COST BENEFIT ANALYSIS OF DIFFERENT ENERGY SOURCES USED IN PUBLIC SECONDARY SCHOOLS IN MTITO ANDEI DIVISION, MAKUENI COUNTY

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DECLARATION

I understand that plagiarism is an offence and I therefore, declare that this thesis is my original work and has not been presented for an academic award in any university or any institution of higher learning.

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DEDICATION

I dedicate this study to my family, particularly to my parents Mr. Samuel Kazungu Masha and Mrs. Margaret Kazungu for their invaluable support and prayers during my study.

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ACRONYMS AND ABBREVIATIONS

ACEEE	American Council for Efficient Energy Economy
ASALs	Arid Semi-Arid Lands
BCR	Benefit Cost Ratio
BOM	Board of Management
CBA	Cost Benefit Analysis
CBK	Central Bank of Kenya
DEAT	Department of Environmental Affairs and Tourism
EIAs	Environmental Impact Assessments
FAO	Food and Agricultural Organization
FDSE	Free Day Secondary Education
FPE	Free Primary Education
GoK	Government of Kenya
HO	Null Hypothesis
IAP	Indoor Air Pollution
ICT	Information Communication Technology
IEA	International Energy Agency
IRF	InforResources Focus
IRR	Internal Rate of Return
Kcal/g	Kilo calories per gram
KFS	Kenya Forestry Service
Km^2	Square Kilometres
Kshs	Kenya Shillings
kWh	Kilo watt hour
LPG	Liquid Petroleum Gas
m	Meter
MCADP	Makueni County Annual Development Plan
MCSP	Makueni County Strategic Plan

MPR	Market Price Method
N	Population of study
NGOs	Non-Governmental Organizations
NPV	Net Present Value
OECD	Organization for Economic Cooperation and Development
OSHA	Occupational Safety and Health Act
PPEs	Personal Protective Equipments
PVB	Present Vvalue of bBenefits
PVC	Present Value of Costs
RET	Renewable Energy Technology
RETAP	Renewable Energy Technology Assistant Programme
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
SRD	Survey Research Design
SSA	Sub Saharan Africa
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
WEC	World Energy Council
WHO	World Health Organization

ABSTRACT

Energy affects all aspects of development: social, economic and environmental, including livelihoods, access to water, agricultural productivity, health, population levels and education. Public schools spend a lot of money every year on energy bills. Currently, they are experiencing an exponential increase in student enrolment which puts more pressure on energy needs. This study focuses on cost benefit analysis of different energy sources used in public secondary schools in Mtito Andei Division, Makueni County. The specific objectives are to: (1) establish the sources of energy used in public secondary schools, (2) investigate the factors determining the choice of the energy source(s), (3) assess environmental and socio-economic impacts of major energy sources and (4) conduct cost benefit analysis of major energy sources. The study used Survey Research Design (SRD) and a census survey, with all 30 schools in the study site studied via questionnaire administration, observation, interview and photography for data collection. Both descriptive and Benefit Cost Ratio analytical procedures were used. The study findings showed that firewood was the most popular cooking energy source with all (100%) schools using it while charcoal came second (23%) followed by LPG gas (10%) and paraffin (7%). Only 3% of the schools used electricity for cooking. The over reliance on firewood for cooking is expected to have negative environmental consequences in the study area. Electricity was the most popular source of energy for lighting (60%) followed by solar energy (27%) and paraffin (7%). These are expensive sources of energy. An investigation into forms of low cost energy technologies as perceived by the respondents revealed energy saving stoves (87%), solar power (27%) and energy saving bulbs (10%). The reasons for adoption of these energy technologies was mainly high cost of other energy sources and need to conserve the environment. The challenges associated with the different types of energy identified were; electricity (unreliability), firewood (scarcity), charcoal (scarcity) and solar power (high installation cost). The study found firewood consumption was on average 10 tonnes per school per term and that firewood had been used for cooking for more than 13 years on average in all schools in the study area. The study found the Benefit cost ratio (BCR) of solar power at 1.19 and BCR of firewood at 0.19. The study concludes that there was over reliance on firewood for cooking and adoption of modern energy technologies like solar power was very low with adoption by only 27% of schools. The study recommends: (1) the national and county governments to come up with policies such as subsidies, grants and tax relief that will make these technologies affordable and accessible to schools for adoption, (2) establishment of school-based woodlots consisting of fast-growing tree varieties to address the school wood fuel demands instead of escalating the destruction and loss of indigenous forest ecosystems in the area, (3) since solar power has a BCR greater than 1, the study recommends that schools should consider installing more of solar power to reduce huge energy bills and to reduce over dependency on firewood.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Energy plays a vital role in the sustainable development of a society. According to Yuko (2004), energy is not regarded as a basic necessity, but it is a basic ingredient in the successful satisfaction of almost all basic human needs. It affects all aspects of development: social, economic and environmental, including livelihoods, access to water, agricultural productivity, health, population levels, education and gender-related issues (United Nations, 2010). As the UN (2010) notes, energy is important in achieving universal primary education since it is required to attract teachers to rural areas and also enables studies to continue after dusk in homes and schools.

The demand for energy has continued to increase as the world population and industrialisation continue to increase. For example, global primary energy supply increased by 30 percent between 1990 and 2005 and the worldwide demand is projected to double by 2050 according to the International Energy Agency (IEA, 2007). The increasing global demand on energy is becoming a critical challenge for the world's energy leaders (WEC, 2012). For instance, conservative estimates predict that the world′s energy needs will increase approximately three-fold by the end of this century (Donohue & Cogdell, 2006). The World energy consumption is projected to grow by 56 percent between 2010 and 2040. Most of this growth will come from non-OECD (non-Organization for Economic Cooperation and Development) countries, where demand is driven by strong economic growth (IEA, 2013).

An estimated two billion people worldwide continue to lack access to efficient clean energy services. To address this situation, the United Nation Development Program, called for all nations to put special emphasis on renewable sources of energy (UNDP, 1997). According to World Bank (1996), most rural societies experience limited access to modern energy services, due to problems of availability and/or affordability. Instead, they rely on traditional fuels predominately animal dung, crop residues, and wood for the majority of their energy needs. It is further noted that while the developed countries are concerned about rising global prices and the urgent need to curb climate change, the developing countries are faced with the challenge of lack of access to clean and efficient energy (Practical Action, 2009).

Sub-Saharan Africa (SSA) is the least electrified region of the world, with rural electrification levels that are routinely below 5 percent. Rural Africa continues to be home to the majority of Africans. This large segment of the African population relies on biomass to meet their fuel needs. World Bank (2001) estimates indicate that 68% of inhabitants of Sub Saharan Africa reside in rural areas. Provision of modern energy services to this large segment of Africa's population is, therefore, of paramount importance.

In developing countries, most of the biomass energy is consumed in households mainly for heating and cooking and this is expected to remain the same for a long time (FAO, 2007). IEA (2010) estimates, about 2.7 billion people rely on traditional biomass, such as fuelwood, charcoal, agricultural waste, and animal dung, to meet their energy needs for cooking and a significant proportion of these people are mainly the poor.

