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DEPARTMENT OF GEOGRAPHY & ENVIRONMENTAL STUDIES

ASSESSING CONTRIBUTION OF IMPROVED COOK STOVES IN REDUCING WOODFUEL CONSUMPTION IN KENYA, CASE STUDY OF PUBLIC SECONDARY SCHOOLS IN MACHAKOS COUNTY

ANNEH WANGARI MWAURA

C50/88213/2016

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DECLARATION

I affirm that this project paper is my original work and that it has not been presented for award of any degree in The University of Nairobi or in any other institution of higher learning.

Sign:  Date: 14/09/2020

ANNEH WANGARI MWAURA

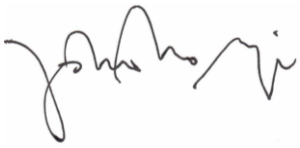
C50/88213/2016

This research project has been submitted for examination with our approval as university supervisors.

Name: DR. BONIFACE WAMBUA

Sign:  **Date: 14/09/2020**

Name: DR. JOHN MUSINGI

Sign:  **Date: 17/09/2020**

DEDICATION

To my family for their endless support.

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ABBREVIATIONS AND ACRONYMS

DEEP: Developing Energy Enterprises Project

EIA: Environment Impact Assessment

EMCA: Environmental Management and Conservation Act

EnDev: Energizing Development

ERC: Energy Regulatory Commission

FAO: Food and Agriculture Organization

GACC: Global Alliance for Clean Cook stoves

GEF: Global Environment Facility

GHGs: Green House Gases

ICS: Improved Cook Stove

ICCD: Improved Cook stove for Community Development

IEA: International Energy Agency

IPCC: Intergovernmental Panel for Climate Change

JDPC: Justice Development for Peace Commission

KFS: Kenya Forest Service

KIPPRA: Kenya Institute for Public Policy Research and Analysis

LPG: Liquefied Petroleum Gas

MoE: Ministry of Energy

MoEd: Ministry of Education

MNRE: Ministry of New and Renewable Energy

NEMA: National Environment and Management Authority

NGOs: Non-Governmental Organizations

RETAP: Renewable Energy Technology Assistant Program

RTE: Rural Technology Enterprises

SDGs: Strategic Development Goals

SEI: Stockholm Environment Institute

SME: Small and Medium Enterprises

UNEP: United Nation Environment Programme

USAID: United States Agency for International Development

WHO: Worlds Health Organization

ABSTRACT

The motive of this research was to assess the contribution of improved cook stoves in reducing wood fuel consumption in Kenya, the case of public secondary schools in Machakos County. There has been a significant shift in the use of biomass fuel due to the increased level of poverty. Household consumption of biomass has risen to 83% in 2020 from 73% in 1980. Charcoal and firewood take up as the main source of fuel especially in Kenyan schools, hospitals, hotels and prisons. Firewood is increasingly supplied from smallholder lands and farm woodlots. There is more than 90% supply of biomass for the rural household consumption as the demand hits close to 70%. Presently, development of biomass energy is the subject matter ascribed to diminishing worldwide fossil fuels resources and escalating fuel prices. The demand for biomass energy has an annual growth of about 2.7% as the available sustainable provision has an increase rate of 0.6%. Schools are one of the bulk consumers of wood fuel and therefore there is need to have a sustainable solution to the high wood fuel consumption like adoption of the improved cook stoves. The demand for the wood fuel is high leading to deforestation thus its implications which include floods, soil erosion, loss of biodiversity and exposure to desertification. The objectives that steered this research included; to determine the adoption rate of the energy saving stoves, to assess the rate of wood fuel consumption and to determine factors influencing choice of cook stove by public secondary schools in Machakos County. Data was collected from a stratified sample of 80 secondary schools in Machakos County using survey questionnaire. Data from qualitative interviews and observation complemented questionnaire data. The hypothesis was tested using Chi-Square test. The collected data was analyzed using Statistical Package for Social Sciences (SPSS) and presented by use of descriptive statistics such as tables, Charts, Graphs and Diagrams. The study findings revealed that modern cook stoves are energy efficient and their use results into a significant reduction in the amount of wood fuel consumption compared to the traditional cook stoves. The findings also showed that over 90% of the secondary schools in Machakos County were already using modern improve cook stoves as one way of reducing the use of wood fuel. In addition, the study revealed that the adoption rate of the improved cook stoves was moderate at 50% and was determined majorly by socio –economic factors such as availability of funds, type of school (boarding or day), number of students, type and number of meals prepared on daily basis. The study therefore concluded that secondary schools in Machakos County are adopting the use of modern cook stoves because they have been found to be energy efficient and using them resulted into a significant reduction in the amount of wood fuel consumption compared to the traditional cook stoves. Based on the findings and conclusion, the study recommended to the managements and the stakeholders of all the secondary schools in Machakos County that they should strive to acquire the improved cook stoves as one way of reducing wood fuel consumption; in so doing the implication of deforestation will be contained.

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CHAPTER ONE: INTRODUCTION

1.1 Background of study

Most biomass energy researches in the past focused on household energy demand and supply chains giving little attention to other large scale biomass energy consumers (MOE, 2002; O'keete *et al.,* 1984). Studies (Kituyi and Kirubi, 2003; Kituyi *et al*., 2001; Ngeywo, 2008; RETAP, 2007, 2010) have focused on biomass energy consumption in other institutions in Kenya. Most of these institutions rely on traditional cook stoves that are inefficient (5-10%) leading to high fuelwood demand and pressure on natural resources and emission from the products due to incomplete combustion.

There is a significant shift to use of biomass fuel due to increased population, high level of poverty and lack of cheap alternative source of fuel. Wood fuel remain the main source of cooking fuel especially in Kenyan schools, hospitals, hotels and prisons. Biomass make provision to more than 90% of the countryside consumption as the demand hits close to 70%. The demand for biomass energy has an annual growth of about 2.7% while the continuous provision is growing at a rate of 0.6% (Helios International, 2009).

This demand especially for firewood and charcoal exert a lot of constraints on our accessible woodland and forest resources (UNEP, 2007; KIPPRA, 2010) considering that Kenya has a constrained forest cover of about 5.9% which is below the minimal 10% of forest cover (KFS,2012). Kenya also has a wood deficit of about 57.2% (Mugo & Gathui, 2010). There is need to relief schools of the burden incurred in heating water and cooking since most of them depend majorly on biomass. Use of cleaner cooking fuel will greatly reduce Kenya's carbon footprint. Kenya's over usage of biofuel as the main energy source is largely an outcome of poor electrification. There has been a propulsion towards utilization of other sources of energy due to greater awareness of the unfavorable impact which consumption of biomass has on nature such as pollution and deforestation.

Usage of biomass in inefficient stoves lead to emission of large quantities of black carbon and carbon based Green House Gases (Ramanathan & Carmichael, 2008: 223). A report by the Energy Regulatory Commission (2004:6) revealed massive reliance on woodpiles and other biomass that constitute of about 68 % of the total energy consumed.

Usage of traditional stoves wastes an inestimable amount of fuel due to its inefficiency which result into unfavorable environmental effects. Smoke emissions from biomass combustion are important source of Indoor Air Pollution. It contains pollutants that adversely affect health such as Carbon (II) Oxide, Particulate Matter and polycyclic organic matter (Koning *et al*, 1985). Approximately, 90% of around 20,000 institutions here in Kenya are depending on biofuel as the foremost energy source for cooking (Waithera, 2008; Kituyi, 2000). A recent study by RETAP (2007) reveals that over 1.7 million tonnes of wood fuel are used yearly by institutions in Kenya for meal preparation. Enhanced biomass energy technologies are devices that have been developed to replace traditional biomass energy technologies (GACC, 2013). They are designed to enhance ignition efficiency of biomass, use less fuel, save cooking time, increase convenience in cooking process and reduce smoke production during cooking.

According to Kitheka et al., (2019), biofuel energy render 68% of the entire national energy demand in Kenya and this trend is anticipated to carry on as the major energy source for the next uncertain period of time. In 2000, a report revealed that Kenya consume 34.3 million tonnes of biofuel of which 15.1 million tonnes was wood fuel while 16.5 million tonnes was wood for coal manufactured in kilns which has only 10% efficiency. 43% of the national usage was obtained from sustainable provisions while 57% came from unsuitable provisions. The entire land area in Kenya is approximate 57.6 million hectares and only 6% (3,456,000) is woodland and is estimated to be dwindling at the rate of 52,000 hectares (0.09%) annually (Hamid & Blanchard, 2018). In 1980, of all the wood reaped in the country 94% was used for wood fuel, 4% for poles and 2% for timber. By the year 1997, the proportions estimation was 90% wood fuel, 5% for industrial feedstock and 5% for poles and posts.

Educational institutions are one of the sub-sets of service-sector that depend almost entirely on fuelwood. Several studies have been carried out to understand the fuelwood consumption rates and patterns by schools. An example was a study by Kituyi (2000) that revealed 90 percent of 20,000 institutions depended totally on fuelwood for day-to-day cooking and heating purposes. In 2007, another research by RETAP announced that 75% of all secondary schools in Kenya were boarding type and relied completely on wood fuel for cooking and boiling water. The study reported a consumption estimate of 200- 300 tons of fuelwood annually for a typical boarding school. An exception was a handful of mainly high cost schools that used electricity and LPG. This scenario changed in 2010 according to a study by RETAP that revealed some prominent schools had switched back to using fuelwood. These prominent schools included Kenya High

School in Nairobi, which had switched from using steam boilers that depended on oil to fuelwood. Similarly, Lenana High School also switched from LPG to fuelwood. This was done so as to cut on the cost because after the modifications of the energy sector in 1994, the charges of petroleum products reduced and this included LPG whose cost had been escalating.

1.2 Problem statement

Usage of traditional stoves waste an inestimable amount of fuel due to its inefficiency which result to unfavorable environmental effects. Usage of biomass in inefficient stoves lead to emission of large quantities of black carbon and carbon based Green House Gases (Ramanathan & Carmichael, 2008: 223). Most of the stoves used in Kenyan secondary school are inefficient and consume more wood fuel because of their physical design which do not make a complete combustion as required (Bailis, 2004), they have poor heat transfer efficiency to the cooking pot (Mark *et al*,2007). There has been massive loss and destruction of indigenous forests in Africa thus having depletion of more than three quarters of their forest cover (WHO, 2006). In this case, there's degradation of water catchment areas, destruction of carbon (ii) oxide sink and soil erosion due to lack of soil protective cover.

Educational institutions are one of the sub-sets of service-sector that depend almost entirely on fuel wood. Approximately, 90% of around 20,000 institutions in Kenya are depending on biofuel as the foremost energy source for cooking (Waithera, 2008; Kituyi, 2000). Learning institutions especially the secondary schools most of them having boarding facilities are the largest consumers of wood fuel and the rate at which they are consuming is alarming. There is environmental impact brought about by this large consumption and there is need to reduce and have regulation measures to ensure conservation and protection of our forests and woodlands and find alternative ways of reducing wood fuel consumption which include adoption of the modern cook stoves.

Considering the recent floods, erosion and landslides experienced we need to act urgently and work towards preventing such occurrences in future. Most of this is due to climate change where most of the forest covers and vegetation has been cleared thus making it easy for the soil to be carried away by the rains.

Kenya has a constrained forest cover of about 5.9% which is below the minimal 10% of forest cover (KFS,2012). The land area in Kenya is approximate 57.6 million hectares and only 6% (3,456,000) is woodland. It is estimated to be dwindling at the rate of 52,000 hectares (0.09%)

annually (Hamid & Blanchard, 2018). By 2000, Kenya consumed 34.3 million tonnes of biofuel of which 15.1 million tonnes was wood fuel. Machakos County is dry, semi-arid with sloppy terrain and this state exposes it to natural calamities such as drought and famine. Machakos County had a forest cover of 477.617km2 accounting for 7.6% of the total land area but has dropped to 3.3% due to deforestation. The remaining forest cover should be protected and conserved so as to prevent the area from becoming a desert. Recently there has been cases of floods, erosion and landslides as a result of climate change where most of the forest covers and vegetation has been cleared thus making it easy for the soil to be carried away by the rains.

This study assessed the contribution of the improved cook stove in reducing the quantity of wood fuel consumed by the secondary schools in Machakos County. Use of improved cook stove is known to reduce significantly the quantity of wood fuel consumed because of their physical make that make them more energy efficient. Wider adoption of the improved cook stove will reduce the pressure on the available forest resources thus contain the implications of deforestation that are being experienced in the County and other parts of the country.

1.3 Research questions

i. What is the adoption rate of the improved cook stoves in public secondary schools in the study area?
ii. What is the rate of wood fuel consumption in public secondary schools in the study area?
iii. What factors influence the choice of cook stove in public secondary schools in the study area?

1.4 Objectives of the study

The overall objective of this study was to assess the impact of use of improved cook stoves in reducing implications of desertification in Kenya, the case of public secondary schools in Machakos County.

i. To determine the adoption rate of the improved cook stoves by public secondary schools in the study area.
ii. To assess the rate of wood fuel consumption in public secondary schools in the study area.
iii. To determine factors influencing choice of cook stove by public secondary schools in the study area.

1.5 Research Hypotheses

H_{01}: There is no difference between quantity of wood fuel used by modern cook stoves and traditional cook stoves.

1.6 Scope of the study

The focal point of this study was on public secondary schools in Machakos County since most institutions have a consistent feeding program for their students as most of them are boarding schools. The type of cook stove and the number of students were some of the determining factors on the rate of wood fuel consumption. Other factors included the type and number of meals prepared each day as well as the cost of the wood fuel. Considering most of the schools are boarding, the day schools were also being considered as they make at least one meal in a day. The reason for choosing Machakos County as the study area is because of its confined atmospheric conditions which is dry, semi-arid with sloppy terrain and an elevation of 1000 to 2100 meters above sea level. This semi-arid state exposes it to natural calamities such as drought and famine and therefore the available forest cover should be protected and conserved so as to prevent the area from becoming a desert.

1.7 Justification of the study

The lack of adequate and reliable data is a challenge in achieving a devolved sustainable energy plan especially for resources like biomass. The same case applies in learning institution where most of them do not keep records of the fuel consumed but a budget is allocated for the purchase. This study will enable documentation of detailed analysis of fuel consumption comparing learning institutions using the energy saving cook stoves and those that use other types of cook stoves. This data will lead to wider adoption of the energy saving cook stoves by other learning institutions and the country as a whole to ensure sustainability of wood energy.

