmental sciences, the arguably most relevant theories used in conceptualizing the advent of innovation are the technology push / market pull and the co-evolution approaches. However, the Diffusion of Innovations Theory can be effectively used to understand uptake of new technologies such as the briquettes. The theory sees innovations as being communicated through certain channels over time and within a particular social system. Individuals are seen as possessing different
degrees of willingness to adopt innovations and thus it is generally observed that the portion of the population adopting an innovation is approximately normally distributed over time (Rogers, 1995). Adoption means that someone does something differently from what they did previously i.e. purchase or use a new product or pick up a new behavior.

There are five main factors that influence adoption of an innovation; Relative advantage – the degree to which an innovation is seen to be better than the product it replaces; Compatibility – how consistent the innovation is with the needs of the potential adopters; Complexity – how difficult it is to understand or use the product; Triability – extent to which the innovation can be tested before a commitment to adopt and lastly Observability – extent to which the innovation provides tangible results.

According to Rogers (1995), adoption of innovations is influenced by specific factors. In the case the energy efficient briquette technology the following factors as illustrated in figure 1.1 below are appropriate: a perception that the briquettes are superior to the existing fuel sources; ease of use; perceived risks associated with adopting the briquettes; alignment with cultural values; and opportunities to observe what happens when others adopt the fuel briquettes.
Compatibility
- Compatible cooking stoves.
- Compressor machines.

Complexity
- Ease of lighting
- Ease of extinguishing

Relative Advantage
- Longevity of burning time.
- Low ash content
- Environmental sustainability – recycling waste, improved forest cover, lowered GHG emissions.
- Cheap, Smokeless, Available

Implementation success
- Adoption of energy efficient fuel briquettes.

Triability
- Ability to test before a commitment to adopt.

Observability
- Tangible results.

Fig 1.1: Theoretical Framework.
DEFINITION OF TERMS

Briquettes are a household and institutional fuel made by compacting/solidifying biomass waste - sawdust, bagasse, coffee husks, maize cobs, wheat/beans/barley straws and paper (Grover and Mishra, 1996).

Carbonization is a process that drives off volatile compounds to leave more or less pure carbon; the biomass is heated to within a critical temperature band (around 300°C) but with a restricted supply of air so that it does not ignite. Various processes options are available including simple earth kilns to more complex retorts that make use of the volatile compounds in heating the process (GVEP, 2010).

Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (Barker et al., 2007).

Climate change mitigation is an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC Third Assessment Report - Climate Change 2001).

Energy means any source of electrical, mechanical, hydraulic, pneumatic, chemical, nuclear, or thermal power for any use; and includes electricity, petroleum and other fossil fuels, geothermal steam, biomass and all its derivatives, municipal waste, solar, wind and tidal wave power (GoK, 2006).

Energy efficiency is the ability to provide the same (or higher) level of energy services, such as thermal comfort, high-quality lighting, etc. at lower energy consumption and cost (Barker et al., 2007).

Fossil fuel refers to an energy source formed in earth’s crust from decayed organic material e.g. petroleum, coal and natural gas (UNEP, 2006).

Fuel wood refers to wood and wood products, possibly including coppices, scrub, branches etc bought or gathered and burnt primarily for heating and cooking (UNEP, 2006).

Household energy is the type of energy utilized in a household (Iwayemi, 1998).
**Improved jiko** is a stove designed to retain heat with a clay liner to insulate the coals. This makes the stove more efficient than traditional jikos (Adapted from Granier *et al.*, 2010).

**Jikos** – An improvised container made of clay and used for burning charcoal or small pieces of wood. It is used for cooking or to give heat (Adapted from Granier *et al.*, 2010).

**Kenya Ceramic Jiko (KCJ)** is a light, portable charcoal burning stove consisting of two distinct units – a metallic cladding and a ceramic liner (Iwayemi, 2008).

**Traditional energy** refers to low quality and inefficient sources of energy predominantly biomass in nature and not often traded e.g. wood fuel, crop residues and dung cakes (UNEP, 2006).
CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

The fuel crisis in many parts of the developing world caused by an increasing shortage of traditional fuel (firewood, charcoal) creates a need for alternative sources of domestic fuel (Vest, 2003). Agricultural and forestry residues in rural areas and parts of the organic waste generated in urban areas (e.g. waste paper) are such alternative sources of energy.

Energy efficiency is assuredly the most effective and economically advantageous means to provide the services desired by energy users. The lower cost of energy production through energy efficiency actually spurs economic growth and this tends to outstrip their original energy investment costs. The overall objective of briquette manufacture is to reduce the emission of greenhouse gases by implementing energy efficiency improvements as an integral part of Cleaner Production mechanisms in the local community (Grover et al., 1996).

In the majority of the developing world, heat for cooking is provided by biomass, normally in the form of wood, charcoal or animal dung. Traditional open fires tend to be smoky. As cooking is usually done indoors this leads to significant respiratory problems. This results in more than one and a half million deaths a year – mostly amongst women and children. Millions more suffer from chronic lung disease (SURUDE, 2002).

2.2 The global wood fuel situation

The total production of wood in the year 2000 reached approximately 3.9 billion cubic meters of which 2.3 billion cubic meters were used for wood fuels. This means that approximately 60 percent of the world’s total removals from forests and trees outside forests are used for energy purposes (FAO, 2006). It is thus very important for efforts to be made in order to reduce the demand on wood biomass and in doing so conserve forests and the environment.
In Africa, 90 percent of the wood taken from forests is wood fuel with a varying but substantial amount (80 percent) made into charcoal the most important source of household energy in many African cities. Wood is the most important of several biomasses, however in many individual nations, dependence on wood varies. In some countries like Nepal in Asia, wood fuels provide 80% or more of total energy requirements. Table 2.1 below shows that there will be a greater demand for wood fuel by the year 2030 in Africa and yet there is shortage in its supply currently. There is therefore need for adoption of technologies that minimize wood fuel consumption in order to make its usage sustainable and also encourage aforestation and re-afforestation (Seidel, 2008; Kammen et al., 2005).

**Table 2.1: FAO projections of wood fuel consumption to 2030 in Africa**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel wood (million cubic meters)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>261.1</td>
<td>305.1</td>
<td>364.6</td>
<td>440.0</td>
<td>485.7</td>
<td>526.0</td>
<td>544.8</td>
</tr>
<tr>
<td><strong>Charcoal (million tons)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Africa</td>
<td>8.1</td>
<td>11.0</td>
<td>16.1</td>
<td>23.0</td>
<td>30.2</td>
<td>38.4</td>
<td>46.1</td>
</tr>
</tbody>
</table>

*Source: Adopted and modified from Seidel, (2008).*

Demand for firewood and charcoal is driven primarily by growing numbers of the rural poor who depend on these for their cooking and heating needs. Charcoal is also an important fuel among the urban population whose number is expanding rapidly. According to Mangat (2009), statistics provided by Camco Global show that wood fuel is one of the major causes of environmental degradation and accounts for about 18 percent of the world’s GHGs. It is estimated that 17 to 18 percent of GHGs produced in tropical regions (most of the region covers developing nations) by land that is cleared for agriculture, logging and activities that degrade the forests.
The current biomass demand in Kenya is estimated at 40.5 million tons against a sustainable supply of 16 million tons (Kamfor, 2002). Biomass energy (mainly firewood and charcoal) constitute 70 percent of national energy supply, 90 percent of which is consumed by households (UNEP, 2006). To date, firewood and charcoal are still the most significant energy resources in Kenya and will be in the foreseeable future. Firewood is mainly a rural fuel with more than 90 percent of the population using it for cooking and heating. Charcoal is predominantly an urban fuel with 82 percent of the urban population as users. Due to decreased wood availability, some parts of the country are opting for Agricultural residue and animal dung as energy for cooking (Kamfor, 2002).