Kenya has experienced an increase in energy demand which is linked to the rising population and expanding economy, with 60% of the electricity being hydro generated and supply has not been able to meet the increasing demand due to prolonged drought (Schutz, 2007).

Makueni County has one of the lowest household accesses to electricity in the Country (Makueni County Annual Development Plan (MCADP, 2016). Current statistics show that only 5.7% of the households are connected to the national grid against a national average of 22.9% (MCADP, 2016). There are three key undelaying factors to the low coverage and distribution of electricity including low population density, low investment in electricity distribution, and low adoption of alternative sources of energy (MCADP, 2016). In addition, adoption of other alternative sources of energy in the County has been limited due to high levels of poverty among majority of the population, estimated at 64%. Currently the percentage of houses using solar energy is estimated at 3.8% (MCADP, 2016).

Biomass is the most common form of energy used by a majority of the population in the county including learning institutions (MCADP, 2016). A study by Kariuki (2002) observed that charcoal making was more prevalent in Kibwezi Forest Reserve leading to massive deforestation. Results of the study further showed that at least 32 different tree species are used for charcoal making. This revelation is significant to this study as it points out that there is high dependence on biomass energy within the county. As a result, the County faces a serious challenge of environmental degradation attributable to deforestation for charcoal burning and firewood production. At the same time the County has abundant potential for generation of green energy from a number of sources: wind energy, solar energy and biogas energy (Makueni County Strategic Plan (MCSP, 2015).

It was against this background that the study set to conduct a cost benefit analysis of different energy sources used in public secondary schools in Mtito Andei Division, Makueni County.

1.2 Statement of the Problem

Currently, public schools in Kenya are experiencing an exponential increase in student enrolment and boarding facilities, which is likely to put more pressure on energy needs. This can be attributed to the introduction of Free Primary Education (FPE) in 2003 and Free Day Secondary Education (FDSE) in 2008 by the government so as to enhance retention of learners in schools. The launch of FDSE in 2008 led to an increased enrolment in public secondary schools (Republic of Kenya, 2005). This has resulted in increased demand for energy.

Schools use different types of energy such as firewood, charcoal, electricity, LPG-gas, solar power and kerosene to meet their energy needs. However, a majority of schools use wood biomass for cooking (Moronge and Maina, 2015).

Schools consume large quantities of firewood. A study by (Renewable Energy Technology Assistant Programme (RETAP, 2007) shows that a typical boarding school in Kenya consumes between 200-300 tonnes of fuelwood annually. This indicate that schools spend a lot of money on energy bills. Schools in Mtito Andei division, Makueni County are not exempted, therefore, it is expected that they spend a lot of money every year on energy, which may have a profound impact on the schools' financial resources and to the environment. An efficient and cost-effective energy system to schools is central to reducing the huge amount of money spent on energy and to conserve the environment.

The fact that Mtito Andei Division is largely Arid to Semi-Arid Lands (ASALS), where firewood and charcoal is scarce, the schools are forced to look for these resources in neighbouring areas. Tender to supply fuelwood to school is awarded to vendors who deliver the preferred species even if the source is across a different Agro-Ecological Zone (Kituyi, 2000).

Cooks in schools where wood biomass is the main energy source may be at high risk of suffering from health problems due to smoke as a result of continued burning of wood biomass. Exposure to Indoor Air Pollution (IAP) from the combustion of biomass and fossil fuels is the causal agent of several diseases such as; Acute Respiratory Infections (ARI), lung cancer, asthma, tuberculosis, low birth weight and diseases of the eye (WHO, 2003).

Alternative and environmental efficient energy sources are considered crucial for meeting current and future energy needs in schools and adoption of renewable cost-effective energy sources is likely to contribute to environmental conservation. There is, therefore, need to understand the current status of energy sources used by schools in Mtito-Andei Division and evaluate their costs and benefits in order to identify the most suitable. This study aims to establish the different energy sources used in public secondary schools in Mtito Andei Division, Makueni County and conduct cost benefit analysis of these energy sources, in order to identify the most appropriate energy sources for use in institutions.

1.3 Objectives of the Study

1.3.1 General Objective

The main objective of the study was to conduct cost benefit analysis of different energy sources used in public secondary schools in Mtito-Andei Division, Makueni County and evaluate their environmental and socioeconomic impacts.

1.3.2 Specific Objectives

The specific objectives of the study were to:

1. Establish the types of sources of energy used in public secondary schools in Mtito-Andei Division, Makueni County.

2. Investigate the factors that determine the choice of energy source(s).
3. Assess environmental and socioeconomic impacts of major energy sources.
4. Conduct cost benefit analysis of the major energy sources used in schools.

1.4 Research Questions

1) Are there different energy sources used in public secondary schools in Mtito-Andei Division, Makueni County?
2) What factors determine the choice of energy source(s)?
3) Are there existing environmental and socioeconomic impacts of major energy sources used in the study area?
4) How is the cost benefit analysis of the major energy sources used in schools?

1.5 Significance of the Study

This study is instrumental in revealing the importance of having an effective energy source that conserves the environment, as it highlights challenges and opportunities of different energy sources. The findings provided information, which can be used in decision making on environmental conservation in case of use of biomass. Further, the study provided information, which can be used by the national and county governments to develop energy and environment policies to make modern energy technologies affordable and accessible to schools for adoption. Finally, the study contributed to the existing body of knowledge on cost benefit analysis of energy sources and pointed to areas for further research.

1.6 Scope of the Study

This study was carried out in Mtito Andei Division and aimed at conducting cost benefit analysis of major energy sources used in public secondary schools and evaluate their environmental and socioeconomic impacts. The study focused on establishing the sources of energy used in schools and on investigating the factors that determine the choice of energy source(s) by the secondary schools. Data collection was strictly confined within the boundaries set by the objectives of this study. The study was limited to public secondary schools in Mtito Andei Division, Makueni County.

1.7 Assumptions of the Study

The study was based on the following assumptions:

1. Schools in the study area used different sources of energy.
2. All the participants involved in the study survey would be co-operative.
3. Secondary data would be readily available and accessible from the relevant government authorities and institutions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature reviewed in relation to the research problem. This is structured into: energy sources, factors influencing the choice of energy source, environmental and socioeconomic impacts of energy sources, concept of cost benefit analysis and ends with the conceptual framework.

The main purpose of the literature review work was to survey previous studies and to position the current study in relation to others in the field. This activity raised the opportunities for articulating a critical analysis of the study topic to avoid reinventing the wheel and helped in identifying the gaps in current knowledge.

2.2 Energy Sources

According to UN (2010), energy is pivotal to the issues of development, global security and environmental protection. The main sources of energy are divided into two main categories: conventional and renewable energy sources. Conventional energy sources (also called non-renewable energy) do not renew themselves on meaningful human time frames and are mainly fossil fuels. On the other hand, renewable energy can in general terms be defined as energy that can be derived from resources which are naturally replenished on a human timescale and the main ones are sunlight, biogas, wind, hydropower, tides, waves and biomass (Energy Information Administration (EIA, 2008). Renewable energy sources can provide energy in four important areas: electricity generation, cooking, hot water/space heating, transportation, and rural (off-grid) energy services (EIA, 2008).