This study may help schools ensure efficient access, utilization, planning, and management of wood resources. There is significant economic benefit to schools and direct financial saving from reduced wood fuel consumption. Energy being a devolved function it may help in formulation of County Integrated Development Plans which may help protect our forests. Additionally, the results of this study may assist the secondary schools in Machakos to come up with proper initiatives of adopting the use of improved cook stoves so as to diminish the pressure on forests in the region. For policy makers it may help and guide in formulation of laws, policies and regulations towards protection, conservation and management of natural resources in our

counties. To ensure high and wider adoption of the energy saving cook stoves, some schools need empirical evidence of the economic, environmental and social benefits for them to be interested. The use of modern cook stoves helps in poverty eradication and this helps Kenya as a country to achieve the set Strategic Development Goals (SDGs). Furthermore, there is significant reduction in deforestation. Environmental and natural resources have been devolved from national to county level and therefore there's need for County Integrated Development Plan to allow proper planning and management. County Energy Development Plans need comprehensive analysis on supply-demand for all consumer levels so that there can be proper documentation on usage of the available energy resources in the counties. Every institution should have a data base for comparison on usage and consumption of energy resources as this may enable them to have a clear guideline on venturing in energy saving methods if most of their cash flow is directed towards purchase of fuel. The focus of this study is to fill the void on use of improved cook stoves in learning institutions. This is important for developing an effective and long term plan for wood supply in the learning institution. The study may also examine the adoption rate of the improved modern cook stoves as this will be relevant for the biomass policy at both county and national level.

CHAPTER TWO: LITERATURE REVIEW

2.1 Background Information on Wood Fuel Consumption

Currently, the global biomass energy supply is approximated to be at 10% of which mostly is consumed in the economically developing countries for cooking and heating purposes. A research done in 2009 showed that manufacturing industries consumed 15%, transportation 4% while power generating companies consumed 13%. The world obtains an estimation of 11% of its energy from biofuel (IEA, 1998b) and more than two and a half billion people (Kituyi and Odongo, 2008) rely majorly on traditional fuels for cooking. But in the poor developing nations, 90 percent of energy supply is from biofuel and mostly it's in traditional or noncommercial forms (firewood, charcoal, dung and agricultural residues) owing to continued lack of access to, availability and affordability of improved energy technology. In sub-Sahara Africa, firewood dominates the traditional consumption of biofuel for cooking and heating.

In terms of health, the use of biomass raises concerns with regard to wood fuel-associated indoor air pollution in view of its health impacts. This health dimension adversely diminishes the quality of life, especially for the cooks. Kenya obtains about 75% of their total energy from biomass while India derives 50%, China 33% and Brazil 25%. Other industrialized countries such as Finland, Ireland, Sweden and USA also derive a considerable amount of energy of 18%, 16%, 9% and 3% respectively.

2.2 Global biomass energy consumption

Biomass energy matrix is very key for countryside and urban groups with decentralized settlements in India (Sreenivas, Rao & Patwardhan, 2018). In India, there is an annual investment of about $ 9251 directed towards development of biomass related projects and as a result 5000 million units of power are generated. The Ministry of New and Renewable Energy (MNRE) is set to generate 10 GW of power from biomass as a national target by the year 2022 even though India has a potential of generating about 18 GW. Presently, the total energy used in India 32% of it is obtained from Biomass. According to Parihar, Sethi & Banerjee (2019), more than 70% of India's population rely on biofuel for its energy requirements. The country has more than 5GW capacity biomass powered plants of which 83% of it is connected to the grid while 17% are off-grid plants.

As indicated by Sunita, Faran and Ganguly (2018), biofuel is the fourth largest energy source worldwide and the first in India. The power stations have the capacity of storing 10 folds the

present annual energy consumption. Nonetheless, this power is mostly consumed inefficiently and goes to waste due to constrains such as technological and economical. Biomass energy research is of essence for India since the country has an extreme reliance on local energy resources in most rural settlements. Also, high population growth rate, rising cost of transportation by the commercial fuel carriers, electricity, gas, and other petroleum products lead to increased biofuel energy utilization. On the other hand, biofuel encounters various challenges such as accessibility, intensive labor and inflexibility in consumption although they can be transformed into many other forms.

In Nigeria, modern biomass consumption is reported at 434160 (World Bank, 2018). This is based on collection of development indicators, compiled from officially recognized sources. In most cases, the subject matter of energy in Nigeria focuses on its ability to produce and export crude oil and natural gas as well as discuss and analyze the emphasis on internal development on curbing any form of theft, smuggling, supply disruptions and/or on the macroeconomic effects of oil revenues. However, there are a few researches on the use of commercial energy. Over the years, biofuel consumption in Nigeria has been a source of many challenges; ranging from health hazards, socioeconomic problems for women and children, soil erosion, environmental degradation as well as deforestation. The overreliance of biofuel consumption can be linked to factors such as economic aspects including large population density, destitution levels, inaccessibility to other sources as well as high cost of modern fuel. Despite all these challenges, biofuel have a great potential to contribute to the broadening of the economy and development.

In 1980, wood fuel provided 71% of Kenya's total energy requirements. Two decades down the line, the current study on national biomass energy (Republic of Kenya, 2017) showed that biofuel contribute up to 68% of the national energy requirements. The usage is said to be 34.3 million tonnes of which 15.1 million tonnes is in form of wood fuel while 16.5 million tonnes is used for charcoal (Johnston, Matare, Pettersen, Mumba, Pullanikkatil, Zachary & Karimi, 2018). This means 240,000 and 298,000 hectares will have to be harvested for firewood and coal respectively per year. To manage and conserve the forests and woodland resources in the country, proper conservation measures need to be put in place such as afforestation and reforestation.

2.3 School Use of Biomass

In the United States of America, most institutions have been executing earnestly different initiatives to lessen their carbon footprint and free themselves from environmental destruction by use of biofuel such as woodchips, wood pellets, and cellulosic byproducts. This provides institutions access to other sources of fuel, that is coal since biomass energy is considered both renewable and carbon neutral (Young, Anderson, Naughton & Mullan, 2018). For instance, the University of Cincinnati (UC), has tried out biofuel use, such as woodchips and paper pellets, and is now considering use of wood pellets. The university obtained a permit for burning clean cellulosic fuels after numerous tests approximately three years ago and indicated that consumption of such fuel could meet appropriate standards. As showed by Shahbaz, Solarin, Hammoudeh and Shahzad (2017), most of the U.S. institutions have focused on local biomass provisions, typically within 100 miles, to reduce transportation costs. There is still research on energy crops such as switch grass and miscanthus which have a stable feedstock supply even though large quantities are needed than coal due to its lower heating value and, therefore, spacious storage facility is an important requirement. In addition, proper design modifications on the feeding system is required as well as proper staff training to operate the biomass boilers is essential.

In South Africa, Khangezile School was lucky enough to be selected to benefit from a project where renewable energy technologies were installed in the school by Earthlife Africa, an environmental justice organization, as part of the Sustainable Energy and Livelihoods project alongside four other schools (Rupf, Bahri, de Boer & McHenry, 2016). The school in KwaThema, east of Johannesburg provide food for 400 children twice a day as part of the Gauteng Department of Education ‘school nutrition program. European Union and Oxfam provided the funds for the project. The school was able to go almost entirely off the grid with installation of a biogas digester as well as solar panels. The social effects of utilizing biomass at a school was observed through the improved standards of living as well as quality of life for both the learners and their families due to the reduction of waste and associated health problems. This achievement saw an increase in demand to install the system in other schools around the country. The USAID South African Low Emissions Development (SA-LED) Program conducted a study on the use of biomass in institutions and was able to observe and learn from the impacts as a result of using biogas to cook food for learners in Khangezile Primary School. According to Roopnarain and Adeleke (2017), biogas from food and other organic waste is not a new source

of natural gas production even though biogas technology has really developed such that most people can benefit from it.

In South Africa there is production of small scale "drop-in" plastic biogas digesters that are currently being used in schools and communities. In the Eastern Cape alone, at least 65 biogas digesters have been installed at schools to achieve the feeding schemes by providing gas for cooking since they can use the food scraps and waste from the kitchen. Unfortunately, due to lack of knowledge, competence and expertise in maintaining this system by the local stakeholders, most of them are not working as planned since they do not know how to keep them functioning.

In Kenya, the energy consumed range from 68% biomass; 22% petroleum; 9% electricity and 1% other (Sarkodie & Adom, 2018). A number of researches show that there has been a rapid increase in the overall biomass consumption in comparison to other sources in the past two decades. According to Mbaka, Gikonyo and Kisaka (2019), 95% of around 20,000 institutions in Kenya depend on firewood as their main energy source. This tendency is exerting pressure and constraining the wood lands and vegetation cover thus hastening land depravation. To manage these impacts, the Ministry of Energy developed a 4-year Global Environment Facility (GEF) project on *Market transformation for highly efficient biomass cook stoves* that was executed between 2007 and 2010. The project aimed at alleviating the changing atmospheric conditions by encouraging acquisition and installation of the modern cooking technology by institutions and small businesses with the aim of avoiding emission of Green House Gases (GHGs) and carbon sequestration through creation of fuel woodlots. It also focused on eliminating market blockade to the acquisition of the modern cooking technologies by encouraging use of energy saving cook stoves by institutions and other private enterprises. The project was executed by Renewable Energy Technology Assistance Programme (RETAP) a Non-Governmental Organization (NGO) in conjunction with Rural Technology Enterprises (RTE) a private company that has been designing and manufacturing energy saving stoves for close to 30 years.

The project was successful as over 2000 cook stoves were installed in about 1000 institutions across the country and there was provision of hundreds of household and SME stoves to be used by the small and medium size enterprises such as hotels and restaurants (Carvalho, Lindgren, García-López, Nyambane, Nyberg, Diaz-Chavez & Boman, 2019). Over 600,000 trees were also planted by schools and small and medium-size enterprises. The installation of these energy

saving stoves led to reduction of over 12,000 tons of Carbon Dioxide emissions while the creation of the woodlots has sequestered over 10,000 tons of the emissions. RETAP also participated in the Clean Energy Access Program (a joint program of the Ministry of Energy and UNDP Kenya) to assist in the establishment of fuel woodlots by households and help them adopt the new improved biomass technologies.

2.4 Use of Improved Cook Stoves

Improved stoves are very efficient and emit very low emissions as well as very secure to use. Globally, over three billion people still depend on the traditional energy technologies to attain their household energy requirements. In Central America, over 20 million people who represent half the regions population use traditional cook stoves and 86% of the population is located in cities such as Guatemala, Honduras, Nicaragua and El Salvador (Wang et al. 2013). Indoor air pollution has been found to be the main cause of acute lower respiratory infection (Smith 2000; Ezzati et al. 2004; Lim et al. 2012) as well as chronic obstructive pulmonary disease (Bruce et al. 2002; WHO 2002). Other side effects on health caused by use of biofuel in households with varying degrees of epidemiological evidence include adverse pregnancy outcomes, tuberculosis, depression, pediatric sleep disorders, asthma, bacterial meningitis as well as a variety of moderate to-severe physical injuries caused by firewood picking, burns and widespread minor ailments as a result of smoke inhalation such as eye irritation and mild headaches.

Most countries in Asia have increasingly focused on energy control, management and conservation, both in the industrial/commercial and domestic sectors. Since use of traditional cook stoves in developing countries thus high biofuel consumption in the domestic sector, conservation measures have concentrated on the development, introduction and provision of improved cooking stoves (ICS). For a considerable period of time, the Indian government has always offered its support in cook stove design, development and dissemination programme. Next to China, India have the largest number of improved cook stoves installed. Subsidies were provided for the installation of the cook stoves and Technical Backup Centres were created in many States.

In Nigeria, there was an implementation of a project in 2014 dubbed ‘Improved cook stove for Community Development’ (ICCD). Christian Aid’s in conjunction with the Justice Development for Peace Commission Jos (JDPC Jos) and Sosai Renewable Energy, Kaduna, the ‘Improved cook stove for Community Development’ (ICCD) executed a pilot project that focused on

improving the health conditions as well as improve the standards of living of the poor, vulnerable and marginalized households through the adoption and use of improved cook stoves (ICS) that lasted six months. The pilot project was executed using a business model to increase utilization of the energy saving cook stoves by the households to ensure an increment in the demand and supply of the stoves through community sensitization, awareness and mobilization. 70% of Nigeria's population continue to use the traditional cook stoves in their households despite the health dangers poses to them. Despite the development of these improved cook stoves which are cheap, use less fuel and have no side effects on health, the low levels of illiteracy, ignorance, lack of knowledge and awareness of their benefits has acted as a major barrier on the adoption and uptake of these improved and clean stoves.

In Kenya, the Energizing Development Partnership Programme (EnDev) aims at contributing to the achievement of the Millennium Development Goals by providing the less fortunate people with sustainable access to modern energy services. The cooking devices have to be cheap and locally available to the people. Kenyans in the rural areas can only depend on the use of wood fuel since there is hardly any other source of fuel they can use. Therefore, EnDev Kenya provides Kenyans with energy saving cooking devices that enable them utilize the little and scarce firewood resources available more efficiently.

The improved cook stoves had a major socio-economic impact. EnDev launched in November 2005 in Kenya aimed at promoting the utilization of energy saving cooking devices to the rapidly growing population. The ultimate goal of the project was to distribute the modern cook stoves to more than 3.73 million Kenyans by the year 2014. To achieve the goal, EnDev Kenya followed a market-based approach. EnDev Kenya supported interventions that established a sustainable market for the energy cooking devices instead of disseminating them but maintained the projects focus since it was designed to create awareness. Disseminating stoves helped in achieving many important goals. Improved and efficient cooking devices are very essential tools for protecting women and children from the health problems associated with inhaling smoke and indoor pollution. Consumption of less firewood reduces unsustainable deforestation thus helping conserve the forest cover.

With the use of the energy saving cook stove, household monthly budget on fuel is less than Ksh.500 while on the other hand households using a three-stone fire spend up to 2,000 KES per month.