2.3 Energy demand patterns in urban areas

As the population moves from rural communities to increasingly crowded cities, their energy choice and patterns change. Charcoal, kerosene and LPG replace wood as the primary cooking fuel. The three stone fire is abandoned, charcoal braziers, kerosene stoves and LPG become the cooking devices of choice in the households as new household energy devices are acquired (Barnes, 1995).

Energy demand patterns of the urban areas largely revolve around household energy and uses such as cooking and lighting as well as energy services for small-scale and informal commercial and productive activities at household level. In the urban areas of Sub-Saharan Africa, countries rely on Biofuels for cooking often charcoal and wood in Eastern and Southern Africa. LPG is used by medium and high income households. Kerosene is the energy of choice in the low income households for lighting and electricity for the high income households (Karekezi and Majoro, 1999). The demographic shift in urban areas triggers change in type and choice of energy used, also per capita energy uses increase significantly as the population moves from rural communities to urban conglomerations (Karekezi, 2000). Increasing demand for various energy choices is subject to rising income for the majority of the residents.
A study by Hosier and Kipondya (1993) in Tanzania’s urban areas found that while kerosene consumption decreases with increasing income, electricity accounts for a large share of energy requirements as income increases. Charcoal is the dominant household energy in the urban areas and its use varies little with income. While firewood use decreased with increase in income in two urban areas, it increased in the third where scarcity of firewood is most acute. Generally, charcoal is the basic energy; electricity is a preferred type of energy and kerosene is a transitional energy until households get access to LPG and kerosene. Time series evidence presented by Hosier and Kipondya (1993) observed that even though the overall trend is towards moving up the energy ladder, there are some households moving down.

The transition to clean modern energy in urban areas is heavily reliant on increased incomes. Energy demand patterns of urban households especially the poor revolve around household energy uses such as cooking and lighting as well as energy services for commercial and productive activities (Iwayemi, 1998). Ensuring people in urban areas gain access to fuel energy is a great challenge, but the means available for realizing this goal have expanded considerably in recent years. As renewable energy systems come down in cost, they are becoming an increasingly attractive way to provide electricity to urban areas. Concerted efforts by governments, policy makers, the private sector and NGOs coupled with significant local participation, can lead to impressive results.

It is becoming clear that decentralization of urban energy planning and its integration with other aspects of development has a number of advantages, particularly in assisting planners to formulate strategies and projects that more closely meet the needs of local residents. However apart from the changes in attitude required, there are some further constrains that have to be dealt with in order for it to be effectively implemented.

One of the most important of these is lack of adequate information. As a first step, a more comprehensive and reliable urban energy information system needs to be
developed in many countries at all planning levels. In addition, it needs regular updating. It should include assessments of urban energy needs on an area basis, patterns and trends in traditional and commercial energy consumption, economic, social and environmental indicators of urban development. Under conventional approaches, substantial financial and human resource commitments would have to be made for the surveys necessary to capture the data, and for establishing information systems that could be accessed by the various agencies involved in urban energy development. Increased access to information from advances in information technology has the potential to redress this. This will not happen overnight; however, it is a lack that must be addressed by policy makers and urban energy planners at a more centralized level. The factors involved in the urban choice are many, complex and often conflicting and partially understood (Iwayemi, 1998).

2.4 Awareness levels of energy efficient fuel briquettes

The Kenya Briquette Industry study report indicates that activities such as product samples and demonstrations were found to be an effective method of raising awareness and impacting positively on consumer perceptions which is important in the early stages of (briquette) business growth. Further, it acknowledges that if Kenya’s dependency on unsustainable charcoal is to be reduced in line with the Energy Act of 2006, a paradigm shift in cooking habits is required (GVEP, 2010).

A recent survey done in four study locations, namely; Kahawa Soweto, Githurai 44, Jua Kali, and Kamae found that 55% of the respondents were aware of the fuel briquettes, especially those from Kahawa Soweto village and at the Nakumatt Thika Road supermarket both of which could be due to a current project in the former case and exposure for the later. However of those who had heard about the energy briquettes, 57% had never used them possibly because they were not in the market. For those who had used the briquettes they identified the preferred qualities as: length of burning time, high thermal heat, less smoke, price and shorter time to ignite (Njenga et al., 2009).
2.5 Adoption of energy efficient fuel briquettes

Adopting cleaner cooking methods will in addition to improving health and reducing illness-related expenditures, improve family livelihoods, stimulate development and contribute to environmental sustainability (WHO, 2003). These benefits include time savings due to fewer days of illness and less time spent on fuel collection and cooking.

There exists considerable resistance to the adoption and assimilation of renewable energy technologies, especially among the decision makers within the African Energy Sector. Lack of information and understanding in an area perceived as new, and therefore untested, has encouraged decision makers to stick to ‘business as usual’ policies, even when the facts indicate a new alternative should be explored (Yuko, 2004).

A recent study in Kenya’s urban and peri-urban areas showed that for consumers to demand briquettes there must be a clear advantage on price over the main competing fuel. This can be based upon either a lower cost per unit of energy or lower cost per hour of burn time (GVEP, 2010). Compatibility of briquettes with existing cooking equipment was also a crucial factor. Briquettes can be burned in a traditional or improved jiko, however this assumes that consumers own such a stove. Table 2.2 below presents a summary of the key drivers and barriers found in the study areas.
Table 2.2: Observed drivers and barriers to urban and peri-urban household use of briquettes in Kahawa Soweto, Githurai 44, Jua Kali, and Kamae in 2010.

<table>
<thead>
<tr>
<th>Observed drivers</th>
<th>Observed barriers</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price Factors</strong></td>
<td>• The price of competing fuels (charcoal) per unit energy is higher than briquettes.</td>
<td>• The price of competing fuels (charcoal) per unit energy is lower than briquettes.</td>
</tr>
<tr>
<td>• The burn time of briquettes is higher than competing fuels (charcoal).</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Non-Price Factors</strong></td>
<td>• Most urban consumers desire a smokeless fuel, briquettes can meet this need.</td>
<td>• Consumers do not own compatible jikos for burning briquettes.</td>
</tr>
<tr>
<td>• Most urban consumers have compatible cooking equipment (jikos).</td>
<td>• Competing products (kerosene) heat more quickly and were preferred for certain applications e.g. for making tea.</td>
<td>• More awareness must be build to increase adoption.</td>
</tr>
<tr>
<td>• Awareness of briquettes is high.</td>
<td>• Competing products are available at more convenient locations, and often on credit.</td>
<td>• Existing networks of fuel suppliers should be used in distributing fuel briquettes.</td>
</tr>
<tr>
<td>• A limited number of households are willing to pay.</td>
<td>• Competing products are often easier to light and extinguish.</td>
<td>• Awareness of briquettes is very low.</td>
</tr>
</tbody>
</table>

*Source: Adapted from GVEP, 2010*
2.6 Raw materials used in the manufacture of fuel briquettes

In the manufacture of fuel briquettes, the availability of raw materials has a strong influence over producers’ success. There are three main dimensions to this; proximity, suitability, and quantity (Nuova, 2007). Fuel briquettes can contain things like: Waste paper and cardboard; Water hyacinth; Agricultural residue - Leftover leaves, grasses, stems and straw from agriculture (if not needed for soil improvement); Charcoal dust; and Sawdust (Gladstone, 2003). Components of Municipal solid wastes that burn without producing toxic ash or fumes can be used to manufacture briquettes. Figure 2.1 below shows various compositions from around Africa.