The International Energy Agency (IEA, 2006) noted that in order to meet the households' energy needs, about 70% of rural households in sub-Saharan Africa rely on fuel wood, charcoal, kerosene oil or wood and wastes.

Kituyi (2000) revealed that 90% of 20,000 schools in Kenya relied entirely on fuelwood for daily cooking and heating purposes. RETAP (2007) reported that 75% of the 4215 boarding secondary schools in Kenya, depended entirely on fuelwood for their daily cooking and water heating purposes.

The limited studies done on overall daily consumption rates of fuelwood in schools ranged between 99.9-178.2Kg (RETAP, 2007). This was irrespective of the combustion devices used, the type of school, number of meals being cooked and other factors that influence fuelwood consumption rates (Kituyi, 2000; Kituyi and Kirubi, 2003; RETAP, 2007; Ngeywo, 2008 as cited by Nyambane (2016).

Moronge and Maina (2015) documented that firewood, electricity, diesel, liquefied petroleum gas (LPG) kerosene and charcoal are the main sources of energy for cooking, lighting and laboratories in schools in Thika Sub-County. This revelation indicates that schools rely on wood fuel (firewood and charcoal) in their energy matrix which can contribute to deforestation and land degradation.

2.3 Factors Influencing Choice of Energy Source

In Africa, cooking often accounts for between 90 and 100% of household energy consumption due to limited space conditioning loads (Karekezi and Kithyoma, 2002). Household energy consumption levels and the types of energy used depends on a variety of factors but mainly on availability and cost of energy resources (Karekezi and Kithyoma, 2002). Also, among the poor, biomass resources are used in unsustainable and inefficient ways due to lack of access to information, financial resources and technology (Kammen and Ezzati, 2001).

A study done in Nigeria by Adepoju *et al.,* (2012) concludes that availability, affordability and convenience of usage are critical issues to be taken into consideration when making choices among available energy sources. Further, their findings showed that respondents without formal education had higher likelihood of using fuel wood and charcoal as major sources of energy. However, if prices of fuel wood and charcoal increase due to scarcity less of them would be bought.

Student population influences the choice of energy in schools. For instance, a study by RETAP (2007) found that the demand of fuelwood by schools is likely to continue increasing in Kenya because of the increase in the number of schools yearly due to population growth hence increased deforestation rates.

2.4 Environmental and socioeconomic impacts of different energy sources

A number of studies have been conducted in the past on energy. This section attempts to group the reviewed literature into thematic areas to address some of the energy issues in relation to the study.

2.4.1 Adoption and affordability of energy sources

A major constraint to the adoption of cost-effective energy technologies is that the initial capital outlay for these technologies tends to be high (Bazart 2003; Ilie *et al*., 2007). Shutz (2007) observes that the current state of the energy sector costs billions in public subsidies and leaves many developing countries exposed to high oil import prices. For instance, she notes that oil accounts for 10 -15% of total imports for oil-importing African countries and absorbs over 30% of their export revenue on average.

The share of poor families' incomes spent on fuels is a significant portion of their total expenditures and can sometimes overtake other essential items such as schooling and health costs when local fuel prices rise (UNDP, 2005; Modi *et al*., 2006). Studies by Lay *et al*., (2013) reveals that income plays an important role in switching to transitional and more modern energy sources. Chapman and Erickson (1995) found that cost reduction is necessary to make renewable energy sources (RETs) broadly competitive in developing countries. Moreover, empirical evidence on adoption of renewable energy technology (RET) in Kenya arrives at the conclusion that such technology could meet a significant proportion of the country's energy demand (Karekezi and Kithyoma 2003).

Studies conducted by the American Council for Efficient Energy Economy (ACEEE, 2009) indicate that although people are often aware of the benefits of using energy more efficiently, a variety of social, cultural, and economic factors often prevent them from doing so. Even when high efficiency technologies have been installed, 30 percent or more of the energy savings that could potentially be realized through such technologies is lost.

2.4.2 Energy and Health

The social cost brought by use of biomass is enormous. For instance, Ezzati and Kammen (2002) contends that exposure to indoor air pollution (IAP) from the combustion of traditional fuels in Kenya enhances the risk of acute respiratory infection.

According to Bruce *et al*., (2000), IAP is responsible for nearly two million deaths in least developed countries. Evidence from studies in least developed countries indicate that, IAP is associated with low birth weight, infant and prenatal mortality and pulmonary tuberculosis (WHO, 1997; UNEP, 2002).

A large number of existing studies in the broader literature have shown that adopting cleaner cooking methods will improve health and reduce illness-related expenditures, stimulate development and contribute to environmental sustainability (World health organization (WHO, 2003).

Society's reliance on fossil fuels energy represents one of the major challenges to global environmental sustainability and economic stability. Fossil fuel combustion is also a major source of 'greenhouse gas' and chemicals that have been implicated in numerous health problems. Consequently, there are calls from governments, private sector and the scientific community to develop and adopt alternative energy sources that couple reductions in the use of fossil fuels with decreased greenhouse gas emissions (Donohue & Cogdell, 2006).

2.4.3 Energy and Education

Previous studies have shown that modern, cleaner and affordable energy options can help create a more child-friendly environment that encourages school attendance and reduces the significant dropout rates experienced in many low-income countries (Mapako, 2010). For example, studies have provided evidence that electricity can facilitate access to educational media and communication in schools and in homes and it can increase use of distance-learning modules (Mapako, 2010). Access to electricity provides the opportunity to use more sophisticated equipment for teaching such as projectors, computers, documentary videos, printers, photocopiers, and science equipment, which allows wider access to more-specialized teaching materials and courses (Mapako, 2010).

In their study, Sovacool *et al*., (2013) noted that in Mali, electrification has increased levels of girls' school attendance, improved performance, and drastically improved boy to girl ratios. Electrified schools and villages have been documented to have lower drop-out rates, higher test scores, and higher proportions of girls entering secondary education. Anup *et al*., (2011) documented that in Nepal, girl student enrolment increased by 23.3 percent across a sample of villages that had received electricity at schools. In Kenya, lighting has enabled teachers to provide extra teaching early in the day and late at night to make up for material not adequately covered during normal hours (Kirubi *et al*., 2009).

2.4.4 Benefits in relation to modern energy sources

Modern cost effective and clean energy sources such as biogas offers various benefits such as saving fuel wood and protecting forests as well as reduces expenditure on fuels. In addition, it reduces the time spent on cooking and improves hygienic conditions (Gregory, 2010). Adoption of modern efficient energy sources contributes in saving money initially used to buy kerosene, charcoal or firewood. Murphy (2001) contend that, women and children in particular will have more time for education.

Togola (2005) reported that about 73% Nigerians lack access to electricity, thereby making economic development very difficult. Igbinovia and Orukpe (2007) also noted that utilization of adequate form of energy is a propellant for job creation and socioeconomic development. Inadequate access to electricity is a major limitation to development of rural cottage industries.