2.5 Wood Fuel Consumption and Patterns in Kenyan Schools

Over 95% of all institutions rely on biofuel as their main energy source. This troubling trend is causing constraints on forest cover and vegetation stocks and accelerating the rate of land degradation. A study by Kituyi in 2000 that revealed 90 percent of 20,000 schools relied entirely on fuelwood for meal preparations. In 2007, another study by RETAP reported that 75% of the 4215 secondary schools in Kenya, which were boarding type also depended entirely on fuelwood for cooking. RETAP (2008) indicates that a Kenyan secondary school in 2007 had a mean student enrolment of 427 (minimum of 86 and maximum of 1300 per school) students, each of whom consumed wood fuel at a weighted mean rate of 0.5 Kg/ day.

To manage this impact, the Ministry of Energy developed a 4-year Global Environment Facility (GEF) medium-sized project to focus on the Market transformation for highly efficient biomass cook stoves project that was executed between 2007 and 2010. The project aimed at alleviating the changing atmospheric conditions by encouraging acquisition and installation of the modern cooking technology by institutions and small businesses with the aim of avoiding emission of greenhouse gases (GHGs) and carbon sequestration through creation of fuel woodlots. It also focused on eliminating market blockade to the acquisition of the modern cooking technologies by encouraging use of energy saving cook stoves by institutions and other private enterprises. The project was executed by Renewable Energy Technology Assistance Programme (RETAP) a Non-Governmental Organization (NGO) in conjunction with Rural Technology Enterprises (RTE) a private company that has been designing and manufacturing energy saving stoves for close to 30 years.

Firewood picking leads to elimination of wood lands and vegetation cover that could absorb Green House Gases (GHG) emissions that degrade local ecosystems. With the demand for firewood by schools increasing rapidly, the impact it has on the environment cannot be over looked. In estimation, a big truck often carries up to 500 logs costing a school about Ksh. 600,000 while a smaller truck carries about 300 logs and costs a school between Shs300, 000 and Shs400, 000.

2.6 Benefits

2.6.1 Health; Studies show the use of improved cook stove has a noticeable impact on the health condition of women and children in terms of respiratory complications and breathing problems; compared to an open fire, energy saving cook stoves minimize up to 70 percent of the emissions.

2.6.2 Climate & environment; Unlike the traditional three-stone cook stove, the energy saving cooking devices saves up to 70 percent of firewood. The high adoption rate of the modern cooking technologies has led to positive impact on both the environment and the climate. Every stove has a major contribution in reducing the emission to about 0.94 million tonnes per annum. This is quite encouraging considering that an average family of five members in Kenya emit about 1.5 tonnes of Green House Gases (GHG) every year.

All improved cook stoves help save up to about 1.42 million tonnes of wood fuel which translates to about 78,000 hectares of mature forests.

2.6.3 Saving time and money; the energy saving cook stoves take less time to prepare a meal and reduces the time required for wood picking since much less fuel is required. It's a huge relief for women and girls especially those who live upcountry who are tasked with a heavy burden of their daily household chores and obligations.

2.7 Factors Influencing Wood Fuel Consumption Rates in Learning Institutions

Studies, (Kituyi, 2000; Kituyi and Kirubi, 2003; Ngeywo, 2008; RETAP, 2008, 2010; Marufu et al., 1997) done in Kenya on biomass energy have improved our understanding of factors that affect biomass consumption rates and patterns, fuelwood included. Type of cook stove used. Fuelwood consumption rate is reported to reduce progressively as one moved up the technology ladder from traditional cook stoves to improved, state-of-the art cook stoves (RETAP, 2010) which is attributed to their varying efficiencies.

According to RETAP (2008), the increase in rate of deforestation and the unsustainable way in which fuelwood is being consumed in most of the learning institutions is attributed to the use of inefficient stoves as well as open fires. Many Kenyan schools use these traditional cook stoves for their day-to-day cooking and water heating purposes and their daily mean fuelwood consumption rates is reported to be between1.4 and 1.7 Kg per student (Kituyi, 2000; Ngeywo, 2008). Improved stove is a cook stove designed to significantly improve energy efficiency, reduce indoor air pollution and increase ease of use (World Bank, 2012). The Cook stove has a large cylindrical stainless steel casing with a brick lining and an inner metal casing. The cooking pot fits neatly into the center of each stove hence completely surrounded by the stove wall. The cook stoves have a higher efficiency of between 35- 45%, which is due to their inbuilt characteristics. These cook stoves have reported a daily mean fuelwood consumption rate of

between 0.35- 0.55 Kg per student (Kituyi, 2000; Ngeywo, 2008) in schools where they are being used.

Plate 2.1: Modern Cooking Stoves and Traditional cook stove

Source: field survey data (2019)

2.7.1 Number of students

Enrolment, which is the number of students registered in an institution hence the number of students being cooked for daily is an important parameter when studying fuel wood consumption patterns. A study by RETAP (2010) revealed that schools with high number of students had a low fuel wood consumption rate per student compared to those with fewer students. This was attributed to economies of scale where the more the number of individuals being cooked for, the lower the consumption rate per individual/student.

2.7.2 Number of meals

The more the number of meals the more fuel consumption especially in the boarding schools where they make at least three meals a day.

2.7.3 Type of meals

In almost all schools githeri is the main meal cooked for the students which consumes more fuel wood for it to cook. For a change some schools make rice or ugali.

2.8 Environmental Implications

There is need for a sustainable energy sector due to the rising importance and demand for wood based biomass consumption to attain energy requirements. This will greatly reduce Green House

Gases (GHG) emissions and play a key role in implementing low-carbon growth strategies in Sub-Saharan Africa. Currently, 18% of the current global GHG emissions is as a result of using traditional cook stoves and technologies (SEI, 2008). The traditional Charcoal production emits an estimate of nine tons of CO_2 for every ton of charcoal produced. However, if charcoal production was sustainable, it would be carbon neutral since the emitted carbon could be sequestered by trees planted: One ton of sustainable charcoal would offset one ton of non-sustainable charcoal or nine tons of carbon dioxide (GEF, 2010).

2.9 Literature Gaps

Biomass resource mapping and planning have been a challenge due to inadequate and unreliable data at both national and local level. Biomass planning requires quality and reliable data for its effective and efficient planning. Furthermore, most studies do not include learning institutions in the biomass energy mapping exercise though these institutions are among the bulk users of fuel wood. However, one of the major roles of the devolution to County government is planning for energy resources within the county. The role of energy planning had encountered challenges among them being lacks baseline data upon which their energy planning activity could be based. There is need to effectively engage schools in County energy resource planning because they are among the bulk users of wood for energy. This could be achieved by having a clear understanding of the demand dynamics (influence of enrolment, stove type, the cost and commonly-used tree species) and the supply dynamics (commonly-harvested tree species for wood energy, areas where the wood is harvested from and fuelwood suppliers) of wood energy. This study may provide a detailed wood resource base analysis for sampled secondary schools in Machakos County. The information if used would ensure sustainability in the biomass energy sector at the County level.

2.10 Theoretical and Conceptual Framework

2.10.1 Theoretical framework

According to Kaplan (1964), he defined theory as a group of related generalizations that indicate new observations, which can be empirically tested for the purpose of explaining or predicting. Mugenda (2008) defines a theory as a framework for explaining phenomena by stating construct and laws that interrelate these constructs.

The ‘Fuelwood Gap Theory’ was formulated in 1970 and it implied that the rate of wood fuel consumption was non-sustainable. In most countries the demand is outstripping the sustainable

supply thus creating the 'gap'. Even though forest resources are renewable, their over consumption is at unsustainable rate.

The basic premise of this theory is that the consumption of wood fuel is the major cause of deforestation and its implications thus leading to wood fuel scarcity. In Sub-Saharan Africa there is wood fuel shortage due to high consumption rates that exceed the renewable supplies.

A study conducted in Nepal predicted the demand and supply of wood fuel since it was the most important source of energy. The study assumed that all wood fuel derived from accessible forests leading to an assumed 'fuelwood gap'. Even though it was anticipated that the total forest cover of 6.4 Million Ha and all the accessible forest which accounted for 50% of the total forest area would be completely wiped by 1990 unless there is a massive dissemination of improved cook stove which would delay the disastrous effect by 3 years.

This theory has been legitimately criticized especially through the forecasting methodology where wood fuel consumption is assumed to rise as the population increases even though the supplies keep on dwindling. This was termed as unrealistic since new coping strategies can be applied to ensure adequate supply to the growing population. Afforestation, use of improved cook stove and use of crop residue are some of the efforts that can be put in place to intensify and encourage the natural regeneration of woody vegetation.

2.10.2 Conceptual Framework

Figure 2.1 below indicates the relationship between the dependent and independent variables. This shows the relationship between the type of stove being used to cook and the number of students being cooked for, and the fuel wood consumption, demand and supply. The wood fuel consumption rate and pattern in turn determines the fuel wood consumed, which finally determines the amount of wood fuel supplied in a school. Wood fuel consumption rate was reported to reduce progressively as one moved up the technology ladder from traditional cook stoves to improved cook stoves (RETAP, 2010) due to their efficiency.

A study by RETAP (2010) showed that schools with high number of students had a low fuel wood consumption rate per student compared to those with fewer students. This was attributed to economies of scale where the more the number of individuals being cooked for, the lower the consumption rate per individual/student. In addition, another study by Kituyi (2000) made an observation that collective cooking to serve many people (commercial enterprises and academic institution) demands less fuel wood consumption per student, than cooking for smaller groups.

The results from a study by Ngeywo (2008) proved that, as the number of students enrolled in an educational institution increased, the fuel wood consumption rate per student decreased. Since the amount of fuel wood consumed per student in schools was important in determining the consumption patterns, there was need to determine the minimum number of students in a school above which fuel wood consumption rate did not show a significant change.

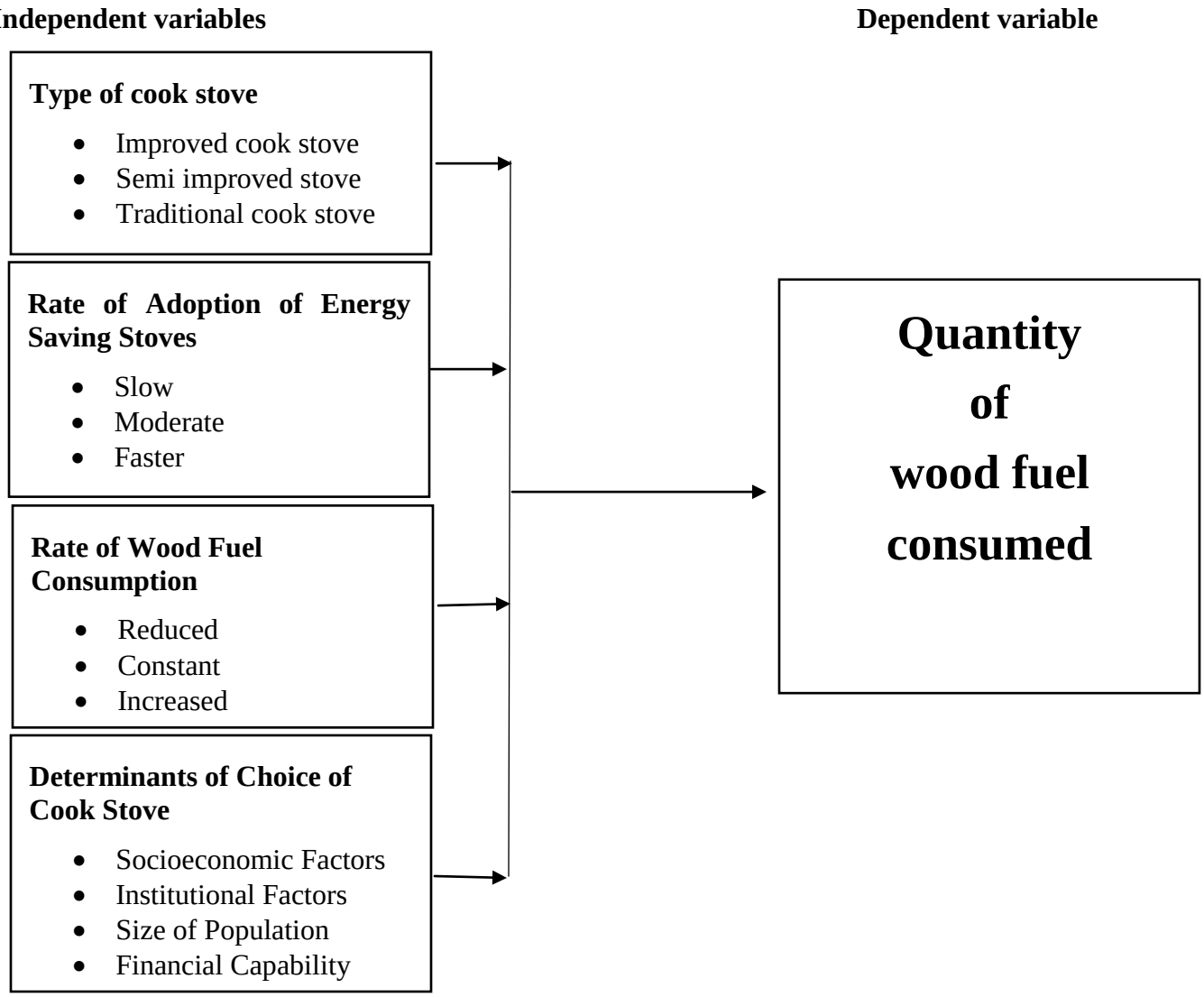


Figure 2.1: Conceptual Framework

Source: field survey data (2019)

The above framework would help reduce wastage of fuel wood by schools with few students especially for the new upcoming learning institutions in the County. These variables are significant to the learning institutions as it will enable them plan and budget for the fuel and type of cook stove to be used.