![Pie charts showing fuel briquettes composition from Upper Shiwi River, Malawi and Bamako, Mali](image)

**Figure 2.1: Fuel briquettes composition from around Africa.**

*Source: (Stanley, 2003).*
2.7 Characterization of briquette and determination of cooking qualities

During a survey done at Kahawa Soweto Informal Settlement in Nairobi by Njenga et al., (2009), three types of briquettes were tested. Different compositions were mixed at the ratio of 4:1 of principle raw materials and waste paper as a binder. Types I and III contained equal amounts of charcoal dust and maize cob or sawdust:

- Type I: Charcoal dust, maize cob dust and waste paper
- Type II: Charcoal dust and waste paper
- Type III Charcoal dust, sawdust and waste paper

The parameters measured were; ash content, moisture content, level of volatile matter and calorific value. This was replicated three times and the means are presented in table 2.3 below.

Table 2.3: Characteristics of the three types of energy briquettes in Kahawa Soweto Informal Settlement in 2009.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Wood charcoal</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash content (%)</td>
<td>33.58</td>
<td>37.15</td>
<td>53.4</td>
<td>2.4</td>
<td>The ash content much higher in the briquettes than wood charcoal</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>5.45</td>
<td>5.83</td>
<td>5.24</td>
<td>7.135</td>
<td>Briquettes had a better moisture content than charcoal</td>
</tr>
<tr>
<td>Volatile matter (%)</td>
<td>15.87</td>
<td>17.6</td>
<td>17.57</td>
<td>21.15</td>
<td>Briquettes have better levels of volatile matter than wood charcoal</td>
</tr>
<tr>
<td>Calorific value (Kj/g)</td>
<td>15.11</td>
<td>18.68</td>
<td>15.79</td>
<td>25-33</td>
<td>Briquette Type II had the highest calorific value which meant that Type II briquettes had the highest thermal heat energy.</td>
</tr>
</tbody>
</table>

Source: Adapted from (Njenga et al., 2009).
The results presented in Table 2.4 below showed that briquettes had a longer burning time than wood charcoal by over 1 hour. Analysis was done in terms of briquette quality and sourcing of raw materials.

**Table 2.4: Participatory briquette testing and demonstration at Kahawa Soweto village**

<table>
<thead>
<tr>
<th>Type of Briquettes and Experiment procedure</th>
<th>Average time to fully Ignite (mins)</th>
<th>Smoke produced by the Briquettes</th>
<th>Flame characteristics</th>
<th>Time taken to cook</th>
<th>Time to burn into ashes</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type I:</strong> Charcoal dust + maize cobs + waste paper weighing 420g (two briquettes)</td>
<td>12</td>
<td>Very Little smoke</td>
<td>Small hot yellow flame</td>
<td>3hr 4 min</td>
<td>3hr 24 min</td>
<td>Poorest briquette in quality and sourcing of raw materials.</td>
</tr>
<tr>
<td><strong>Type II:</strong> Charcoal dust + waste paper weighing 418g (two briquettes)</td>
<td>11</td>
<td>No smoke</td>
<td>Small hot yellow flame</td>
<td>2hr 16 min</td>
<td>3hr 09 min</td>
<td>The best briquette in quality and sourcing of raw materials.</td>
</tr>
<tr>
<td><strong>Type III:</strong> Charcoal dust + saw dust + waste paper weighing 433g (two briquettes)</td>
<td>15</td>
<td>Very Little smoke</td>
<td>Small hot yellow flame</td>
<td>2hr 07 Min</td>
<td>3hr 11 min</td>
<td>The second best briquette in quality and sourcing of raw materials.</td>
</tr>
<tr>
<td>Wood charcoal weighing 400g</td>
<td>11</td>
<td>Very Little smoke</td>
<td>Hot yellow flame</td>
<td>Not available</td>
<td>1hr 57 min</td>
<td>Fuel burned to ash before it was cooked.</td>
</tr>
</tbody>
</table>

*Source: Adapted from (Njenga et al., 2009).*
2.8 Conclusions

As demand for fuel energy used in cooking and heating increases with the growing population, emission of GHG responsible for climate change continue to increase. There is need to find suitable energy efficient technologies in order to reduce the demand on firewood, charcoal, LPG and agricultural residues and in doing so conserve forests and the environment. Increased rural – urban migration has led to overpopulated cities and increased the need for convenient, cheap and efficient fuels for urban households most of whom are living below the poverty line.

Activities such as product samples and demonstrations are effective methods of raising awareness and impacting positively on consumer perceptions about fuel briquettes and could inspire a paradigm shift. Adoption of cleaner cooking methods will in addition to improving health and reducing illness-related expenditures, improve family livelihoods, stimulate development and contribute to environmental sustainability.

In the manufacture of fuel briquettes, the availability of raw materials has a strong influence over producers’ success. There are three main dimensions to this; proximity, suitability, and quantity (Nuova, 2007). Fuel briquettes can be manufactured from easily available municipal solid wastes including waste paper, cardboard, leftover leaves, grasses, charcoal dust sawdust. Finally, more studies need to be done on the briquette industry in Kenya. There is need to determine the levels of adoption of fuel briquettes as an alternative source of energy and to examine the obstacles to their adoption as a viable alternative source of energy. There is also need to study municipal solid wastes as well as other readily available materials that can be effectively used in the manufacture of quality fuel briquettes. This study, therefore, provided a case for the briquette industry in Ruiru Municipality, Kiambu County, Kenya.
CHAPTER THREE: METHODOLOGY

3.1 Study area

Ruiru Municipality is administratively located in Kiambu County which lies between Latitude: 1°08'24"S and Longitude: 36°57'36"E. Kiambu County is located in central Kenya, it borders Murang’a County to the North and North East, Machakos County to the East, Nairobi and Kajiado Counties to the South, Nakuru County to the West, and Nyandarua County to the North West. Temperatures range from a minimum of 12.8°C to a maximum of 24.6°C with an average of 18.7°C. The average rainfall is 989mm per annum. It lies on an altitude of approximately 1600m above sea level. The area is 22 kilometers from Nairobi City and falls within the Nairobi Metropolitan area (See plate 3.1 below) The Nairobi metropolitan records one of the highest population densities and is considered the region’s commercial hub. Administratively, Ruiru Municipality is divided into six wards; Gitohua, Biashara, Murera, Kahawa Sukari and Githurai.

Plate 3.1: Map of Kenya showing Location of Ruiru.

Source: Coffee and Conservation organization

Website: http://www.coffeehabitat.com/ (Obtained July 6, 2012)
3.2 Study design

A research design, according to Burns (2000), is a conceptual structure within which research would be conducted aimed at providing for the collection of relevant evidence with minimal expenditure of effort, time and money. The study was carried out through descriptive research approach. A descriptive research attempts to describe characteristics of phenomena, opinions, preferences, subjects and perceptions of people of interest to an investigation (Borg and Gall, 1993). According to Best and Kahn (1993), descriptive research is concerned with conditions or relationships that exist; practices that prevail; points of view or attitudes held by people; processes that are going on; effects that are felt or trends that are developing. Descriptive study is also concerned with what exists and related to some preceding event that has influenced or affected the present condition or event such as age, occupation, gender and education level that pointed to factors influencing the choice of household energy and energy sources. To a greater extent, a descriptive survey aims at obtaining information from representative sample of the population from which the researcher is able to generalize findings of the larger population as a whole (Bell, 1993).