2.4.5 Energy and Environmental Degradation

There have been numerous studies to investigate environmental degradation attributed to biomass energy production and consumption. These studies show that biomass production has impact on hydrology, soils, wildlife and species habitat. Its use over time has contributed to forest degradation, soil erosion, desertification, loss of biodiversity due to preference to particular wood types and adverse health effects as a result of indoor air pollution (Bruce *et al.*, 2000; IRF, 2006; Mugo and Gathui, 2010). For instance, the World Bank (2006) reports that the massive loss of forest cover in Malawi is attributed to biomass use for fuel wood and charcoal production and as such the high demand for biomass fuels has been seen to be a threat to forests (World Bank, 2006).

Biomass harvesting and use for energy has been associated with serious environmental degradation in Kenya (Republic of Kenya, 2004). In Addition, the use of biomass especially charcoal and firewood is said to be one of the main causes of loss of biodiversity and wide scale deforestation in Kenya (Mugo and Gathui. 2010).

Past studies have reported that charcoal is heavily used in urban areas. For instance, Takase (1997) and Kituyi (2001) documented that charcoal is the preferred fuel in urban areas of developing countries because of factors such as long-life storage, low-cost of transportation due to its smaller volume and weight, and its high heat content, which is about 7,000 kcal/g compared to 3,000 kcal/g from dry fuelwood and 1,000 kcal/g from green fuelwood.

Currently, wood fuel is a scarce resource that should be more efficiently and sustainably managed (FAO, 2007). Kituyi (2001) and IEA (2007) noted that the distance to the wood sources in many regions has increased forcing many households especially in the urban areas to rely on the nearby markets. Karoliina (2012) concludes that the availability of firewood in the Taita Hills has diminished. People have to collect firewood from further away and from smaller areas. This has also increased the time used for collecting wood for fuel. Use of firewood increases households' vulnerability by raising the work-load of women in particular, and also by its effect on the environment and health (Karoliina, 2012). In addition, this energy supply requires larger economical contributions, while people have to more often resort to purchased energy which is not free. This weakens the economic situation of families and lessens their opportunities to plan their future or make other investments (Karoliina, 2012).

Recent studies by Moronge and Maina (2015) reveal that over-reliance on firewood, as a source of energy in schools is not sustainable and may contribute to environmental degradation. The study findings indicate that firewood, electricity, diesel, liquefied petroleum gas (LPG) kerosene and charcoal are the main source of energy for cooking, lighting and laboratories in schools in Thika Sub-County. There was limited use of solar and wind energy. This is an indication that most of the schools were using fuelwood. Kirai (2009) notes, the over-reliance on primary biomass energy by over 68% of the population has led to widespread exploitation of forest resources with adverse environmental impacts.

Globally, in line with the Sustainable Development Goals (SDGs) the UN (2015) reported that 1.3 billion people-one in five globally lack access to modern electricity, it further noted that 3 billion people rely on wood, coal, charcoal or animal waste for cooking and heating. UN (2015) reported that 13 billion hectares of forests are being lost every year. Around 1.6 billion people depend on forest for their livelihood (UN, 2015). Forests are home to more than 80% of all terrestrial species of animals, plants and insects. It further noted that due to drought and desertification each year, 12 million hectares are lost (23 hectares per minute) (UN, 2015). By integrating the SDG dimension, particularly SDG-7 (Affordable and Clean Energy) whose aim, among other things, is to increase the proportion of renewable energy (e.g. solar energy, wind energy) in the energy mix in all sectors including educational institutions, schools may greatly contribute to saving the environment (UN, 2015).

2.5 Concept of Cost Benefit Analysis

Cost-Benefit Analysis (CBA) is a technique for systematically estimating the efficiency impacts on policies (Weimer and Vining 1991). The broad purpose of CBA is to help in decision making and more specifically to facilitate efficient allocation of resources (Boardman *et al.*, 2006). According to European Union (2006) all impacts; financial, economic, social or environmental are required to be assessed when conducting CBA.

There are two major types of CBA. *Ex ante* CBA is conducted while the project or policy is under consideration or before it is started or implemented. It is used in deciding whether some resources should be allocated to a certain project. *Ex post* CBA is conducted at the end of the project in order to help find out if the project was worthwhile. Some CBA are conducted in the course of life of the project (Magati, 2009). For this study, some elements are similar to *ex ante* and *ex post* analyses.

CBA considers both direct costs such as the cost of running a project and indirect costs such as costs to the public sector. In addition to financial costs and benefits, CBA also includes those costs and benefits which are not directly measured in monetary terms; for example, 'in-kind' contributions including volunteer time, and benefits such as improvements in quality of life.

2.5.1 Application of Cost Benefit Analysis

Cost Benefit Analysis (CBA) is used at two basic levels: in the private sector and social level (Department of Environmental Affairs and Tourism (DEAT, 2004). In the private sector, financial CBA is used to justify equipment and technology investments, measure life cycle costs, meet regulations cost-effectively, and quantify hidden costs and intangible benefits (DEAT, 2004). It is also a useful tool to show how quality improvements can affect returns. The second one is the social level, where CBA is used to appraise the social merit of projects or policies. The projects may be public or private, and the analysis is typically used to inform public decision makers. This type of CBA is the form typically used in Environmental impact assessments (EIAs) (DEAT, 2004).

CBA can be used to evaluate or rank the feasibility of projects, analyse the effect of regulation, justify equipment and technology investment (DEAT, 2004). It can also be used to determine whether a new investment in equipment or technology for government is an efficient use of the taxpayers' money, determine the most effective way to cut costs, determine the relative benefits, quantify hidden costs and intangible benefits and to ensure accountability by public sector decision-makers (DEAT, 2004).

2.5.2 Cost Benefit Analysis Processes/ Methodology

Cost-benefit analysis (CBA) compares costs and benefits, both of which are quantified in common pecuniary units (Yogesh and Kuldeep, 2013).

Economic analysis involves comparing the costs and consequences of different interventions, enabling conclusions to be drawn about their relative efficiency. The goal of CBA is to identify whether the benefits of an intervention exceed its costs (Yogesh and Kuldeep, 2013). A positive net benefit indicates that an intervention is worthwhile from an economic perspective. However, as public funds are limited, some ranking of the alternatives is necessary to enable decision makers to choose the interventions that have the highest return on investment and/or bring the greatest benefit to target populations (Yogesh and Kuldeep, 2013).

Only two energy sources, namely: solar power and firewood were selected for Cost benefit analysis in this study where valid comparisons and conclusions were then drawn only, by taking into consideration the costs and benefits of the energy source/technology; for this reason, CBA is used.

Lebel (2000) in examining the economic efficiency of alternative renewable energy technologies in Botswana emphasized that valuation of future versus present costs and benefits must be taken into accounts when one is making useful comparisons of whether a given technology is economically viable. This creates a linkage to the term known as the discount rate which defines the decision maker's time preference while valuing the future versus the present costs and benefits (Lebel, 2000).