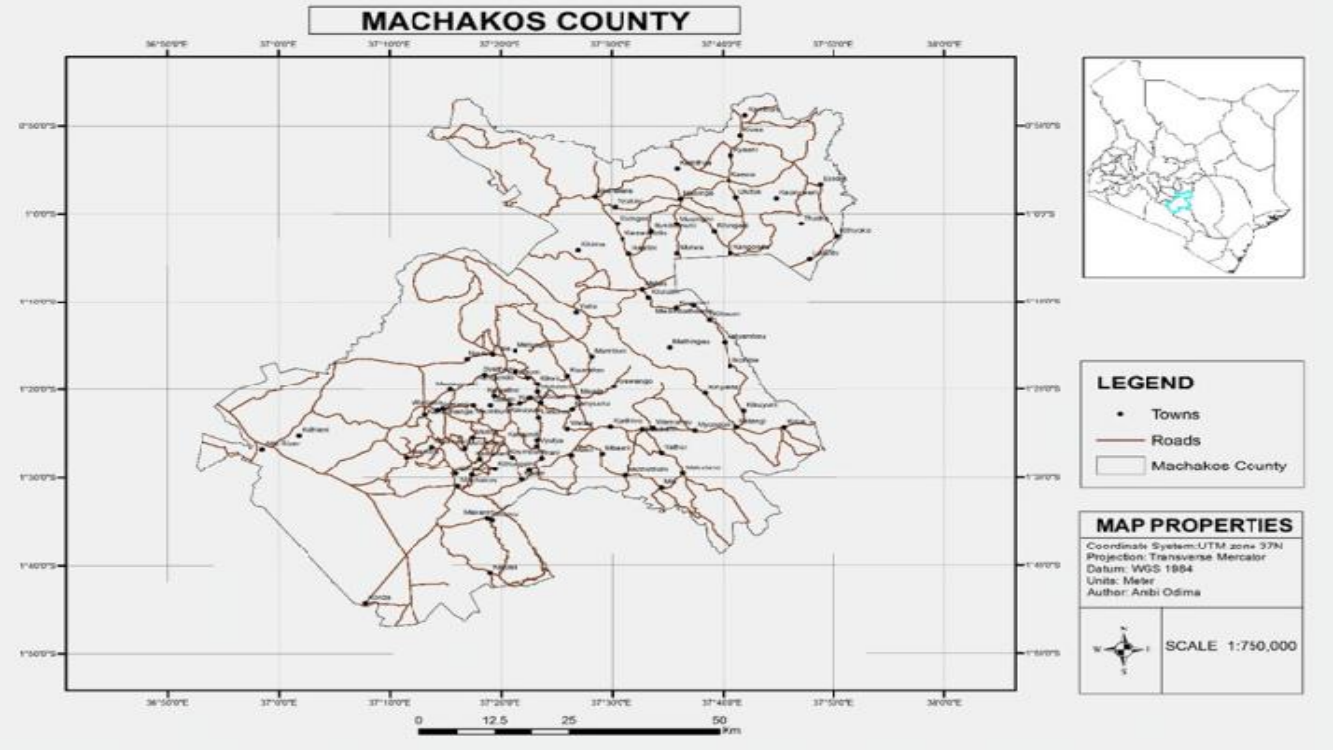
CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Study area

Machakos County was the Kenya's first administrative headquarters. The county had a population of 1,421,932 as of 2019. The county borders Nairobi and Kiambu counties to the west, Embu to the north, Kitui to the east, Makueni to the south, Kajiado to the south west, and Muranga and Kirinyaga to the north west. The county has eight constituencies: Masinga, Yatta, Kangundo, Matungulu, Kathiani, Mavoko, Machakos Town and Mwala Constituency

The local climate is semi-arid with hilly terrain and an altitude of 1000 to 2100 metres above sea level. Subsistence agriculture is mostly practiced with maize and drought-resistant crops such as sorghum and millet being grown due to the area's semi-arid state. Machakos County forest cover spans a total of 477.617km2 accounting for 7.6 per cent of total land area. Gazetted forested area cover 606.97 hectares. The notable forested areas in the county include Iveti hills, Muumandu, Kalimanzalu and Kiima Kimwe.

The reason why the study area was selected is because the researcher is conversant with the area and due to its semi-arid status which exposes it to desertification if proper measures are not put in place to contain the implications of deforestation and protect the remaining forest cover.



3.2 Study Design

This study adopted descriptive study method of research as explained by Hendricks & Pregitzer, (1993). The study also applied both qualitative and quantitative data collection tools.

The qualitative data obtained through questionnaires and interviews enabled the researcher obtain in-depth information on the user experience and effects of the improved cook stove as well as understand the reasons behind the choice of cook stove being used at the study time.

3.3 Target Population

The study targeted only the public secondary schools in Machakos County which has about 350 public secondary schools but only a sample of 80 schools were studied.

Table 3.1: Target Population

No	**Constituency/ sub-county**	**National schools**	**Extra-county schools**	**County schools**	**Sub- county schools**	**TOTAL number of schools**
1	Yatta	0	0	0	57	**57**
2	Matungulu	0	1	8	22	**31**
3	Kathiani	1	1	3	26	**31**
4	Masinga	0	2	2	49	**53**
5	Mwala	0	1	8	57	**66**
6	Machakos town	1	7	3	62	**73**
7	Mavoko	0	0	0	13	**13**
8	Kangundo	0	2	1	23	**26**
TOTAL		**2**	**14**	**25**	**309**	**350**

Source: field survey data (2019)

3.4 Sources of data

Primary sources of data included interviews, surveys, questionnaires, observations, photographs. Secondary sources of data will include; information collected and is available at the government departments, organizational data records and data collected from other research.

3.5 Sample size and sample techniques

The study site was stratified into 8 strata which were the eight sub-counties (Masinga, Yatta, Kangundo, Matungulu, Kathiani, Mavoko, Machakos Town and Mwala). Within each stratum, by use of simple random sampling technique the sampling units were randomly selected since each school had been assigned a number.

Machakos County has 1,736 centers for Early Childhood Development (ECD), 1011 primary schools and 493 secondary schools where 350 of them are public secondary schools which were considered for the study. A list of all the public secondary schools for each strata was developed then simple random sampling was done with each school being assigned a number.

The total sample size was 80 secondary schools and was obtained by use of Yamane, (1967) formula as quoted by Israel (1992).

$$n = \frac{N(CV)\,2}{(CV)\,2 + (N-1)\,e2}$$

$$\frac{350(0.5)2}{0.25 + (350-1)0.052}$$

$$\frac{87.5}{1.1225} = 77.95$$

80 schools

Where n = the sample size

N = the size of population

CV= coefficient of variation

e = the error of 5 percentage points (0.05)

Table 3.2: Sample Size

	Yatta	Matungulu	Kathiani	Masinga	Mwala	Machakos	Mavoko	Kangundo	Total
National schools	0	0	1	0	0	1	0	0	**2**
Extra-County schools	0	1	1	1	1	1	0	1	**6**
County schools	0	1	1	1	1	1	0	1	**6**
Sub-county schools	11	7	7	9	9	12	5	6	**66**
TOTAL SAMPLE	**11**	**9**	**10**	**11**	**11**	**15**	**5**	**8**	**80**

Source: field survey data (2019)

3.6 Methods of data collection

3.6.1 Questionnaire

In this study, a structured questionnaire was one of the tools used to collect data relevant to the study. This is because it is among the most common tools for big enquiries and one was able to do a pilot survey to identify the questionnaire's weakness before the official data collection begins (Kothari, 2004).

3.6.2 Interview schedules

Face to Face interview schedules were administered to the fuel wood supplier and representatives of the different Government Ministries at the County level. In the ministry of Education, the County Education Officer was interviewed. Face to face Interview schedules were used because the researcher was able to obtain in-depth data required and asked for clarification.

3.6.3 Observation

Observation was also employed especially in ensuring that the information given by the respondents is reliable hence enhancing the accuracy of the study (Mugenda and Mugenda, 1999). This included information on the type of tree species frequently delivered which the

researcher was expected to find in the schools' fuelwood store; the type and number of cook stoves used; and reading and recording of the daily consumption estimates.

3.7 Methods of Data analysis

Quantitative data analysis was done using the descriptive statistics which aims at summarizing a sample of the entire population it is representing while the qualitative data analysis was done using interview summary sheet technique so as to achieve the set out objectives and ensure their relevance to education, wood energy planning and forest management and conservation strategies. The collected data was analyzed using Statistical Package for Social Sciences (SPSS) and presented by use of descriptive statistics such as tables, Charts, Graphs and Diagrams. The hypothesis was tested using Chi-Square test.

The data was analyzed and interpreted basing on various parameters such as;

- Fuel consumption rate
- Number of students
- Type of cook stove used
- Number of meals cooked per day

3.8 Study limitations

Language barrier where communication and understanding each other becomes difficult due to language difference and in this case an interpreter was used. Biasness where a respondent can give false information and the study encourage the respondents to be as truthful as possible to enable us gets the necessary information. Illiteracy and ignorance where respondents are unwilling to give information and the researcher explained the questions in a simple form to help them understand.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

The general objective of the study was to assess the contribution of improved cook stoves in reducing wood fuel consumption in Kenya; a case study of public secondary schools in Machakos county. The sample size was 80 public secondary schools in Machakos County consisting of boarding schools, day schools and day/boarding schools. The study used Statistical Package for Social Sciences (SPSS) to analyze the quantitative data collected using questionnaires.

4.1.1 Response Rate

Of the 80 questionnaires administered to the school administration, a total of 68 questionnaires were duly filled and returned representing 85% even though some questionnaires were returned unduly filled while others failed to hand them back completely despite consistent follow up. This rate of response is regarded satisfactory to sum up conclusions for the study according to Bailey (2000) argued that a response rate of 50% is sufficient while greater than 70% is excellent. To some extend the method used in data collection could have contributed to this high rate of response which included use of competent research assistants, free and voluntary participation by respondents, prior notification of respondents, guaranteed confidentiality and anonymity, availability to clarify queries via calls and drop and pick of questionnaires to allow the interviewees ample time to fill them.

4.2 Attributes of the sample

4.2.1 Types of Schools

Figure 4.1 shows categories of schools in which the questionnaire survey was administered.

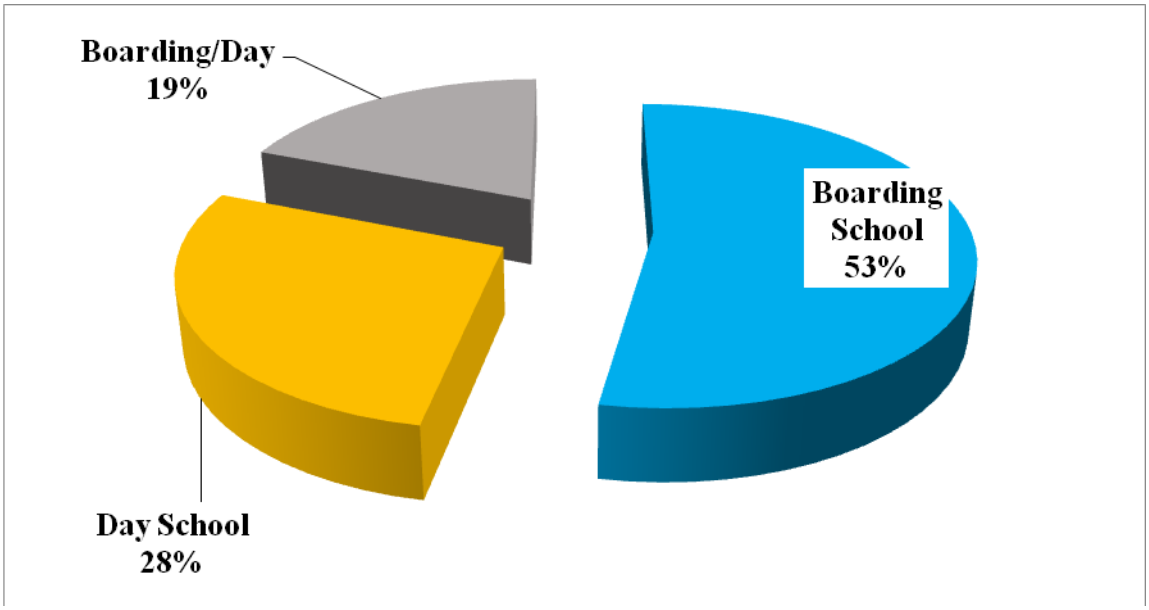


Figure 4.1: School Type

Source: field survey data (2019)

The results in Figure 4.1 show that 53% of the schools involved in the study were boarding schools, 28% of the schools were day schools and only 19% of the schools were partly day and partly boarding. This means that results presented in next sections have a bias towards responses from boarding schools.

4.2.2 Number of Students Enrolled

Enrolment, which is the number of students registered in a school hence the number of students being cooked for daily is an important parameter when studying fuelwood consumption patterns. The least number of students in a sample school was 88 (Mathigau High School); while the highest enrollment was 1500 students (Machakos School). This imply that those schools dealing with extreme cases of number of students will determine the fuel wood consumption rates and pattern, which in turn determines demand and supply. The number of students being cooked for in a school will determine the amount of wood fuel that is required to cook for them. A study by RETAP (2010) showed that schools with high number of students had a low fuelwood consumption rate per student compared to those with fewer students. This was attributed to economies of scale where the more the number of individuals being cooked for, the lower the consumption rate per individual/student. In addition, another study by Kituyi (2000) made an observation that collective cooking to serve many people (commercial enterprises and academic

institution) demands less fuelwood consumption per student, than cooking for smaller groups like in households.

Further, a study by Ngeywo (2008) revealed that, as the number of students enrolled in an educational institution increased, the fuelwood consumption rate per student decreased. For example, in Alliance Girls, where the enrolment 773 students and a daily consumption of 279.5 kg reported a daily consumption rate of 0.26 Kg per student. On the other hand, in Buruburu Girls, the daily consumption rate was reported to be 0.50kg per student, yet it had an enrolment of 550 students and consumed 274Kg of fuelwood daily. Another school, Nembu Girls with an enrolment of 380 students and a daily consumption rate of 218Kg had a daily consumption of 0.57Kg per student. From this result, it is evident that schools with low enrolment consume fuelwood per student than those with higher enrolment.

4.2.3 Position of the Respondent

Figure 4.2 shows the positions of respondents from various schools to which questionnaire survey was administered.