The researcher used both qualitative and quantitative paradigms in collecting and analyzing data. According to Borg and Gall (1993) quantitative research designs are by nature structural, predetermined and specific and yield numbers, charts and tables. Qualitative research designs on the other hand describe and develop an understanding for particular social situation, event or interaction (Bogdan and Biklen, 1982). According to Mugenda and Mugenda (1999), the two methods do complement each other. The data obtained were analyzed both qualitatively and quantitatively.

Qualitative data was obtained from the open ended items in the questionnaires. The data were grouped into different categories depending on the responses given by the respondents. Those categories helped in establishing themes which were further coded and entered in a computer statistical package. The study employed the use of the Statistical Package for Social Sciences (SPSS) software. This software was preferred because it is easy to use and accepts a wide range of data manipulations to
give desired results. The data was analyzed using descriptive statistics such as percentages, means and frequencies. Quantitative data on the other hand was obtained from both the pre-coded and open ended items. These were also coded and entered in the SPSS software. The data was analyzed using simple descriptive statistics such as percentages, mean and frequencies and presented with the aid of tables, notes and graphs.

3.3 Target population
A target population is the larger group to which one hopes to generalize or apply his research findings while population refers to all members of the target study (Fraenkel and Wallen, 1993). The study targeted the 241,007 total population of Ruiru town with 75,184 households (GoK, 2010a), a briquette manufacturer in the area, government officers, chiefs and a local NGO called International Climate Challenge.

3.4 Sample size
Simple random sampling was used to select three wards out of the six in Ruiru municipality. Six balls marked for the six wards were inserted in a basket and three drawn at random. Biashara, Kahawa and Githurai wards were identified. Purposive sampling was used to select 10 respondents who use briquettes; a representative of the population with the sort characteristics. The researcher selected other 60 household respondents randomly from the total population of 75,184 households using the fisher method. Twenty questionnaires were administered per ward. The sample size also included 1 briquette manufacturer and 4 Key respondents; 1 Kenya Forest Service officer, 1 District Environment Officer, 1 local chief, and 1 NGO - ICC (involved with briquette project). The women in the households were targeted as respondents. If unavailable, the oldest member of the household was taken as the respondent for the household. It was assumed that the information given was approximately the same.
3.5 Sampling procedures

The study used purposive sampling and simple random sampling. Purposive sampling was used to select the sample of respondents who use fuel briquettes. The households to be interviewed were selected randomly from the municipality using balloting technique.

3.6 Instruments

This study utilized observation, questionnaires and interview schedules as instruments;

3.6.1 Observation record sheet

This is a special sheet form which was used when quick recording was needed. In its structure it contained the name of the estate, the municipality, household number and the observations made; type of kitchen in the homestead, firewood or charcoal observed, type of wastes etc. This was important because it increased precision and ensured reliability of the information given.

From the observation record sheet, it was noted that the respondents used a variety of energy sources for cooking and heating. In each household, there was an entity of energy mixing, that is the households did supplement and complement energy sources for the household activities that they undertook. LPG, charcoal and kerosene were the dominant energy sources for cooking in most households with the small 6kilogram gas cylinders prominently in use. Briquettes, wood, dung, agricultural and other residues were minimally used as energy sources in the study area.

3.6.2 Questionnaires

The researcher used the questionnaire as the main data collection instrument which was seen as most recommended tool of data collection for a large sample. Kumar (2005) notes, that questionnaires are less expensive since one saves time, human and financial resources and convenient. The questionnaire was prepared after translating and adopting constructs from previous related studies and divided into three sections:
Section A aimed at collecting Bio-Data of the respondents necessary for the study. This was followed by Section B and Section C that focuses on the Energy Sources and Briquettes as Alternative Energy Sources respectively.

The questionnaires were administered by means of personal interviews in order to encourage the respondents to participate and to allow them to share their opinions. The questionnaire items required different responses from the interviewees. Where several alternatives were provided, the respondents were supposed to mark the suitable answer. Other items required the respondents to provide a written statement and fill in the spaces provided. The kinds of questions used in the questionnaires were close ended and open ended. Close ended questions provided a series of choices which allowed the respondents to choose one answer. For instance they provided specific alternatives regarding energy types. The open ended gave the interviewee the freedom to respond without listed options.

3.6.3 Interview schedule
This is an interview with pre-coded questions to produce quick quantitative data. However, instead of writing the response, the interviewer gave the needed information verbally in face-to-face relationship. This type of informal talk created more congenial atmosphere for effective communication. The interviewer explained the purpose of the study and the information required.

3.7 Data collection procedures

3.7.1 Direct interviewing
This was the main method of data collection. The research tools used were a questionnaire and interview schedules. The same questions were used for all respondents in the questionnaire. The data collected included data on educational level, income level and number of children, the type(s) of fuel used and the reasons behind the choice of fuel source.
3.7.2 Direct observation
This included observing and recording the type of fuel and waste in the compound among others.

3.7.3 Focused group discussions
The focus group discussion proved to be a very vital tool for obtaining information from several people within a short period of time. A group interview was done to find out the problem types of fuel used and the factors influencing the choice of fuel in the households. The group considered included women groups and youth groups that were selected through random sampling. Open-ended types of questions were used in the discussions. The size of the focus group was also considered so as to obtain sufficient information.

3.7.4 Key informant interviews
This included interviewing the community’s resource persons including the local KFS officer, DEO, local chief, and 1 NGO – ICC. Key informants were also interviewed on the problems facing the adoption of energy efficient sources of fuel in the area.

3.8 Data analysis
Basing on the mixed method approach, data was analyzed using both descriptive and inferential statistics. Since the Variables were expected to fall within the three scales of measurement: Nominal, ordinal and intervals, Spearman’s Rank Order Correlation and Chi-square non parametric statistical tests were employed.

Data was presented in charts, graphs, frequency tables and pie-charts. Relevant interpretations, discussions and recommendations were drawn from the analyzed data.

3.8.1 Descriptive statistics
Descriptive statistics were used to analyze the characteristics of the population studied. According to Trochim (2006), descriptive statistics are used to describe the basic features of the data in a study providing simple summaries about the sample and the measures; mean, standard deviation, frequency tables, bar charts and percentages
are used. These were used to describe demographic data such as age, education, income levels, number of dependants, etc.

3.8.2 Inferential statistics

According to Smith (2011), inferential statistics are used to make inferential statements about a population. It makes use of random sampling techniques to make sure the sample is representative. The Pearson’s correlation coefficient was used to measure correlation for independent variables and dependent variables in the interval or ratio scale.

3.9 Conclusions

The study was conducted in Ruiru Municipality an urban area administratively located in Kiambu County. The research was conducted through a descriptive survey and analysis of data was based on the research questions. Data was obtained both qualitatively via open ended questions and quantitatively from both pre-coded and open ended items. A representative sample was selected and studied and the results generalized and applied to all members of the study area. Simple random sampling was used to select three wards out of the six in Ruiru municipality and purposive sampling was used to select respondents who use briquettes. The study utilized observation, questionnaires and interview schedules as instruments. Data collection procedures included direct interviewing, focused group discussions and key informant interviews. Data was presented in charts, graphs, frequency tables and pie-charts. Relevant interpretations, discussions and recommendations were drawn from the analyzed data.
CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results of the study and discussions, taking into consideration the study objectives. Research findings are presented on frequency tables, bar charts and pie charts. The chapter starts with an evaluation of the socio-economic factors of the research area. This is followed by an evaluation of the respondents' choice of energy sources, and levels of adoption of fuel briquettes as a source of energy. Finally, the chapter presents municipal solid wastes that can be used in the manufacture of fuel briquettes in the Ruiru Municipality, Kiambu County.