In terms of this research analysis, CBA was conducted by using the Benefit-cost ratio (BCR) and Net Present Value (NPV) decision rule. BCR and NPV decision rule was employed in order to adequately present the required information for the basis of solid decision making. Greater difficulties are always encountered in the actual measurements of costs and benefits as well as selection of an appropriate discount rate (Ogunlade, 2008).

Equations 1 through 3 illustrate the concept of discounting in CBA as adapted from the works of Lebel (2000) in the Financial and Economic Analysis of Selected Renewable Energy Technologies in Botswana. To determine a cumulative Present Value of Benefits (PVB) that are payable in annual instalments over a period of one year is given as:

$$PVB = \sum_{i=o}^{n} \frac{B_i}{(1+R)^i}$$ ………………………………. **Equation 1**

Where *B* is the economic value of benefits in each time period, *R* is the discount rate, *i* is the initial time period and *n* represents the present value period of time to be considered. The discount rate of 13% was used in this study based on the commercial banks interest rate on capital (Central Bank of Kenya (CBK, 2019).

It must be noted that the initial time period is not always discounted, though it appears in the formula. This is so because the exponential of 0 carries the value of 1. The result of using the above discount rate illustrates that by using a discounted value for each benefit for each period of time, one has an accurate way of aggregating the benefits that are expected in the future time period with the present time benefits (ogunlade, 2008).

The following equation is used to determine the cumulative present value of costs (PVC) when conducting CBA.

$$PVC = \sum_{t=o}^{n} \frac{C_i}{(1+R)^i}$$ **…………………………….. Equation 2**

Where R depicts the same discount rate as used in equation 1, C is the economic value of costs in each time period, C_i represents the cost in the *ith* time period and, n again represents the present value period of time to be considered.

Since Equations 1 and 2 are determined, they provide the basis for the determination of the three criteria often used to determine if an investment is economical. They are Benefit-Cost Ratio (BCR), Net Present Value (NPV) and Internal Rate of Return (IRR) (Ogunlade, 2008). In the case of this study the BCR and NPV criterion is used to measure if an investment decision is viable. The benefit-cost ratio is the ratio of present benefits to present costs, which is derived from equations 1 and 2, defined as:

$$BCR = \frac{\sum \frac{B_i}{(1+R)^i}}{\sum \frac{C_i}{(1+R)^i}}$$ .... **Equation 3**

Benefit-cost ratio is always interlinked with the outcomes of the net present value measure. For instance, if the net present value of an investment is positive, the benefit-cost ratio will be greater than one, in which case the project is considered viable. For a minimum level result of acceptability, a zero net present value and a benefit-cost ratio of one is used (Ogunlade, 2008). Therefore, the primary output of a CBA is: The benefit–cost ratio (BCR), which shows the factor by which economic benefits exceed the economic costs. However, the ratio itself is not the only information of interest to decision-makers, who may also wish to know how quickly the investment will be paid back, the attractiveness of the investment compared to placing the funds in a bank and earning interest, and so on (Yogesh and Kuldeep, 2013).

A benefit to cost ratio of over one indicates that benefits probably exceed costs and that the investment is promising. A ratio under one indicates that benefits are probably less than costs and that the project sponsor should consider further study or innovative strategies to justify the project (Jack, 2015). NPV is the difference between the present value of benefits minus the present value of costs, as shown below.

NPV = PVB – PVC; where

$$NPV = \sum_{i=0}^{n} \frac{B_i}{(1+R)^i} - \sum_{t=o}^{n} \frac{C_i}{(1+R)^i}$$ .... **Equation 4**

Once NPV is calculated, it is possible to establish whether a project is recommendable. Boardman (2011) indicated, the general decision rule is to adopt a project when its NPV is positive. There are a number of variations to the Net Present Value decision rule, including situations where not just one project has positive NPV. In such case, the rule should choose the project with the higher net present value (Boardman, 2011). Finally, when none of the proposed projects has positive NPV, then none of the alternatives are superior to the status quo, which should remain in place (Boardman, 2011).

2.5.3 Strengths and weaknesses of CBA

According to Ogunlade (2008), CBA technique is advantageous in identifying alternative options, defining alternatives in a way that allows fair comparison, adjusting for occurrence of costs and benefits at different times. Given this scenario, it is evident that CBA is the preferred choice for this study. Moreover, CBA is a tool that informs the decision maker and the public. Properly presented, it is accessible and makes the issues involved succinct and clear. By doing so it increases accountability in the decision-making process, and can help ease conflict. In this regard it may be introduced to inform interested parties involved in multi-criteria decision analysis. By applying CBA, uncertainty can be reduced and the process of choosing the most beneficial project can be optimised (DEAT, 2004).

CBA has some limitations. For instance, the Federal Management Group (2006) reveals that CBA limitations exist in form of intangibles, where some costs and benefits cannot be monetized. However, despite this CBA method remains one of the most accurate decision-making tools where investment options have to be made (Watkins, 2007).

Some authors have also suggested that CBA can be expensive and time consuming, and results are likely to be sensitive to the many assumptions often required to complete the estimation of the benefits and the costs of the proposed policy and program (Moore, 1995). Moreover, while costs are usually overestimated, non-quantifiable benefits tend to be disregarded (Ackerman and Heinzerling, 2002). The complexity of both estimating environmental effects and valuing non-market benefits in monetary terms, leads to a risk of underestimating the overall benefits (Shapiro and Schroeder, 2008; Salles, 2011). In particular, some ecosystem services are difficult to quantify; there is little to compare them with and they may be subject to many uncertainties (Heal, 2000).

Several studies have also suggested that the lack of information on interactions in the ecological system leads to limited and biased results, due to the high complexity of ecosystems (Hanley, 2001; Nunes and van der Bergh, 2001) and the irreversibility of ecosystem damages once a critical threshold is reached (Pindyck, 2000; UNEP, 2011). But beyond this limitation, CBA requires specific methods to express environmental services in monetised benefits that add even more uncertainty. This is particularly true when it comes to environmental long term or hidden benefits that can hardly be perceived by the population (e.g. biodiversity). This is probably the main weakness of the technique (Boeuf *et al*., 2015).

The focus of this study was to address the issue on cost benefit analysis and environmental and socioeconomic impacts of different energy sources in public secondary schools, since literature on past studies have shown that there is over-reliance on firewood as source of energy in schools which is not sustainable and may contribute to environmental degradation.