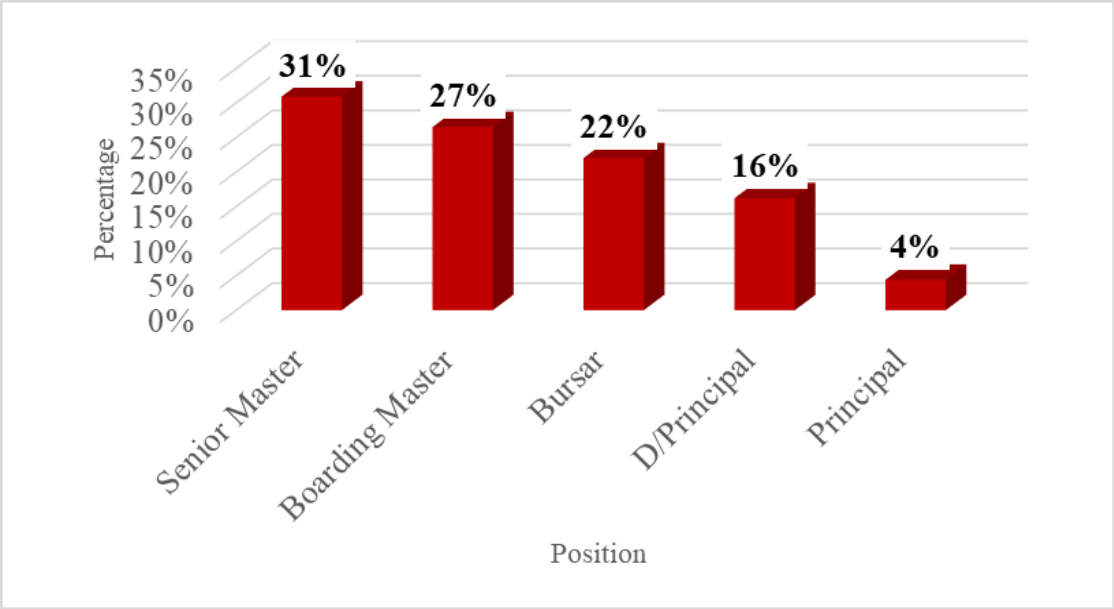


Figure 4.2: Position of Respondent

Source: field survey data (2019)

Based on the results in Figure 4.2, in 31% of the schools senior teachers responded to the questionnaire, in 27% of the schools the questionnaire was answered by boarding masters, while in 22% of the schools bursars responded to the questionnaires. The results further show that

deputy principals responded to the questionnaires in 16% of the schools and in only 4% of the schools the principals responded to the questionnaires. This implies that in various secondary schools in Machakos county duties are delegated such that the issues of fuel consumption within the schools can be addressed by any member of the management.

4.2.4 Constituency

Table 4.1 shows the constituencies in which the secondary schools targeted were situated.

Table 4.1: Constituency

Constituency	Frequency	Percentage
Machakos Town	11	16.2
Yatta	16	23.5
Masinga	11	16.2
Kathiani	8	11.8
Mwala	6	8.8
Mavoko	7	10.3
Kangundo	9	13.2
Total	**68**	**100**

Source: field survey data (2019)

23.5% of the schools that were considered in this study were situated in Yatta constituency, 16.2% were based in Machakos town constituency, another 16.2% in Masinga constituency, 11.8% were based in Kathiani Constituency, 8.8% in Mwala constituency, 10.3% in Mavoko constituency and 13.2% of the schools were situated in Kangundo constituency.

4.3 Woodfuel Efficiency of School Cookstoves

4.3.1 Effect of Source of Fuel on Fuel Consumption

The respondents were requested to state what their schools were using for heating purposes (boiling water) and the effect of various sources on fuel consumption the results in Table 4.2 show their responses.

Table 4.2: Source of Fuel for Heating

Source	Frequency	Percent
Wood Fuel	61	89.7
Solar	3	4.4
Biogas	3	4.4
Other Sources	1	1.5
Total	**68**	**100.0**

Source: field survey data (2019)

Based on the results, 89.7% of the respondents pointed out that they were using wood fuel as the major source of fuel for heating purposes, 4.4% indicated that their schools were using solar energy for cooking, another 4.4% of the respondents indicated that their schools were using biogas for heating purposes while only 1.5% of the respondents indicated that their schools were using other sources of fuel for heating purposes. The fuel was used to heat bathing water for students especially those with respiratory issues such as asthma and those allergic to cold water. It was as well used for heating water provided to the students for breakfast. The results imply that most of the secondary schools in Machakos County are using firewood as their major source of fuel for heating especially in preparing breakfast where most schools provide water, porridge or tea to the students. This means that as much as schools are encouraged to adopt alternative means of heating, schools in Machakos are still relying on wood fuel as their major source of fuel for heating and therefore pressure on the forests in the region is high leading to increased desertification. The results also mean that most schools have not embraced the use of modern improved cook stoves in heating.

4.3.2 Sources of Fuel for cooking Breakfast

The respondents were requested to state the types of meals and the corresponding source of fuel for that meal. The types of meals were classified into breakfast, lunch and supper. Figure 4.3 shows the sources of fuel for cooking breakfast in secondary schools in Machakos County.

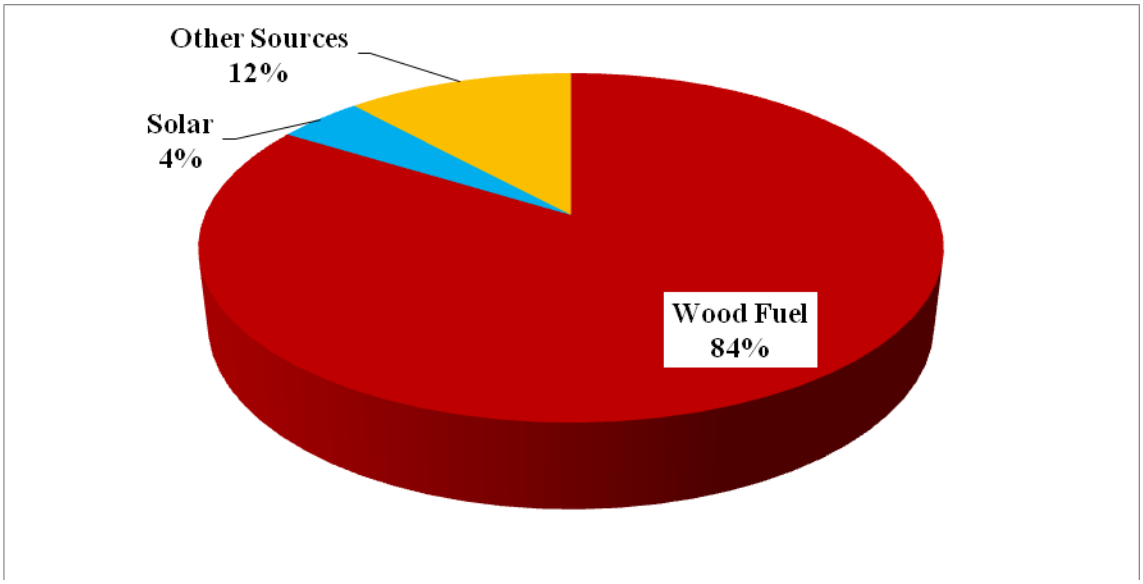


Figure 4.3: Sources of Fuel for Breakfast

Source: field survey data (2019)

The results in Figure 4.3 show that Majority (84%) of the respondents were certain that their schools were using wood fuel in making breakfast, 12% of the respondents revealed that their schools were using other sources which included electricity, charcoal and gas. Only 4% of the respondents indicated that their schools were using solar energy for making breakfast. The results imply that most schools in Machakos County are using wood fuel in preparing breakfast for their students. The results are consistent with the findings derived from a report by RETAP (2007) that 75% of the 4215 boarding secondary schools in Kenya relied totally on firewood for their day-to-day meal preparation and water heating purposes. The study reported a consumption estimate of 200- 300 tons of fuelwood annually for a typical boarding school.

4.3.3 Sources of Fuel for Lunch

Apart from the source of fuel for making breakfast, the respondent was also asked to indicate the sources of fuel their schools were using in preparing lunch. The results are presented in Figure 4.4

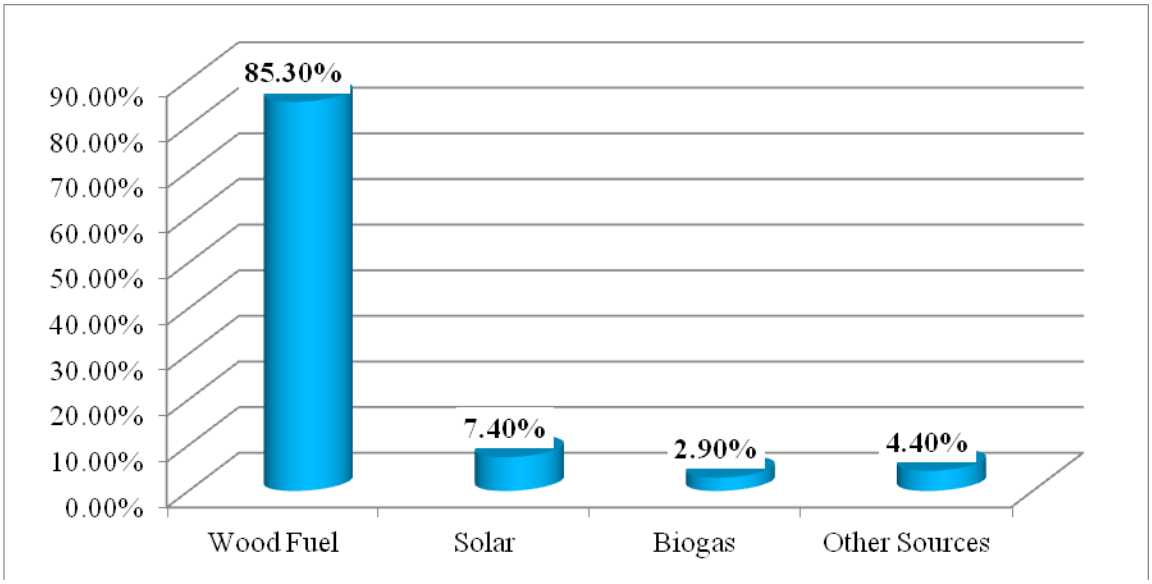


Figure 4.4: Sources of Fuel for Lunch

Source: field survey data (2019)

The results in Figure 4.4 show that 85.30% of the respondents were confident that their schools were using firewood as the major source of fuel for coking lunch for their students. 7.40% of the respondents indicated that their schools were using solar in cooking lunch for the students, 4.40% indicated that their schools were using other sources such as electricity and gas cookers in preparing lunch with only 2.90% indicating that they were using biogas in preparing lunch. The results imply that most schools in Machakos are using wood fuel in cooking lunch for their students despite efforts by government and other stakeholders to encourage the secondary schools to adopt the use of energy saving cook stoves in order to minimize pressure on forest cover for wood fuel.

4.3.4 Sources of Fuel for Supper

The respondents were asked to indicate the sources of fuel their schools were using in preparing supper for their students. The responses were as resented in Figure 4.5.

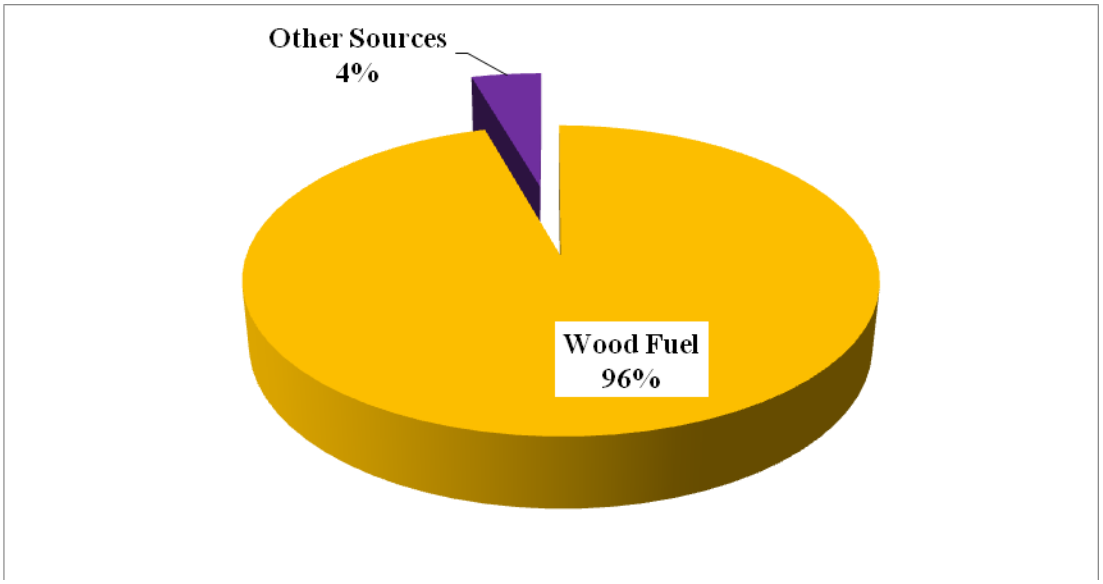


Figure 4.5: Sources of Fuel for Supper

Source: field survey data (2019)

The results in Figure 4.5 show that 96% of the respondents affirmed that the schools used wood fuel in preparing supper with only 4% indicating that they were using other sources of fuel which included electricity and gas. The results imply that majority of the schools in Machakos County are using wood fuel in preparing supper for their students and this mean threat to the forest cover in the area and increase in desertification.