The respondents were drawn from 3 wards; Biashara, Kahawa, and Githurai of the six in Ruiru municipality, Kiambu County. The data was analyzed using both descriptive and inferential statistics. A total of 70 questionnaires were returned out of the 70 issued by the researcher, therefore the return rate was 100%. The findings of the research study are stipulated below.

4.2 Socio-economic factors of the study area

4.2.1 Gender of the respondents

 Majority of the respondents interviewed 71% (n= 50) were Female while the rest 29% (n=20) were Male. Figure 4.1 below Illustrates these findings.

Fig 4.1: Gender of respondents on efficiency of fuel briquettes in Ruiru municipality, Kiambu County in July, 2013.
There were more female respondents than male. This could be explained as most women were left at home involved in domestic chores as men go out in search of income to meet the needs of the family. Thus women are well versed with problems associated with the use of firewood and type of energy efficient technologies for domestic cooking and heating. Due to their involvement in domestic chores, women and children are also the most affected by indoor air pollution (Muchiri, 2008). There was a very weak positive correlation between gender of the respondents and briquette use with Spearman’s Rho Correlation value (r= 0.046; n=70, p=0.05). Female household heads were more aware of briquettes compared to male headed households.

4.2.2 Age distribution of respondents

Among the respondents interviewed 30% (n= 21) were aged between 26-33 years, 20% (n=14) between 34- 41 years, 19% (n=13) between 18-25 years, 11% (n= 8) between 42-49 years, 11% (n=8) between 50-57 years and the rest 9% (n= 6) between 58-65 years as illustrated in figure 4.2 below.

![Age distribution of respondents on efficiency of fuel briquettes in Ruiru municipality, Kiambu County in July, 2013.](image)

Fig 4.2: Age distribution of respondents on efficiency of fuel briquettes in Ruiru municipality, Kiambu County in July, 2013.
Like many urban areas, Ruiru municipality is mainly composed of young people. This could be attributed to rural-urban migration in search of income and employment as the older generation retires to the rural areas after active life in the urban areas during their younger age (UNFPA, 2011). There was a very weak correlation between age and adoption of briquettes, Pearson’s correlation value ($r=0.018, n=70, p=0.05$). More young household heads had acquired briquettes compared to the older household heads. The youth are more adaptive to new ideas compared to the old.

These findings agree with the results of a similar study carried out in Kathiani, Kenya by Karanja (1999) which found out that the age bracket 26-36 years had adopted more energy saving technologies as compared to those over 45 years. He attributed his findings to the fact that middle age respondents are in their reproductive and productive years and this age group had adopted energy conservation technologies for effective performance of both reproductive and productive activities.

4.2.3 Marital status of the respondents

Figure 4.3 below shows the marital status of the respondents. The majority, 80% ($n=56$) were married, 12% ($n=9$) were single, 6% ($n=4$) were separated and 2% ($n=1$) were divorced.

![Marital status of the respondents](image.png)

**Fig. 4.3:** Marital status of the respondents on efficiency of fuel briquettes in Ruiru municipality, Kiambu County in July, 2013.
Marital status can influence acquisition and use of a technology because there is need for consultation in marriage before a decision is made unlike in single headed households where individuals make their own decisions. Married status also points towards consolidation of funds where both partners are earning an income.

4.2.4 Household size of the respondents

Majority of the respondents 83% (n= 58) indicated a household size of 1-3, while the rest 17% (n=12) indicated a household size of 4-6 as presented on figure 4.4 below. Increase in energy-based living standards and appliances for domestic cooking and heating has been fast influencing household energy consumption. A large family size, demands more energy to satisfy the household's energy demands adequately.

![Pie chart showing household size distribution](image)

**Fig 4.4: Household size of the respondents on efficiency of fuel briquettes in Ruiru municipality, Kiambu County in July, 2013.**

The study found out that fewer households with many dependants had acquired the briquette technology compared to households with fewer dependants. There was a negative correlation between the number of dependants in the household and briquette use with a Pearson's Correlation value (r=0.196, n=70, P=0.01). Larger households have many dependants meaning that more money was required to meet the basic needs for energy. Briquettes provide a cheap and efficient technology for domestic cooking and heating. A study by GVEP (2010) found that the price of
competing fuels (charcoal, firewood) per unit energy is higher than briquettes yet briquettes had longer burn duration than competing fuels.

4.2.5 Level of education of the respondents

Majority of the respondents 50% (n=35) were educated at College/University level, 35% (n=24) at Secondary school level, 10% (n=7) at Primary school level and 5% (n=4) informal education as shown in figure 4.5 below. Education level of individuals is a factor that indicates awareness levels informing the choice of energy sources.

![Education Level Chart]

Fig 4.5: Level of education of respondents on efficiency of fuel briquettes in Ruiru municipality, Kiambu County in July, 2013.

Highly educated people have higher energy saving behavior and opt for more efficient energy sources (Njenga et al., 2009). There was a strong positive correlation between the level of education of the respondents and awareness of briquette (r= 0.65, n=70, p=0.05). According to Gardner et al., (2001) highly educated people tend to have higher analytical capability of the information and knowledge necessary to implement new technology and realize the expected results. Hence higher education level allows households to be the early adopters who can take advantage of the new technology and profit from it.
4.2.6 The impact of education on energy choice

There is observed consistent movement up the energy ladder as the education levels of households increase. This can largely be attributed to the important part education plays in increasing the literacy levels of people and improving the quality of life, hence households with better education make more informed choices of the types of energy to use. This can also be attributed to a rise in income levels as a result of increase in education levels hence the affordability of modern types of energy such as LPG.

The findings agree with Karanja (1999), who established that without education respondents may not perceive the importance of technological devices to reduce over-dependence on scarce energy resources. This has an implication on environmental conservation strategy that education is prerequisite to environment management.

These findings also agree with those of a study conducted by Taulo et al., (2008) in Malawi which found that education had a positive influence on adoption of the fireless cooker. Households with one or both parents with some formal education accepted a fireless cooker technology more readily. The ability to make better choices on type of technology to use seems to increase with education level.

4.2.7 Average household incomes of the respondents.

Among the respondents 40% (n=28) had an average monthly income of between Ksh. 30,001-50,000, 26% (n=18) between Ksh. 20,001-30,000, 16% (n=12) between Ksh. 15,001-20,000, 10% (n=7) between Ksh. 10,001-15,000, 5% (n=3) between Ksh. 50,001-100,000 and the rest 3% (n=2) were earning over ksh. 100,000. Figure 4.6 below illustrates these findings.
Fig 4.6: Average household incomes of the respondents on efficiency of fuel briquettes in Ruiru municipality, Kiambu County in July, 2013.

Household income levels determine available capital for investment in the adoption of technologies and are a means through which the effect of poverty can be assessed. According to the World Bank (2006), poverty has a strong association with environmental degradation. Low income levels in developing and under developed countries limits access to resources for the majority resulting in livelihood alternatives with direct negative impact on the environment. There was a strong negative correlation between average monthly household income and adoption of fuel briquettes \((r = 0.76, n=70, p=0.05)\). More respondents with low average monthly incomes used briquettes compared to the higher income end.