2.6 Conceptual Framework

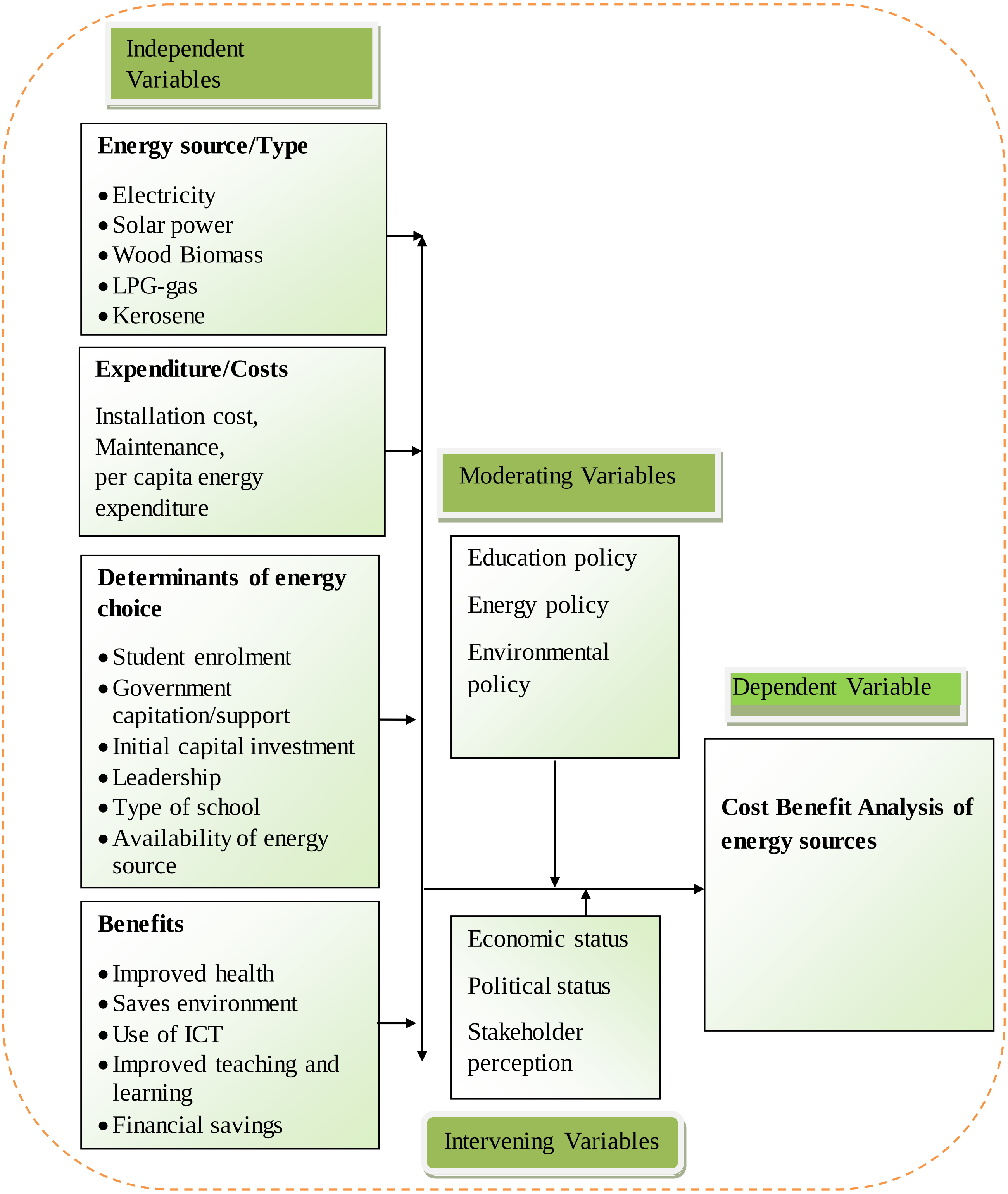

Figure 2.1: Conceptual Framework

(Source: Authors' own conceptualization, 2017)

CHAPTER THREE

3.0 METHODOLOGY

3.1 Introduction

This chapter first presents the background information of the study area including geographical location of the study area. The second part addresses research design used in the study. It also presents sampling procedures, data collection tools and methods as well as the key parameters studied and analysis procedures used in the study.

3.2 Study Area

The study area lies in Makueni County which covers an area of 8,034.7 Km^2. The County borders Kajiado to the West, Taita Taveta to the South, Kitui to the East and Machakos to the North (Figure 2). It lies between latitude 1º 35´ and 30º 00´ South and between longitude 37º 10´ and 38º 30´ East. The County lies in the arid and semi-arid zones of the Eastern region of the country. Its terrain is generally low-lying from 600m above sea level in Tsavo at the southern end of the County. The County is currently divided into nine Sub-counties and twenty-five divisions. Specifically, the study was carried out in Mtito Andei Division which lies in Kibwezi East Sub-county and it borders Tsavo East National Park to the West and Tsavo West National Park to the South.

Mtito-Andei Division is the largest amongst the three divisions in Kibwezi Sub-County. In terms of the schools it has 30 public secondary schools and 76 primary schools according to records from the Kibwezi Sub-County Education office (2017). A list of the secondary schools per zone in Mtito-Andei Division and the 2017 student enrolment is presented in Table 3.1.