4.4 Adoption Rate of Energy Saving Stoves in Public Secondary Schools in Machakos County

The first objective of the study was to determine the adoption rate of the energy saving stoves by the schools in the County. To be able to establish the rate of adoption of energy saving stoves, the interviewees were asked to state the type of stoves their schools were using. The responses were captured and presented in Figure 4.6

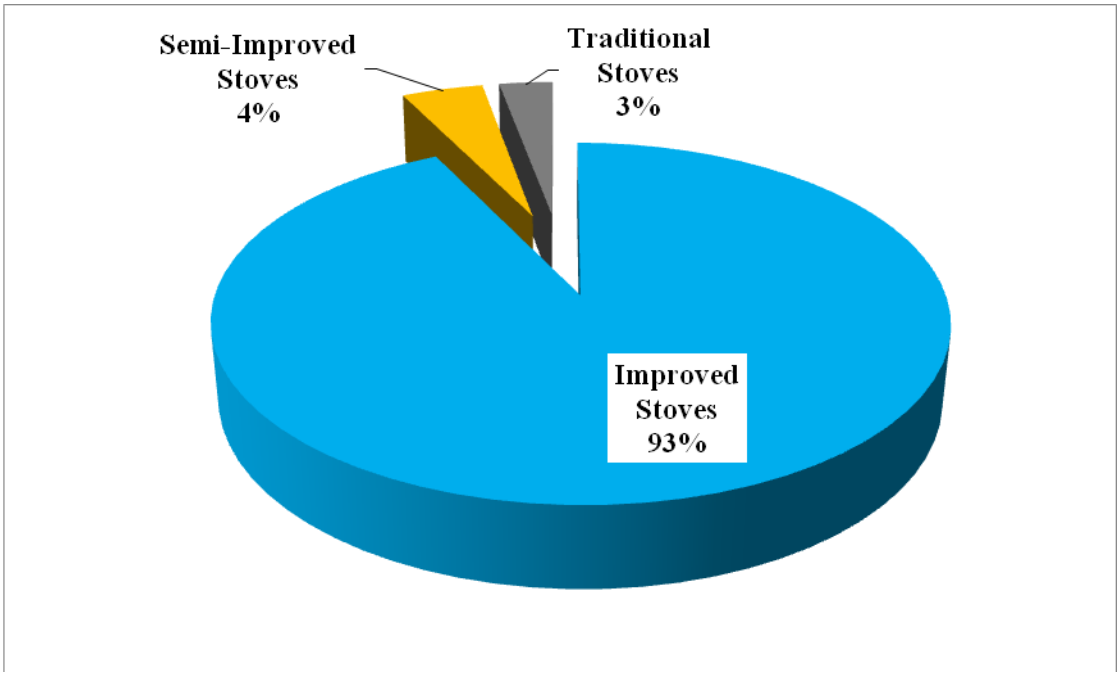


Figure 4.6: Type of Cook Stove in Use

Source: Field data (2019)

Based on the results, 93% of the schools in the County were already at the time of this study using improved cook stoves, 4% indicated that their schools were using semi-improved cook stoves while only 3% of the respondents indicated that their schools were still using traditional stoves. The results insinuated that most schools are already adopting the use of modern improved cook stoves as one way of cutting down biofuel consumption and by so doing pressure on the forests is reduced resulting into reduced implications of desertification. The interview revealed that the partial or lack of adopting improved cookstoves in some of the sampled schools was due to; Lack of finances to adoption and /or fully shift to improved cookstoves and Lack of awareness of the existence of other improved cookstove designs suitable for cooking small meals for few individuals. This was because most of the traditional or semi-improved cookstoves were only used to cook meals for teachers and students on special diet. The latter was found to be happening yet the improved cook stoves manufacturers have tailored a two to four burner improved cook stoves as shown in appendix III to suit these special needs in schools.

The study further found that day secondary schools had the least full adoption rate of these improved cook stoves. This was likely due to first, lack of finances since most of them are public schools, attributed to the free secondary education policy hence the schools are left with too little to invest in other projects like purchasing improved cook stoves. Secondly, the poverty levels in

rural areas of Machakos County where most of parents pay their fees in kind through fuelwood hence schools lack solid cash to purchase these improved cook stoves.

The results are contrary to the findings of Kituyi (2000); Ngeywo (2008) which indicated that many Kenyan schools use traditional cook stoves for their daily meal preparation and water heating purposes and their daily mean fuel wood consumption rates is reported to be between1.4 and 1.7 Kg per student.

Further, the respondents were asked to indicate the number of cook stoves their schools owned and the results are presented in Table 4.3

Table 4.3: Number of Cook Stoves Owned

Number of Cook Stoves	Frequency	Percentage
1	12	17.6
2	18	26.5
3	21	30.9
4	2	2.9
5	4	5.9
6	11	16.2
Total	**68**	**100**

Source: field survey data (2019)

The results in Table 4.3 show that 30.9% of the respondents indicated that their schools were owning 3 cook stoves, 26.5% of the schools were owning 2 cook stoves, while 17.6% of the schools were owning only one cook stove. The results further show that 16.2% of the schools were owning 6 pieces of cook stoves, 5.9% of the respondents indicated that their schools were owning 5 cook stoves with only 2.9% indicating that their schools were owning 4 pieces of cook stoves. The results imply that most of the schools in Machakos County own at least 3 pieces of cook stoves of whatever type. The results imply that since majority of the schools in the County are already adopting the use of improved stoves and huge numbers, the level of wood fuel consumptions is now reduced among the schools since improved cook stoves are efficient and economical in terms of fuel consumption.

A part form the number of cook stoves owned, the interviewees were asked to indicate the amount of money their schools had spent on the purchase of cook stoves. The responses are shown in Table 4.4

Table 4.4: Amount Spent on Cook Stoves by Schools

Amount Spent (000'Kshs)	Frequency	Percentage
80	5	7.4
120	2	2.9
150	3	4.4
160	1	1.5
180	3	4.4
200	5	7.4
240	2	2.9
250	5	7.4
270	3	4.4
300	6	8.8
330	3	4.4
350	2	2.9
450	2	2.9
500	3	4.4
540	1	1.5
600	3	4.4
750	4	5.9
860	2	2.9
1080	2	2.9
1200	4	5.9
1300	5	7.4
1500	2	2.9
Total	**68**	**100**

Source: field survey data (2019)

The results show that most (8.8%) of schools spent approximately Ksh.300, 000 to acquire their cook stoves, 7.4% spent approximately Ksh.80, 000 on their cook stoves. The results also show

that another 7.4% of the schools spent approximately Ksh.250, 000 to acquire their cook stoves, another 7.4% of the schools spent approximately Ksh.1, 300, 000 on their cook stoves, 5.9% spent approximately Ksh.1, 200, 000 to acquire their cook stoves. Further, the results show that 5.9% of the schools spent approximately Ksh.750, 000 on their cook stoves. 4.4% of the schools spent approximately Ksh.150, 000 on their cook stoves; another 4.4% spent approximately Ksh.180, 000 on their cook stoves. In addition, 4.4% of the schools spent approximately Ksh.270, 000 to acquire their cook stoves. 2.9% of the schools spent approximately Ksh.120, 000 to purchase their cook stoves, another 2.9% of the schools spent approximately Ksh. 240,000 on cook stoves, 2.9% others spent approximately Ksh. 350,000 on their cook stoves. In addition, the results show that 2.9% of the schools spent approximately Ksh.1, 500,000 to acquire their cook stoves. The results imply that most of the schools in Machakos County have spent in excess of Ksh.300, 000 to acquire their cook stoves.

The descriptive statistics of amounts of money spent by secondary schools in Machakos County to acquire their cook stoves and the findings revealed that the minimum amount spent was approximately Ksh. 80,000, the maximum amount spent was approximately Ksh.1, 500, 000. The results show that the mean amount of money spent on acquiring cook stoves by secondary schools in Machakos County was Ksh.510, 882.35. This implies that approximately each and every secondary school in Machakos spent Ksh.510, 882.35 on cook stoves. The results had a standard deviation of Ksh.418, 949.416 implying that the amount of money spent by secondary schools in Machakos on cook stoves was varied and spread about the mean amount spent by each school.

The interview findings further revealed that the overall daily fuelwood consumption per secondary school in Machakos County varied between 48 and 384kg determined by the size of school, with a mean school consumption of 159.2 ± 91.75kg in the studied secondary schools. The daily consumption rate ranged between 0.12 -1.67kg per student and yielded a weighted mean consumption rate of 0.524kg per student daily. This value was irrespective of the number of meals being cooked per day, the type of meal being prepared, the type of school, the type and number of cook stoves used per school. The findings also showed that schools with students ranging 100-250 had the highest mean consumption rate of 0.72 ±0.372 kg per student daily, yet they had the least number of cook stoves. In addition, such schools relied on the traditional and semi-improved cook stoves and were day schools.

In addition, the county director of education in Machakos County was asked to indicate whether there were schools in the county still using traditional cooking stoves or not. The director was also asked to give some of the reasons as to why some schools had not started using modern cooking stoves if any. The director responded as follows;

…Yes there are schools in this county which are still using traditional cooking stoves. Some schools still use the traditional or semi improved cook stove as they find the installation cost of the improved cook stove high that the school cannot manage due to the fact that the school population is small, delay in disbursement of funds and being a day school they have other projects of top priority.''

The findings of the study revealed that most of the schools in Machakos County were already adopting the use of modern improve cook stoves as a way of reducing wood fuel usage and by so doing, pressure on the forests is reduced resulting into reduced implications of desertification. Some schools such as Machakos girls' school and Machakos Boys were found to be using electricity in baking bread so as to cut down on the wood fuel consumption. The results are contrary to the findings of Kituyi (2000); Ngeywo (2008) which indicated that many Kenyan schools use traditional cook stoves for their daily meal preparation and water heating purposes and their daily mean fuelwood consumption rates is reported to be between 1.4 and 1.7 Kg per student.

The results also indicated that, many secondary schools were already adopting the use of modern cooking stoves; other schools were still finding it a challenging exercise. The county director of education in Machakos County supported this fact while responding to interview questions by indicating that;

''…Yes there are schools in this county which are still using traditional cooking stoves. Some schools still use the traditional or semi improved cook stove as they find the installation cost of the improved cook stove high that the school cannot manage due to the fact that the school population is small, delay in disbursement of funds and being a day school they have other projects of top priority.''

In addition, the county director of education in Machakos County indicated that;

''…In our county, improved, clean and energy-efficient bioenergy stoves (referred to as clean bioenergy stoves) have been found to increase fuel efficiency by 25–60% and reduce significantly indoor air pollution compared to the traditional three-stone fire.''

4.5 Rate of Wood Fuel Consumption in Public Secondary Schools in Machakos County

The second objective of this study was to assess the rate of wood fuel consumption in public secondary schools in Machakos County. The respondents were asked to indicate an estimate of daily wood fuel consumption in their schools in Kgs. The results are presented in Figure 4.8

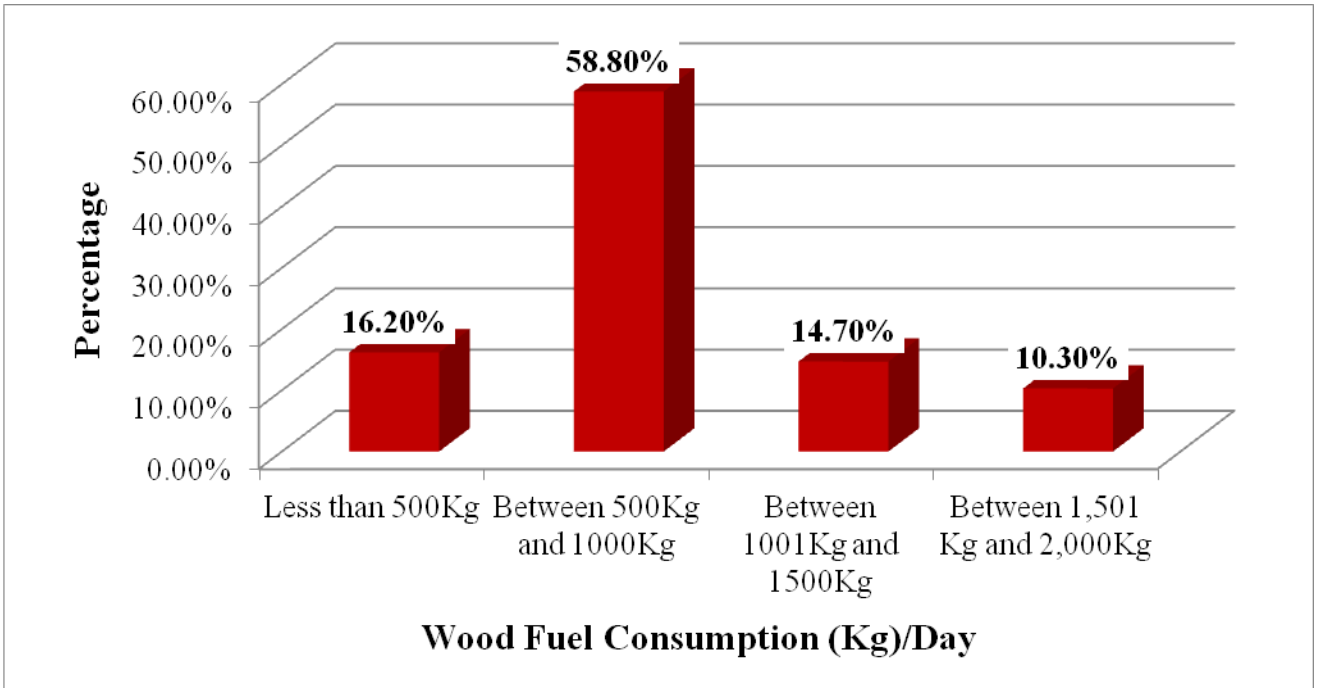


Figure 4.7: Wood Fuel Consumption/Day

Source: field survey data (2019)

The results show that 58.80% of the secondary schools in Machakos County were consuming between 500kg and 1000kg of wood fuel per day, 16.20% were consuming less than 500kg of wood fuel per day, 14.70% of the respondents indicated that their schools were consuming approximately between 1,001kg and 1,500kg of wood fuel per day. The results show that, only 10.30% of the schools were consuming approximately between 1,501kg and 2,000kg of wood fuel per day. According to statistics from the Ministry of Energy (2016), on average a typical secondary school in Kenya with 500 students consumes an average of 1,250kg of wood fuel per day. Basing our argument on this statistics, it is evident that most of the schools in Machakos County were consuming way less than the average daily consumption as per Ministry of Energy statistics. Initially before the schools started using the modern cook stoves, a school with an average of 500 students consumed approximately between 1500kg and 2000kg per day while schools with over 800 students consume an average of 2500kg of fuel a day. This show that, the

daily wood fuel consumption by secondary schools in the region had gone down, a reduction which could be attributed to the adoption of energy saving and improved cook stoves by the schools.

The study in addition found that the use of improved cook stoves by secondary schools in Machakos County was mostly associated with fuelwood saving among other benefits as shown from previous studies done by RETAP (2008); Ngeywo (2008); Kituyi (2000). For this study, a secondary school in Machakos County that had adopted fully the improved cook stove had a daily mean consumption rate of 0.46 kg per student while the ones using semi-improved and traditional cookstoves consumed 0.61 and 0.80kg per student daily respectively. When comparing these values, the mean daily per student consumption rate of improved cookstove users was 1.33 times and 1.74 times that of the semi-improved and traditional cookstoves users respectively. Based on these results, it is clear that a secondary school in Machakos County switching from using a traditional to an improved cook stove would save 0.34 kg per student or 43% daily. Similarly, a school using a semi-improved cook stove would make a daily fuel wood saving of 0.152 kg or 25% per student, if it switched to using improved cook stoves.