4.2.8. Impact of income on energy

According to Reddy and Reddy (1994), there exists an energy ladder made of several rungs with traditional fuels such as wood, dung and crop residues occupying the lowest rung. As one moves up the ladder, energy efficiency and cost increase while pollutant emissions typically decline due to improved cooking environment and use of alternative sources of energy.
Household energy prices are not constant, more so, the forces of market demand influence them. This makes the affordability of household energy prohibitive to majority of the residents. It is the onus of the government to provide affordable household energy like fuel briquettes to its population. In depth studies should be done to explore ways and alternatives to provide affordable and efficient household energy to the citizens.

4.3 Respondents Choice of Energy Sources

4.3.1 Respondents rating of energy sources

The respondents were asked to rate energy sources indicating 1 for “Never used”, 2 for “Rarely used”, 3 for “Frequently used” and 4 for “Always used”. The following were the findings as displayed on table 4.1 below;

Liquid Petroleum Gas (LPG)

Among the respondents 7% (n=5) Never use, 2% (n=1) Rarely use, 26% (n=18) Frequently use and the majority 65% (n=46) Always use.

Briquettes

An overwhelming 70% (n=49) of the respondents Never use briquettes, 4% (n=3) Rarely use, 16% (n=14) Frequently use, and 20% (n=4) always use briquettes as an energy source.

Firewood

Among the respondents 79% (n=55) Never use, 9% (n=7) Rarely use, 10% (n=7) Frequently use while 2% (n=1) Always use firewood.

Charcoal

Among the respondents, 56% (n=40) Never use charcoal, 2% (n=1) Rarely Use, 30% (n=21) Frequently use, while 12% (n=8) Always use charcoal.

Kerosene

Among the respondents, 62% (n=43) Never use, 10% (n=7) Rarely use, 18% (n=13) Frequently use and 10% (n=7) Always use Kerosene.
Electricity
A majority 89% (n=62) Never use, 6% (n=4) Rarely use, 4% (n=3) Frequently use and 1% (n=1) Always use electricity.

Agricultural Residues
A majority 86% (n=60) Never use, the rest 14% (n=10) rarely use Agricultural residues.

Others
None of the respondents reported using other sources of energy.

Table 4.1: Respondents ratings of energy sources in Ruiru Municipality, Kiambu County in July, 2013.

<table>
<thead>
<tr>
<th></th>
<th>Never Used</th>
<th>Rarely Used</th>
<th>Frequently Used</th>
<th>Always Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Briquettes</td>
<td>70%</td>
<td>4%</td>
<td>20%</td>
<td>6%</td>
</tr>
<tr>
<td>Firewood</td>
<td>79%</td>
<td>9%</td>
<td>10%</td>
<td>2%</td>
</tr>
<tr>
<td>Charcoal</td>
<td>56%</td>
<td>2%</td>
<td>30%</td>
<td>12%</td>
</tr>
<tr>
<td>Kerosene</td>
<td>62%</td>
<td>10%</td>
<td>18%</td>
<td>10%</td>
</tr>
<tr>
<td>LPG</td>
<td>7%</td>
<td>2%</td>
<td>26%</td>
<td>65%</td>
</tr>
<tr>
<td>Electricity</td>
<td>89%</td>
<td>6%</td>
<td>4%</td>
<td>1%</td>
</tr>
<tr>
<td>Agric. Residues</td>
<td>86%</td>
<td>14%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Others</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

The findings and in table 4.1 above, 65% (n=46) of respondents indicate that they always use LPG gas compared to 6% (n=4) who always use Briquettes. Liquid petroleum gas was the most preferred source of fuel energy for heating and heating in this area.
4.3.2 Factors informing choice of energy sources.

As asked what factor best informs their choice of energy sources, respondents answered as follows, 24% (n=17) Easily Available, 36% (n=25) Affordable, 14% (n=10) Highly effective, 7% (n=5) Compatible Equipment, 3% (n=2) Less smoke, 10% (n=7) Ease of Lighting, 0% (n=0) Ease of Extinguishing, 6% (n=4) Environmentally Friendly and 0% (n=0) Other. Figure 4.7 below represents the findings.

Economic factors play a major role in determining whether one acquires a new technology or not. Usually, the lower the level of income, the lower the level of new technology, while the higher the level of income, the higher the level of acquiring and usage of a new technology. This is because most of the new technologies have a cost implication and only those with money are able to adopt the technologies faster.

Adoption of briquettes is, however, less costly as they can be used in the already available equipment including jikos and improved cooking stoves. A study by GVEP (2010) found that most urban consumers have compatible cooking equipment (jikos) and consequently low cost implication in adoption of briquettes. This study also
agrees with a report by UNEP (2006) which revealed the increasing trend of the improved ceramic charcoal stove among the urban communities over the past decades (see plate 4.1 and 4.2). Over 85% of the urban households used these stoves in 2002 compared to 47% in the year 2000 and only 13% in 1997.

Plate 4.1: improved ceramic charcoal stove  
Plate 4.2: Metallic Jiko. 
Photo credit: Paul Mugo (03/11/2012)  
Photo credit: Paul Mugo (03/11/2012)

4.3.3 Environmental considerations in choice of energy

Environmental concerns are important components in choice of household energy. A study by Klingshirn (2000), found that a well integrated concept in rural development should include environmental concerns. Biomass energy impacts directly on the everyday life of the rural families and is a powerful factor in raising awareness of the need to protect the environment at the individual and household level. Environmental issues of household energy are important since they include indoor air pollution, a leading cause of deaths in Sub-Saharan Africa, and the emission of GHGs responsible for climate change.

It is important to study why respondents had little thought or consideration; and do not factor environmental issues in their purchase of household fuel energy, lucid explanation should be sought through further studies.
4.4 Briquettes as Fuel Energy

4.4.1 Awareness levels

The second hypothesis of the study was that low awareness levels of Briquettes have led to their poor adoption as viable alternative energy sources. Asked if they were aware of fuel briquettes as alternative sources of fuel energy 30% (n=21) said Yes and the majority 70% (n=49) said No. Figure 4.8 below illustrates these findings.

Fig 4.8: Awareness levels of fuel Briquettes in Ruiru Municipality, Kiambu County in July, 2013.

As the findings illustrate a majority of respondents were not aware of fuel briquettes as an alternative source of fuel energy. These findings prove hypothesis 2 that low awareness levels of briquettes have led to their poor adoption as viable energy source.

Awareness creation is one of the important ways of society overcoming ignorance and disseminating knowledge about household energy efficiency. This is important in achieving a population well versed with energy conservation and that articulates environmental issues objectively. Education on household energy efficiency appliances and energy types should be carried out to the large masses of the population, in order to encourage energy efficiency and environmental conservation as a whole. Studies on better methodology to carry out public awareness campaigns
on household energy efficiency types and appliances should be undertaken in order to arrive at a better strategy of disseminating education on energy efficiency.

4.4.2 Source of information

The 21 (30%) respondents who were aware of the fuels briquettes indicated the source of the information as follows; 3 (41%) NGOs, 14 (66%) Traders, 2 (10%) Women/Youth Groups and 2 (10%) Trade Fairs/Shows. Table 4.2 below illustrates these findings.

Table 4.2: Sources of information for fuel briquettes in Ruiru municipality, Kiambu County in July, 2013.