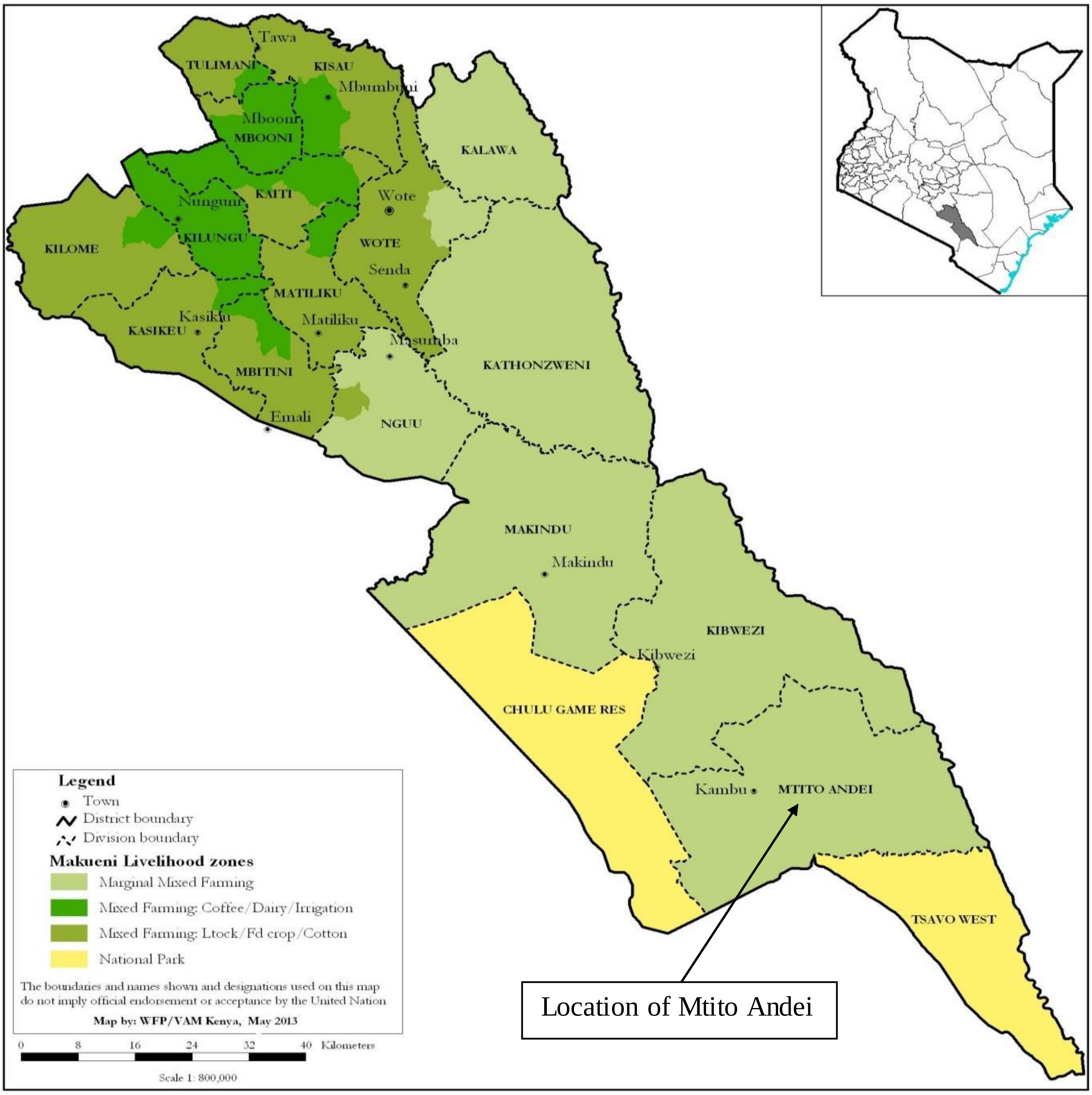

Figure 3.1: Map showing Makueni County and Location in Kenya (inset)

Table 3.1: Public secondary schools in Mtito Andei Division by zone, category and student enrolment

ZONE	NAME OF SCHOOL	TYPE/CATEGORY	ENROLMENT 2017
Mtito-Andei	1. Joanna Chase	Boys boarding	280
	2. Miangeni	Mixed day and boarding	179
	3. Nzoila	Mixed day	92
	4. Mbeetwani	Mixed day	78
	5. Mavindini	Mixed day and boarding	182
	6. Kyusiani	Mixed day and bording	85
	7. Kathekani	Mixed day and boarding	240
Kambu	8. St. Mary's Komboyo	Girls boarding	246
	9. Iiani	Boys day and boarding	316
	10. Muthingiini	Boys boarding	287
	11. Darajani	Boys day and boarding	389
	12. Kamulalani	Mixed day and boarding	247
	13. St. Lucy Kilimani	Mixed day	72
	14. Silanga	Mixed day	168
	15. Komboyo Mixed	Mixed day	181
	16. Molemuni Girls	Girls boarding	270
	17. Canaan	Mixed day	120
Nthongoni	18. Mwitasyano	Mixed day	210
	19. Kithing'iisyo	Mixed day and boarding	326
	20. Kiuani	Mixed day and boarding	310
	21. Kasue girls	Girls boarding	425
	22. Matulani	Mixed day and boarding	308
	23. Ivingoni	Mixed day and boarding	210
	24. Tsavo West	Mixed day	91
Ngwata	25. Ititi	Mixed day and boarding	165
	26. Kiteng'ei	Mixed day	213
	27. Yumbuni	Mixed day and boarding	190
	28. Misuuni	Mixed day and boarding	344
	29. Yikitaa	Mixed day and boarding	135
	30. Ngwata	Mixed day and boarding	333
TOTALS	**30**		**6692**

Source: Kibwezi Sub-County education office 2017

The choice of the study area was influenced by a number of factors: 1. The area neighbours Chyulu Hills, which is one of the eighteen (18) national government gazetted water towers (GoK, 2012), is characterized by indiscriminate clearance of indigenous trees and shrubs which are used by locals for firewood and charcoal burning; 2. It is located in a dryland and Semi-Arid region where firewood is a scarce resource; and 3. The area is faced with major challenges in accessing alternative sources of energy due to high levels of poverty (Makueni County Annual Development Plan (MCADP), 2016), which hinders acquisition, leading to dependence on trees and shrubs by learning institutions for firewood. As a result, the area is bound to suffer a great deal of environmental degradation and loss of biodiversity.

3.3 Research Design

The study employed a survey research design (SRD). The survey design was relevant to this study as it served to describe the attitudes, opinions, behaviour, trends and characteristics of the population.

3.4 Sampling Procedure

The study employed census survey, where all public secondary schools (30) in the study area were interviewed. Due to the small population of schools in the study area, census survey was relevant for this study as it allowed for the acquisition of valid and reliable data, since it captured all the units of study.

Purposive sampling was used to identify respondents with desired information in line with the study objectives. They included the school principal, bursar(s) and cook(s). The principal was interviewed to provide data on background information of the school, energy needs and sources, determinants for the choice of energy source, expenditure on energy as well as the benefits associated with different energy sources. The school bursar was interviewed in gathering data on energy expenditure over the years. The school cook(s) provided useful general information on the benefits and challenges of the various energy sources; these include problems of smoke and suitability of the energy sources.

3.5 Methods of Data Collection and Analysis

3.5.1 Types of Data

Primary data was collected through administration of questionnaire (Appendix 1). The data collected included;

1) Sources of energy such as electricity, firewood, solar, LPG-gas.
2) Determinants for the choice of energy source such as school type, government capitation/support, education level of school head, energy availability, cost of other energy sources.
3) Environmental and socioeconomic impacts of major energy sources; such as land degradation, increased desertification, loss of biodiversity, indoor air pollution, scarcity of firewood and charcoal.
4) Costs and benefits of energy sources in monetary value; such as the initial capital investment, running costs, maintenance costs and reduced energy bills. These costs and benefits were used in conducting the CBA.

3.5.2 Data Collection Tools and Methods

Data collection was done using different methods depending on the specific objectives. These included structured questionnaires (Appendix 1), observation (Appendix 2), interviews (Appendix 3) and photography. The questionnaires were divided into modules each addressing a specific objective. It was also structured with closed and open-ended questions to gather information from the respondents.

Interviews were used to collect data on the benefits and challenges of the various energy sources in the study area from the school cook(s) and key informants. Observation was used to support the information gathered through questionnaires and interviews based on the objectives of the study. This method also facilitated gathering of first-hand data as observed in the study area. Photographs were used to support data collected from the study area by other methods.

Secondary data was obtained from internet, journals and books. The research was designed to undertake collection of data from respondents in public secondary schools on the different energy sources.

In identifying the sources of energy, the research relied on both primary and secondary sources of data. Additional investigation methods included observation and photography.

To determine the factors influencing the choice of energy source, the study relied on the questionnaire and interview schedule. The interview schedule was administered to respondents with the aim of bringing to light the relative importance of investing in cost effective energy sources in schools.

To assess environmental and socioeconomic impacts of energy source, the study relied on both primary and secondary data. The questionnaire was administered to respondents with the aim of gathering data on energy costs/challenges and benefits over the years. Secondary data provided information on what has already been done in relation to the study and link the findings based on the objectives.