Finally, the study established that annually, up to 91.8 kg and 41.04 kg of fuel wood per student in secondary schools in Machakos County could be saved by traditional and semi-improved cook stove users respectively if they switched to using improved cook stoves. This was with an assumption that there are 270 operation schooldays each year. Furthermore, a typical school using traditional or semi-improved cook stove in Machakos County, with an average of 300 students could make a saving of about 27.5 tonnes and 12.3 tonnes of fuelwood annually respectively if they switched to using an improved cook stove. These figures demonstrated that there was environmental savings in terms of reduced deforestation, associated with the switch to using an improved cookstove by secondary schools in Machakos County.

The county director of education in Machakos County in support of these findings had the following to say;

‘‘...In our county, energy saving cook stoves also known as clean bioenergy stoves have been found to have incredible impact as it increases fuel efficiency by 25–60% while significantly reducing indoor air pollution in comparison to the use of traditional cook stove.’’

These results were affirmed by Mrs. Muthoni an administrator at the Outspan Medical Training College in Nyeri, Central Kenya. Mrs. Muthoni indicated that, before the purchase of the energy

saving cook stoves; the institution used the inefficient traditional three-stone cook stove for meal preparation and heating and they would use electricity from time to time whose cost was very high for the institution, so they resorted to using the old inefficient stoves. According to Mrs. Muthoni, previously they were using six (6) trucks-worth of firewood in four months, but after acquiring the modern improved stoves, now they use three trucks for their four cook stoves 600 litres, 300 litres and two 100 litre capacity and a water boiler also made by Kartech and this now costs them Ksh 180,000 (~US$2,200) compared to earlier when they had to spend Ksh. 230,000 (~US$2,700) for a 300 litre capacity cook stove. This therefore implies that modern cook stoves are capable of cutting cost of fuel by up to 27.8%.

Apart from the schools, interview schedule was served to the county director of education in Machakos County. The County director was asked to indicate whether the ministry of education or students had carried out research on wood fuel consumption in Machakos County or not. In addition, the director was asked to indicate the findings if any. The director responded as shown below;

''...Yes, there have been studies conducted by both the ministry of education and the students on the rate of wood fuel consumption in our county and the findings revealed that; some secondary schools in our county are already using alternative source of fuel such as 'Kuni safi' as was the case with Mavoko secondary school and many others. These schools were found to use 'Kuni safi' alongside the wood fuel and the reason why they have not fully adopted the use of kuni safi is because the suppliers requires cash on delivery and due to financial constraints the schools are unable to purchase the fuel. In addition to this, a number of schools in our county are currently using biogas as source of energy for cooking. For example, Masinga girls use biogas but since the piping system is expensive to install they have connected a small section and it's used to cook light food for the teachers. They use the waste from the girls' toilet''.

Plate 4.1: Cooker Using Biogas at Masinga Girls' School

Source: field survey data (2019)

In addition to this, the respondents were asked to indicate the frequency with which wood fuel was being delivered to their schools per term. The results in Figure 4.8 show the responses.

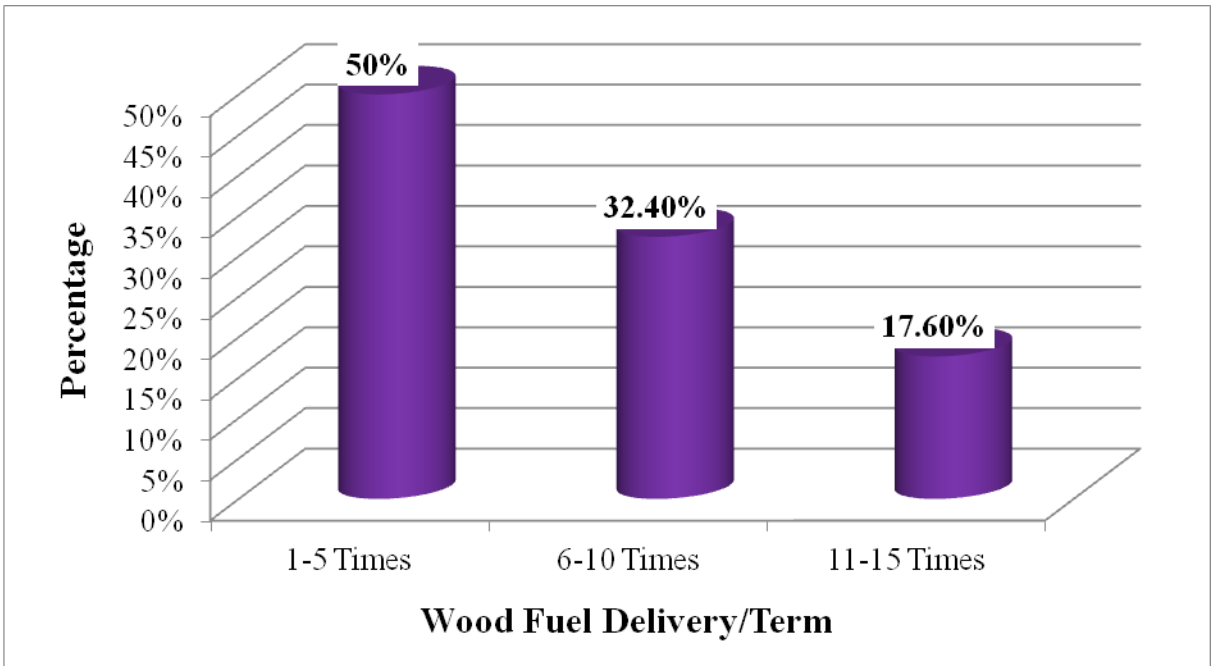


Figure 4.8: Frequency of Wood Fuel Delivery per Term

Source: field survey data (2019)

Based on the results in Figure 4.8, majority (50%) of the respondents indicated that their schools were receiving wood fuel from the suppliers between 1 to 5 times in a term. In addition, the results show that 32.40% of the schools were being supplied with wood fuel between 6-10 times

in a term and only 17.60% of the schools indicated that they were getting delivery of wood fuel between 11-15 times in a term. The results imply that most of the secondary schools in Machakos have low frequency with which wood fuel is supplied to their schools; this can be attributed to the adoption of energy saving cook stoves which are efficient and economical in terms of wood fuel consumption by most of the schools.

In addition, interview guide was served to the county director of education in Machakos County where he was asked to indicate whether there were any plans put in place by secondary schools in his county to use alternative sources of fuel to move away from the use of wood fuel and he responded as follows;

''Yes, some secondary schools in this county are already coming up with alternative sources of fuel and ways of controlling the effects of desertification in our county. For example; Machakos School have never bought wood fuel as they get it from the school land and they harvest 10 tractors every holiday (3 times a year). The school has a tree replacement program where each student is required to plant a tree every season (2 trees in a year) and take care of them. They mostly have yellow barked Acacia. In addition, the school is already subsidizing the use of wood fuel by using electricity in cooking and baking bread. The school has a bakery and they use electricity to bake. The same is being replicated by many other schools within this county.''

Plate 4.2: Machakos School Wood Land

Source: field survey data (2019)

Further, interview schedule was conducted to the Ministry of Environment and Natural Resources in Machakos County to get clear and more information on policies put in place on wood fuel usage in the county. The director of the ministry in Machakos County was asked to indicate if there are any policies put in place by the ministry to control the usage of wood fuel by secondary schools in the county. In addition, the director was asked to describe some of the policies in place and how they were being implemented. The director responded as follows;

''...Yes we have policies in place to reduce the impact of desertification in this county. Currently we are encouraging secondary schools to adopt alternative cooking methods that do not entirely rely on wood fuel or at least subsidize the wood fuel. Many secondary schools are already embracing the use of alternative sources of fuel. For example, Machakos girls' school and Machakos boys are currently using electricity to bake bread since they have bakery in schools. Machakos Girls' had a bakery where they used wood fuel in their oven but it's no longer operational since it was consuming more wood fuel, they later resorted to using electricity.''

Plate 4.3: Machakos School Bakery

Source: field survey data (2019)

The study revealed that most of the schools in the County were consuming between 500kg and 1000kg of wood fuel per day. It was established that most schools in Machakos County were

consuming way less than the average daily consumption according to Ministry of Energy statistics. This meant that, the daily wood fuel consumption by secondary schools in the region had gone down, a reduction which was attributed to the adoption of energy saving and improved cook stoves by the schools.

The responses from the County Director of education in Machakos County while responding to the interview indicated that; there had been studies conducted by both the ministry of education and the students on the rate of wood fuel consumption in our county and the findings showed that; some schools in the county were already using alternative source of fuel such as 'Kuni safi' as was the case with Mavoko secondary school and many others.

These schools were found to use ‘Kuni safi’ alongside the wood fuel and the reason why they have not fully adopted the use of kuni safi is because the suppliers requires cash on delivery and due to financial constraints the schools are unable to purchase the fuel. In addition to this, a number of schools in the county were reported to use biogas as source of energy for cooking. For example, Masinga girls use biogas but since the piping system is expensive to install they have connected a small section and it’s used to cook light food for the teachers. They use the waste from the girls’ toilet’’.

4.6. Hypothesis Testing

The null hypothesis was tested to assess whether there is difference between quantity of wood fuel used by modern cook stoves and traditional cook stoves in secondary schools in Machakos County or not. The hypothesis was tested using chi-square test and results presented in the tables 4.5.

Table 4.5: Hypothesis Test Results

Null Hypothesis (H_0)	**Chi-square**	**df**	**Sig (P-value)**	**Decision**
H_0: There is no difference between quantity of wood fuel used by modern cook stoves and traditional cook stoves	0.120	68	0.029	Null hypothesis Rejected

The null hypothesis was tested that there is no difference between quantity of wood fuel used by modern cook stoves and traditional cook stoves in secondary schools in Machakos County. The

results show that the chi-square statistic value was 0.120 and p-value=0.029<0.05, the null hypothesis was hence rejected and the alternative hypothesis adopted that there is difference between quantity of wood fuel used by modern cook stoves and traditional cook stoves in secondary schools in Machakos County. The findings are consistent with the findings of a study by RETAP (2010) which alluded to the fact that fuel wood consumption rate reduced progressively as one moved up the technology ladder from traditional cook stoves to improved, state-of-the art cook stoves which was attributed to their varying efficiencies.

4.7 Factors Influencing Choice of Cook Stove in Public Secondary Schools in Machakos County

The third objective of this study was to determine factors influencing choice of cook stove by public secondary schools in Machakos County. The respondents who indicated that their schools were using modern cooking stoves were asked to indicate why their schools chose modern cooking stoves over the ordinary one. The results in Figure 4.9 show the responses.

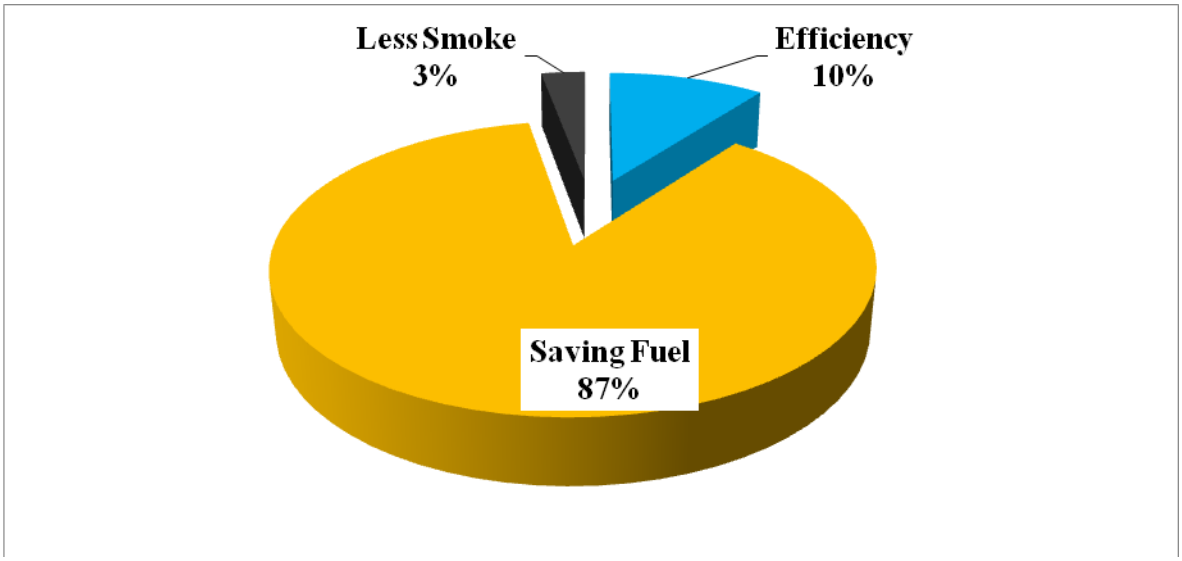


Figure 4.9: Reasons for Choosing Modern Cooking Stoves

Source: field survey data (2019)

According to the results in Figure 4.9, majority (87%) of the schools chose modern cooking stoves over the ordinary ones because the modern ones were saving them fuel. The respondents indicated that the modern stoves were fuel saving and this helped them reduce what they had been spending on fuel before. In addition, the results show that 10% of the schools chose modern stoves over the ordinary ones because they were more efficient compared to the ordinary

traditional cooking stoves. 3% of the schools indicated that they preferred modern cooking stoves over the ordinary ones because they were less sooty, since they produce less smoke. The results imply that most of the schools in Machakos County were adopting the use of modern cooking stoves because they are fuel saving and economical in terms of the amount spent on fuel by the schools. The results are consistent with the conclusion made by Wang *et al.* (2013) that, improved cook stoves are very high performing, emit very low emissions, are very efficient and also very safe in use.

In addition, the results are in agreement with the report by Ministry of Energy (2018) which indicated that with the use of the energy saving cook stove, most households monthly budget on fuel would be less than Ksh.500 compared to the households using a three-stone cook stove who will spend up to 2,000 KES on monthly basis. In this case, the difference is quite substantial. The respondents were asked to indicate other reasons their schools had to choose modern cooking stoves over the ordinary ones and they gave varied reasons including; Modern cooking stoves are user friendly, reduces wood fuel consumption hence reducing implications of desertification on the environment, modern stoves are easy to maintain, modern cooking stoves are hygienic etc.