<table>
<thead>
<tr>
<th>Number of respondents (n)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Workers</td>
<td>0</td>
</tr>
<tr>
<td>Media</td>
<td>0</td>
</tr>
<tr>
<td>NGOs</td>
<td>3</td>
</tr>
<tr>
<td>Traders</td>
<td>14</td>
</tr>
<tr>
<td>Women/Youth Groups</td>
<td>2</td>
</tr>
<tr>
<td>Trade Fairs/Shows</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>21</td>
</tr>
</tbody>
</table>

4.4.3 Frequency of briquettes use

Asked how often they use briquettes for cooking/heating, 4 (6%) indicated they Always use. They attributed this to their affordability, long burning period and ease of access to the briquette trader. Another 14 (20%) indicated frequent use saying they used briquettes when cooking heavy meals and other energy sources for lighter meals. This is because briquettes burn for long making them more affordable over other fuel sources for meals that take longer to cook. 3 (4%) who indicated rarely use cited
unavailability of briquettes in the market. The majority 49 (70%) who Never use briquettes indicated lack of awareness of briquettes as an alternative source of energy.

4.5 Community responses on briquette use.
During the focused group discussions, community members expressed knowledge of the importance of energy for cooking and heating in their households. They listed the major sources of fuel energy as LPG, charcoal, kerosene, firewood, occasional agricultural residues and briquettes. They acknowledged the introduction of new technologies including the fuel saving jikos and briquettes but said these were yet to be fully recognized in the community. They attributed this to community attachments to traditional sources of fuel as well as unavailability. It was clear that more public education on alternative energy sources needed to be done. Suggestions made included government support, education campaigns as well as empowerment of local youth and women groups with skills to develop such technologies locally.

4.6 Components of Municipal solid waste that manufacture fuel Briquettes.
Asked about the Municipal solid waste components used in the manufacture of briquettes, the manufacturer said anything that burns without producing toxic ash or fumes could be used. Locally available materials in Ruiru Municipality include waste paper; cardboard; agricultural residue including leaves, grass, stems and straw; charcoal dust and sawdust (See plates 4.3 and 4.4).

Plate 4.3: Sawdust and workshop wastes.
*Photo credit: Paul Mugo (03/11/12)*

Plate 4.4: Charcoal dust
*Photo credit: Paul Mugo (03/11/12)*
These materials are sorted out in proportions, chopped and mixed into soupy slurry water which is later squeezed inside a porous cylindrical mould to create the hollow round cylinder or briquette. According to Terra Nuova, et al., (2007), a variety of Municipal solid wastes that include both urban and rural organic residues and wastes could be used as alternative domestic fuel if offered in an acceptable form and at a reasonable price. As noted in the literature review, in the manufacture of fuel briquettes, the availability of raw materials has a strong influence over producers’ success. There are three main dimensions to this; proximity, suitability, and quantity (Nuova, 2007). Depending on which materials are used to make the briquettes, they may burn cleaner and longer than conventional fuels like charcoal.

4.7 Conclusions

The first objective of the study was to determine the levels of adoption of fuel briquettes as an alternative source of energy. An overwhelming 70% of the respondents had never used fuel briquettes for cooking and heating in their households; 3% said they used briquettes rarely, 6% used them frequently; and only 20% always used them. The second objective was to examine the obstacles to adoption of fuel briquettes as an alternative source of energy. Majority, 70%, of the respondents were not aware of fuel briquettes. Awareness of briquettes as a viable fuel energy should be increased through concerted efforts by the government and private sector if uptake is to increase. The third objective was to identify components of municipal solid wastes that can be used in the manufacture of fuel briquettes. The local briquette manufacturer emphasized that the availability of raw materials has a strong influence the production process since it influences both the quality of end product as well as the cost of production. Ruiru Municipality, being an urban area and thriving economy provides a variety of wastes from domestic and commercial uses. The wastes identified by the manufacturer and as well identified through observation include charcoal dust; waste paper, sawdust, cardboard and wood pieces; and agricultural residue including leaves and stems.
CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the summary of the research study findings, conclusions and recommendations. The study was designed to assess the use of energy efficient fuel briquettes as an alternative source of fuel in Ruiru Municipality of Kiambu County, Kenya, towards improved energy efficiency.

5.2 Summary

Majority of the respondents interviewed 71% were Female. Since most women are left at home doing domestic chores, they are well versed with the type of fuel energy used for domestic cooking and heating. The study area was dominated by the youth and middle aged with 61% of respondents below the age of 41 years. Since the youth are more adaptive to new ideas compared to the old, it is evident that with enhanced awareness creation the urban population could easily adapt the fuel. Majority of the respondents had household sizes with 83% indicating a household size of 1-3 members. Household size influences household energy consumption and fuel briquettes could offer a cheap alternative for both small and large households since they have longer burn duration than competing fuels.

The study found that half of the respondents were educated to the tertiary level. This population has high analytical capability and would be easily convinced of the comparative advantage of briquettes over other fuels. The study found that the most considered factors in the choice of energy sources are affordability and availability. It is important to study why respondents had little thought or consideration; and do not factor environmental issues in their purchase of household fuel energy. Only 30% of the respondents were aware of fuel briquettes as alternative fuel source. The low adoption levels for briquettes have been attributed to awareness levels. Studies on better strategies of disseminating education on energy efficiency should be done. Many locally available municipal solid waste materials in Ruiru Municipality including waste paper; cardboard; charcoal dust and sawdust could be used in the manufacture of briquettes. However, there is need for more studies on the best ratios
of raw materials that will produce briquettes that burn cleaner and longer than conventional fuels like charcoal.

5.3 Conclusions

Drawing from the results and interpretation of qualitative and quantitative analysis the following conclusions can be made.

Majority (70%) of respondents interviewed did not know about briquettes or their advantages and thus the level of adoption of fuel briquettes in Ruiru was very low.

Choice of energy source was determined by levels of income with more respondents with low monthly incomes using briquettes compared to the high income end; and availability with 24% of the respondents attributing their choice of energy source to availability.

Although they have not managed to penetrate deeper into the market, it is evident that briquette traders are the main source of information about briquettes in Ruiru municipality informing 66% of respondents.

Government has not formulated policies to encourage the use of alternative fuels. Briquettes offer a viable cheap and highly effective source of energy as evidenced by the response of briquette users in Ruiru.

Locally available materials in Ruiru Municipality including waste paper; cardboard; agricultural residue including leaves, grass, stems and straw; charcoal dust and sawdust can be used in the manufacture of briquettes.

5.4 Recommendations

The researcher suggests that the following should be done to improve efficiency of fuel briquettes as an alternative source of fuel.

1. There is need for an aggressive campaign to increase awareness of briquettes technology. Increased adoption of this technology would reduce pressure on forests and other woodlands surrounding Kiambu County.
2. An energy center should be established in Kiambu County to act as the focal point for dissemination of energy efficient briquettes to locals.

3. It is important to build the capacity of field extension staff in the energy sector in order to impart necessary skills to assist in promotion of fuel briquettes at the local level.

4. There is need for standardization in design and making of briquettes to ensure quality is not compromised in the maximization of profits. Compromise of quality may make households revert back to traditional energy sources which are largely environmentally unsustainable.

5. The government and donor agencies should produce subsidized compressors or machines so that manufacturers produce briquettes at low costs.

6. Simplified Climate Change education should be increased at the local level to ensure the citizenry factor in environmental considerations in their choice of energy sources.