The results revealed that most of the schools in Machakos County were adopting the use of modern cooking stoves because they were found to be fuel saving and economical in terms of the amount spent on fuel by the schools. The results further indicated that Modern cooking stoves are user friendly, reduces wood fuel consumption hence reducing implications of desertification on the environment, modern stoves are easy to maintain; modern cooking stoves are hygienic etc. The results were found to be consistent with the conclusion made by Wang *et al.* (2013) that, advanced stoves are very high performing cooking stoves, which emit very low emissions, are very efficient and also very safe in use. In addition, the results are in agreement with the report by Ministry of Energy (2018) which indicated that with an improved cook stove, most households monthly budget on fuel would be less than Ksh.500 compared to the households using a three-stone cook stove who will spend up to 2,000 KES per month and considering the daily wage on the countryside is around 250 – 400 KES the difference is substantial.

CHAPTER FIVE: SUMMARY OF KEY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The overall objective of this study was to assess the contribution of improved cook stoves in reducing wood fuel consumption in Kenya, a case study of public secondary schools in Machakos County. This chapter summarizes the study findings per objective, discusses conclusions and gives recommendations.

5.2 Summary of Findings

The key objective of the study was to assess the contribution of improved cook stoves in reducing wood fuel consumption in Kenya, a case study of public secondary schools in Machakos County.

5.2.1 Adoption Rate of Energy Saving Stoves

The findings of the study revealed that most of the schools in the County were already adopting the use of modern improve cook stoves as a way of reducing the wood fuel consumption thus the pressure on the forests is reduced resulting into reduced implications of desertification. Some schools such as Machakos girls' school and Machakos Boys were found to be using electricity in baking bread so as to minimize the consumption of wood fuel. The results are contrary to the findings of Kituyi (2000); Ngeywo (2008) which indicated that many Kenyan schools use traditional cook stoves for their daily meal preparation and water heating purposes and their daily mean fuelwood consumption rates is reported to be between1.4 and 1.7 Kg per student. The results also indicated that, much as many secondary schools were already adopting the use of modern cooking stoves; other schools were still finding it a challenging exercise.

5.2.2 Rate of Wood Fuel Consumption

On the basis of the study findings, most of the schools in Machakos County were consuming between 500kg and 1000kg of wood fuel per day, the schools were consuming way less than the average daily consumption according to Ministry of Energy statistics. This meant that, the daily wood fuel consumption by secondary schools in the region had gone down, a reduction which was attributed to the adoption of energy saving and improved cook stoves by the schools.

The responses from the county director of education in Machakos County while responding to the interview indicated that; there had been studies conducted by both the ministry of education and the students on the rate of wood fuel consumption in our county and the findings revealed that; some secondary schools in the county were already using alternative source of fuel such as 'Kuni safi' as was the case with Mavoko secondary school and many others. These schools were found to use ‘Kuni safi’ alongside the wood fuel and the reason why they have not fully adopted the use of kuni safi is because the suppliers requires cash on delivery and due to financial constraints the schools are unable to purchase the fuel. In addition to this, a number of schools in the county were reported to use biogas as source of energy for cooking. For example, Masinga girls use biogas but since the piping system is expensive to install they have connected a small section and it’s used to cook light food for the teachers. They use the waste from the girls’ toilet’’.

5.2.3 Factors Influencing Choice of Cook Stove

Based on the study findings, most of the schools in the County were adopting the use of modern cooking stoves because they were found to be fuel saving and economical in terms of the amount spent on fuel by the schools. The schools that had not adopted the improved cook stove revealed that lack of funds, delay in disbursement by the government and small population were some of the key factors hindering the acquisition of the stove. The results further indicated that Modern cooking stoves are user friendly, reduces wood fuel consumption hence reducing implications of desertification on the environment, modern stoves are easy to maintain; modern cooking stoves are hygienic etc. The results were found to be consistent with the conclusion made by Wang *et al.* (2013) that, improved cook stoves are very high performing cooking stoves, emit very low emissions, very efficient and are very safe in use. In addition, the results are in agreement with the report by Ministry of Energy (2018) which indicated that with the use of the energy saving cook stove, most households monthly budget on fuel would be less than Ksh.500 compared to the households using a three-stone cook stove who will spend up to 2,000 KES per month on fuel.

5.3 Conclusions

Based on the study findings, the study made a number of conclusions.

5.3.1 Adoption Trends and Rate of Energy Saving Stoves

The first objective was to determine the adoption trend and rate of the energy saving stoves by public secondary schools in Machakos County. Based on the findings the study concludes that most of the schools in Machakos County are already embracing adopting of the improve cook stoves as a way of reducing wood fuel usage and so the pressure on the forests is reduced resulting into reduced implications of desertification. The study also concludes that some schools such as Machakos girls' school and Machakos Boys are using electricity in baking bread so as to reduce the consumption of wood fuel. This is contrary to the findings of Kituyi (2000); Ngeywo (2008) which indicated that many Kenyan schools use traditional cook stoves for their daily meal preparation and water heating purposes and their daily mean fuelwood consumption rates is reported to be between1.4 and 1.7 Kg per student.

5.3.2 Rate of wood fuel consumption

The second objective of this study was to assess the rate of wood fuel consumption in public secondary schools in Machakos County. Based on the findings, the study concludes that most of the schools in the County are currently consuming between 500kg and 100kg of wood fuel per day which is way less than the average daily consumption according to Ministry of Energy statistics. The study also concludes that there is a steady decline the consumption of wood fuel by schools in Machakos; this is because there is steady increase in the number of schools adopting modern fuel saving stoves. The study in addition concludes that the ministry of education in collaboration with the students from Machakos County has been conducting studies on the rate of wood fuel consumption in the county and the findings have indicated that; some secondary schools in the county are already using alternative source of fuel and modern cook stoves. In addition to this, a number of schools in the county are using biogas as source of energy for cooking. For example, Masinga girls use biogas but since the piping system is expensive to install they have connected a small section and it's used to cook light food for the teachers. They use the waste from the girls' toilet''. Finally the study indicated that those schools dealing with extreme cases of number of students will determine the fuel wood consumption rates and pattern, which in turn determines demand and supply. The number of students being cooked for in a school will determine the amount of wood fuel that is required to cook for them. A study by

RETAP (2010) showed that schools with high number of students had a low fuelwood consumption rate per student compared to those with fewer students. This was attributed to economies of scale where the more the number of individuals being cooked for, the lower the consumption rate per individual/student.

5.3.3 Factors Influencing Choice of Cook Stove

The third objective of this study was to determine factors influencing choice of cook stove by public secondary schools in Machakos County. Based on the findings the study concludes that most of the schools in Machakos County are using of modern cooking stoves because they are fuel saving and economical in terms of the amount spent on fuel by the schools. In addition, the study concludes that Modern cooking stoves are user friendly, reduces wood fuel consumption hence reducing implications of desertification on the environment, modern stoves are easy to maintain; modern cooking stoves are hygienic etc. The findings are consistent with the conclusion made by Wang *et al.* (2013) that, energy saving cook stoves are very high performing cooking stoves, emit very low emissions, very efficient and are very safe in use. In addition, the results are in agreement with the report by Ministry of Energy (2018) which indicated that with an improved cook stove, most households will spend less than 500 Kenyan Shillings (KES) per month, while households using a three-stone fire will spend up to 2,000 KES per month. A daily wage on the countryside is around 250 – 400 KES. In this case, the savings are quite substantial.

5.4 Recommendations

Based on the findings and the conclusions, the study makes a number of recommendations;

First, the use of modern stoves has been found to result into a reduction of wood fuel consumption. The study therefore recommends to the managements and the stakeholders of all the secondary schools in Machakos County that they should strive to acquire the modern cook stoves as one way of reducing wood fuel consumption; in so doing the implication of desertification will be contained. The study recommends to the National Government through the Ministries of Education and Ministry of Environment and Natural Resources that there should be strong policies put in place to regulate the rate at which schools use wood fuel in Machakos County. To the policy makers, the study concludes that stringent measures should be taken against schools found to be misappropriating funds set aside for the purchase of modern cook stoves.

Secondly, it has been found that most of the secondary schools in Machakos County are already embracing the adoption of modern improve cook stoves as a way of reducing the consumption of wood fuel. The study therefore recommends to the managements and the stakeholders of all the public secondary schools in Machakos County that they should keep up with the spirit and even adopt other sources of energy which do not rely on wood fuel at all. The study recommends to National Government through the Ministries of Education and Ministry of Environment and Natural Resources there should be a special task force formed and tasked with looking into the challenges hindering the adoption of modern cook stoves by secondary schools in Machakos County.

Thirdly, it has been established that most of the secondary schools in Machakos County are currently consuming between 500kg and 100kg of wood fuel per day which is way less than the average daily consumption according to Ministry of Energy statistics. The study therefore recommends to the managements and the stakeholders of all the secondary schools in Machakos County which are still using more than this to look for ways of ensuring they also reduce their daily consumption. The study recommends to National Government through the Ministries of Education and Ministry of Environment and Natural Resources that they should follow up on the schools that are still consuming higher than 1000kg of wood fuel per day and find out why they consume so much.

Fourth, the study recommends formulation of policies that will see the replacement of the lost forest cover by schools, wood fuel supplier, charcoal burners and illegal loggers.

Fifth, the study recommends that the government and the stakeholders involved in disbursing the school funds should plan in such a way that the schools receive the funds in time and where need be the government to support the schools in acquiring the improved cook stoves.

Sixth, the study recommends that the schools establish a tree planting programme in the school where each students plants a seedling every year and takes care of it.

Seventh, it has been established that most of the secondary schools in Machakos County are adopting the use of modern cooking stoves because they are fuel saving and economical in terms of the amount spent on fuel by the schools. The study therefore recommends to the managements and the stakeholders of schools which are yet to start using modern cook stoves to start using because they come with a whole lot of benefits to them.

Lastly, there is need for further awareness creation on the importance of using the improved institutional cook stoves in schools within the County hence higher adoption rates. In addition, more knowledge on the financial, environmental and health benefits that schools could accrued from using these cook stoves can be used as a way to ensure schools buy in to the idea of using improved cook stoves.

5.5 Suggestions for further Study

From the analysis of the findings, it can be suggested that more studies should be conducted to establish the factors influencing adoption of modern cooking stoves and how those factors relate to reducing implication of desertification in all the counties located in arid and semi-arid areas of Kenya such as Makueni Kitui, Marsabit, Turkana, Pokot County, Garissa, Mandera and Wajir.

A suggestion can also be made that, a different study design should be employed in a similar study and compare the results with the findings of the current study.
A study can also be done in the private secondary school to establish if there are alternative sources of fuel being used which can be adopted by the public secondary schools.

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APPENDICES

Appendix I: Questionnaire

Section A: Questionnaire for Schools

NAME OF SCHOOL:	
NO. OF STUDENTS:	**CONSTITUENCY:**
TYPE OF SCHOOL⊗DAY/BOARDING)	**CONTACTS:**
INTERVIWEE: **POSITION:**	**DATE:**

1. **Enrolment: No. of students**

2019	

2. **What does the school use wood fuel for heating and cooking purposes?**

	Heating	**Cooking**
Wood fuel		
Solar		
Biogas		
Any other source of fuel		

3. **Type of meals per day and source of fuel;**

	Breakfast	**Lunch**	**Supper**
source / **meal**			

Wood fuel			
Solar			
Biogas			
Any other source of fuel			

4. **Sources, quantity and cost of wood fuel used per term;**

Sources / Vendors	**Quantity kg/tons**	**Cost per kg/ton**

5. **Estimated daily wood fuel consumption in school (kgs).**

6. **How often is the wood fuel delivered per term?**

No. of trucks/ lorry	
1-5	
6-10	
11-15	
Above 15	

7. **Which type of cook stoves do you use?**

Type of stove	**Number**	**cost**
Traditional stoves		

Semi improved stoves		
Improved stoves		
Others		

8. **Are there any major impacts of cook stove change on wood fuel consumption? What is your opinions on wood fuel consumption between the traditional and the modern cook stoves?**
9. **Why did you choose the modern cooking stoves over the ordinary ones?**

Efficiency	
Saving fuel	
Cost	
Smoke	

Any other reason:

12. What are your recommendations on reducing wood fuel consumption?

Section B: Questionnaire to the Ministry of Education, Machakos County

INTERVIEWER:	**CONTACTS:**
INTERVIWEE: **POSITION:**	**DATE:**

1. **Has the ministry or a student carried out a research on wood fuel consumption in Machakos County**

   If yes, when and what were the findings?

2. **Are there any MoE policies/ regulations on wood fuel usage in schools in Machakos County?**

3. **What support is the MoE offering to schools to improve wood fuel consumption?**

4. **What are the main policies on upcoming new schools in terms of enrolment?**

5. **What are your recommendations on wood fuel usage and technology adoption in schools?**

Section C: Questionnaire to the Ministry of Environment and Natural Resources, Machakos County

INTERVIEWER:	**CONTACTS:**
INTERVIWEE: **POSITION:**	**DATE:**

1. **Has the Ministry carried out any research on wood fuel consumption in schools in Machakos County?**

   If yes, when and what were the findings?

2. **Are there any policies on wood fuel usage in schools?**

   If yes, please explain.

   How have they been implemented?

3. **What has the Ministry done to ensure sustainability and continued supply of wood fuel supply in learning institutions?**

4. **What has the Ministry done to create awareness in schools on different technologies that are more efficient in reducing emissions and wood fuel consumption?**

5. **What are your recommendations on wood fuel usage and new technology adoption especially to the upcoming new schools considering we are experiencing climate change and global warming due to deforestation?**

Section D: Questionnaire to wood fuel supplier

INTERVIEWER:	**CONTACTS:**
INTERVIWEE: **CONSTITUENCY:**	**DATE:**

1. **Where do you get your wood from?**

2. **Which is the major tree species that you source/ supply?**

3. **How many schools do you supply the wood?**

4. **For how long have you been in this business?**

5. **Do you have a permit to sell wood fuel? If yes, Where do you get the permit from and for how much?**

6. **Do you face any challenges? If yes, which ones and how do you handle them?**

7. **Do you have any afforestation plan/ replacement program for the trees cut down to ensure sustainability of the resources? If yes, explain**

8. **For the trees you have replaced, have you began cutting them down?**

Appendix II: Traditional Cook Stoves Used

Appendix III: Improved Cook Stoves Used

Appendix IV: Map of Machakos County (Study Area)