7. Municipal waste segregation would go a long way to helping the manufacturers in sourcing the materials.

5.5 Areas for Further Research

The following are recommendations for further research; This study found the following locally available materials in Ruiru Municipality waste paper; cardboard; agricultural residue including leaves, grass, stems and straw; charcoal dust and sawdust. There is need for further research on other materials that could be used in the manufacture of fuel briquettes.

A comparative study should be done on the amounts of pollutants emitted by briquettes from various types of municipal waste.

A country wide study should be done to assess the usage and awareness of alternative sources of fuel including improved firewood stoves, improved charcoal stoves and solar cooking. This will aid policy makers in formulating policies and strategies that promote sources of fuel that preserve the environment.
REFERENCES


Link: [http://www.unep.org/yearbook/2012](http://www.unep.org/yearbook/2012)


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APPENDICES

Appendix 1: Household Questionnaire

I am Mr. Paul W. Mugo, doing research on “Energy Efficient Technologies for Climate Change Mitigation: The Case of Fuel Briquettes in Ruiru Municipality, Kiambu County, Kenya”. Kindly answer the following questions by either ticking the right answer or writing short answers in the spaces provided.

Background Information

Questionnaire number ........................................

House Hold No...........................

Location ........................................

Sub-Location ........................................

Section A: Informant Background

1. Name of Household head ...............................................................  
2. Name of respondent if not household head ...............................................................  
3. Gender: Male □  Female □  
4. Age bracket:  
   a) >18 □  b) 18-25 □  c) 26-33 □  d) 34-41 □  e) 42-49 □  
   f) 50-57 □  g) 58-65 □  h) <66 □  

5. Marital status:  
   a) Married (Go to 6.) □  b) Single □  c) Widow(er) □  
   d) Divorced □  e) Separated □  

6. If married, occupation of spouse..............................................

7. Household size:  
   a) 1-3 □  b) 4-6 □  c) 7-9 □  d) >9 □  

57
8. Level of education (tick one)
   a) None □   b) Primary School □   c) Secondary School □
   d) College/ University □   e) Informal education (Please specify .......)
9. Indicate average household income per month;
   Less than Ksh.5, 000 □   Ksh. 5,001 – 10,000 □   Ksh. 10,001 – 15,000 □
   Ksh. 15,001 – 20,000 □   Ksh. 20,001 – 30,000 □   Ksh. 30,001 – 50,000 □
   Ksh. 50,001 – 100,000 □   Over Ksh.100, 000 □

   Section B: Energy Sources

10. Rate the following types of fuel energy sources as you use in cooking and heating;
   (Indicate; 1. Never used, 2. Rarely used, 3. Frequently used, 4. Always used)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Briquettes</td>
<td></td>
</tr>
<tr>
<td>b) Firewood</td>
<td></td>
</tr>
<tr>
<td>c) Charcoal</td>
<td></td>
</tr>
<tr>
<td>d) Kerosene</td>
<td></td>
</tr>
<tr>
<td>e) Liquid Petroleum Gas (LPG)</td>
<td></td>
</tr>
<tr>
<td>f) Electricity</td>
<td></td>
</tr>
<tr>
<td>g) Agricultural residues (maize stocks, maize cobs, coffee pruning's, etc)</td>
<td></td>
</tr>
<tr>
<td>h) Others (Please specify)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11. Which of the following explains your choice of energy sources in Q.10 above?
   a) Easily Available □ b) Cheap □ c) Highly Effective □
   d) Compatible Equipment □ e) Less Smoke □ f) Ease of lighting □
   g) Ease of extinguishing □ h) environmentally friendly □
   i) Other □ (Please explain .........................)
Section C: Briquettes as fuel energy

12. Are you aware of fuel briquettes as alternative source of fuel energy?
   a) Yes □ (Please go to Qn.13 below)  b) No □

13. If yes, where did you get the information?
   a) Government workers □  b) Media □  c) NGOs □  d) Traders □
   e) Women/ Youth group □  f) Others □ (Please specify .................)

14. How often do you use briquettes for cooking / heating in your home?
   a) Always □  b) Frequently □  c) Rarely □  d) Never □

15. Briefly explain your answer above

........................................................................................................
........................................................................................................
........................................................................................................
........................................................................................................
........................................................................................................
........................................................................................................

16. Do you know of any promoters of briquettes in this municipality?
   Yes □ (Please go to Qn.15 below)  No □

17. If yes, name the promoters

........................................................................................................
........................................................................................................
........................................................................................................
........................................................................................................

Thank you for taking the time to complete this questionnaire.
Appendix 2: Observation record sheet

<table>
<thead>
<tr>
<th>Sheet No.</th>
<th>Household No.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Sub Location</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type of fuel visible</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(e.g. firewood, charcoal, etc)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Availability of traditional kitchen</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type of wastes visible</th>
<th></th>
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Appendix 3: Key Respondents Interview Schedule

a) Kenya Forest Service officer/ Forest guards

1. How has the government forest conservation efforts been affected by increased demand of fuel energy especially firewood and charcoal in this area?
2. What is the Kenya Forest Service doing to protect forests in the area being important carbon sinks?
3. Does KFS involve other stakeholders and private sector in achievement of its objectives?
4. How can strategies for provision of energy efficient fuel technologies be strengthened?
5. What are some of the policy issues that need to be addressed to increase the use of energy efficient technologies among the population in general?

b) District Environment Officer

1. How has increased fuel energy demand affected Environmental conservation in this district?
2. What efforts has your office taken to promote energy efficient fuel technologies for climate change mitigation?
3. How has your office been involved in the management of municipal solid waste in Ruiru?
4. Does your office promote technologies that utilize municipal solid waste to generate energy?
5. How can strategies for provision of energy efficient fuel technologies be strengthened?
6. What are some of the policy issues that need to be addressed to increase the use of energy efficient technologies among the population in general?

c) Chief / Councilor/ Village elder/ Church elder/

1. Which is the most prevalent source of fuel energy for residents in this area?
2. What energy efficient fuel technologies are the residents using in for cooking?
3. How can strategies for provision of energy efficient fuel technologies be strengthened?
4. What are some of the policy issues that need to be addressed to increase the use of energy efficient technologies among the population in general?

d) The briquette manufacturer/seller.
1. For how long have you manufactured/ sold briquettes in Ruiru Municipality?
2. What raw materials do you use in the manufacture? (Availability, cost, sustainability)
3. How do you market your product? (price, distribution, advertising)
4. What challenges do you encounter in manufacture and sale of fuel briquettes?
5. Do you receive assistance of any form from government, private sector or other individuals?
6. What is your opinion on the future of briquettes as an alternative fuel source?
Appendix 4: Focus Group Discussion Guide

Introduction

- The aim of the focus group discussion
- All participants introduce themselves

1. Importance of cooking and heating in the house.
   **Probe:** - What is the use of cooking and heating in the house?
   - What benefits do you get from cooking and heating?

2. What are the major sources of energy for heating and cooking in the house?
   **Probe:** - The energy sources used and their effects on the environment?

3. What alternative sources of energy are available?
   **Probe:** - Available renewable energy sources and energy efficient technologies
   - The uptake levels of these technologies?
   - Awareness of fuel briquettes?

4. What challenges are facing these alternative sources of energy?
   **Probe:** - Why don’t the residents use these technologies?

5. What can be done to increase uptake of briquettes in the area?
   **Probe:** - What individual person can do?
   - What community can do?
   - What government can do?

Break out groups;

- Women
- Men
- Youth