To conduct the cost benefit analysis of the energy source, the study relied on the questionnaire which was administered with the aim of gathering data on the types of costs and benefits in relation to the energy sources and the estimated monetary value. The following method as suggested by Lebel (2000), was used in conducting the CBA in this study by BCR approach.

$$BCR = \frac{\sum \frac{B_i}{(1+R)^i}}{\sum \frac{C_i}{(1+R)^i}}$$

Where *BCR* is the benefit cost ratio for the energy source under consideration, B_i is the economic value of benefits in each time period, *R* is the discount rate, *i* is the initial time period, C_i is the economic value of costs in each time period. By applying this formula, the BCR for solar power and firewood were generated. The value of *R* (discount rate) used in this study was 13% in line with the current borrowing rate (interest rate) from commercial banks in Kenya (CBK, 2019) during the time of study.

The following mathematical expression as suggested by Lebel (2000), was used in conducting CBA in this study by NPV approach.

$$\mathrm{NPV} = \sum_{i=0}^{n} \frac{\mathrm{B_i}}{(1+\mathrm{R})^{\mathrm{i}}} \quad - \quad \sum_{t=o}^{n} \frac{\mathrm{C_i}}{(1+\mathrm{R})^{\mathrm{i}}}$$

Where NPV is the Net Present Value for the energy source under consideration, B_i is the economic value of benefits in each time period, *R* is the discount rate, *i* is the initial time period, C_i is the economic value of costs in each time period. By applying this formula, the NPV for solar power and firewood were generated. The value of *R* (discount rate) used in this study was 13% in line with the current borrowing rate (interest rate) from banks in Kenya during the time of study.

Open - ended questions were included to elicit more extensive discussions on some of the issues raised. These included the institutions future plans on energy needs, sources and conservation, the level of government commitment and other stakeholder's involvement and their suggestions for reducing energy costs, improving energy access, efficiency and reliability as well as enhancing environmental conservation in the study area.

3.5.3 Data Analysis

Both qualitative and quantitative paradigms were used in collecting and analysing data. Qualitative data was obtained from open ended items in the questionnaires. The qualitative data obtained was grouped into different categories depending on the responses given by the respondents. These categories helped in establishing themes which were further coded and entered in a computer statistical package. The study employed the use of the Statistical Package for Social Sciences (SPSS) software. SPSS was preferred for the study since it is easy to use and readily accepts a wide range of data manipulations to give desired results. Data was analysed using descriptive statistics such as percentages, means and frequencies and presented with the aid of tables, charts, notes and graphs.

The first stage of analysis involved generating of descriptive statistics. These were frequency tables and charts to review general findings on the specific research questions. The second stage of analysis involved evaluation of environmental and socioeconomic impacts of major energy sources to determine the challenges and benefits in utilizing different energy sources in line with the objectives of the study. This was conducted in two parts; the first part of analysis involved the monetary/financial expenditure on energy per school. To achieve this the study largely relied on the schools' expenditure records/data on energy over the years. These costs were used in calculating the per capita cost for the energy source. The second part involved the analysis of the non-monetary environmental and socioeconomic benefits and challenges. Since these could not be monetized, were recorded as narratives and presented in form of tables.

In order to conduct the CBA, the researcher relied on the discounted benefits and costs information of the energy source/technology as documented by the respondents. To be most effective in the analysis, this data was supplemented with information that described the type of benefit and cost in their respective context. This also facilitated the grouping of costs and benefits. The types of costs considered for analysis included: initial capital investment, cost of maintenance and operating cost/energy bills, while the types of benefits included: savings from energy bills, savings from regular maintenance cost, savings from paying health bills, reduced indoor air pollution. Those costs and benefit which could not be monetized were excluded (not valued) since there was lack of a suitable methodology to evaluate them during the analysis of this study. After calculating the total discounted monetary value to benefits and costs, the final step of the analysis was to compare the cost and benefit of the energy source/technology in a benefit-cost ratio and net present value approaches. The decision rule is, on the one hand to adopt an energy source if the value of the benefit cost ratio (BCR) is greater than 1, and on the other hand, to adopt an energy source when its NPV is positive as measured in this study. As Boardman (2011) pointed out, the final goal of CBA is to make a recommendation based on a decision rule.

The first benefit cost analysis compares the solar power benefits with the costs in order to establish whether it is a worthwhile investment. The second benefit cost analysis compares the firewood benefits with costs in order to ascertain if it is a worthy investment. These two energy sources (solar power and firewood) were selected for CBA analysis as they were shown in the study to be the major energy sources in use, they may have positive or negative effect to the environment and data on benefits and cost measure was available which facilitated the benefit cost analysis. The NPV was computed by subtracting the total value of discounted costs from the total value of discounted benefits for solar power and firewood projects respectively. NPV has the potential to tell about the magnitude of the values of benefits and costs.

For this study, the analysis assumes a 1-year (2017) benefit horizon starting after project (solar power and energy saving stoves) installation in 2016. These types of projects in schools typically provide a stream of benefits that last for many years. The timeframe for analysis of the benefits and costs must therefore extend well into the future to measure project benefits accurately (Jack, 2015). However, for this study the analysis did not extend into the future since the focus was to determine the energy source that can save the environment by lessening pressure on natural forest ecology rather than the economic aspects of the energy sources. The decision rule for this study was to select the technology if the BCR is equal to or greater than 1 and when the NPV is positive.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter is devoted to presentation of findings obtained from the study. At the outset is a highlight of general characteristics of the selected schools in the study area which forms a basis for presenting results on documentation of energy sources used in the targeted public secondary schools. This is followed by determinants for choice of energy source, an assessment of environmental and socioeconomic impacts of major energy sources and lastly the cost benefit analysis of major energy sources is done.

4.1.1 General characteristics of the schools

4.1.1.1 School land size

In terms of land size owned by schools, the study indicated that 60% of the schools had 1-10 acre of land, 30% had 11-20 and 10% had more than 20 acres of land (Figure 4.1).

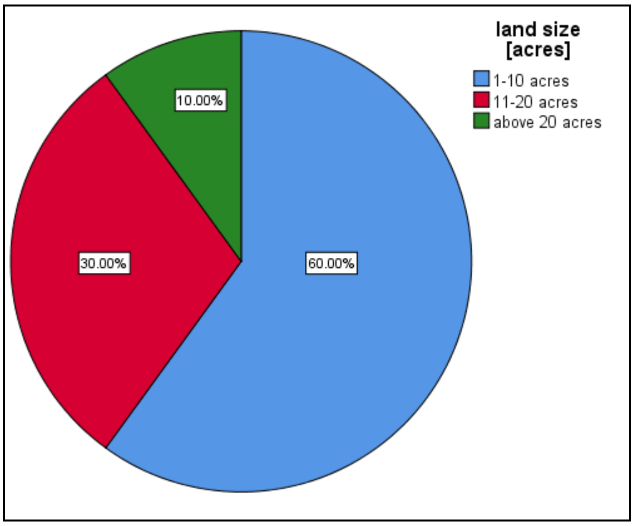

Figure 4.1: School land size (in acres) in the study area

4.1.1.2 School type

From the study, it was established that 47% of the schools were mixed day and boarding, 30% were mixed day, 10% were boarding girls', boarding boys' and boys' day and boarding were both at 7% respectively as shown in Figure 4.2 below.

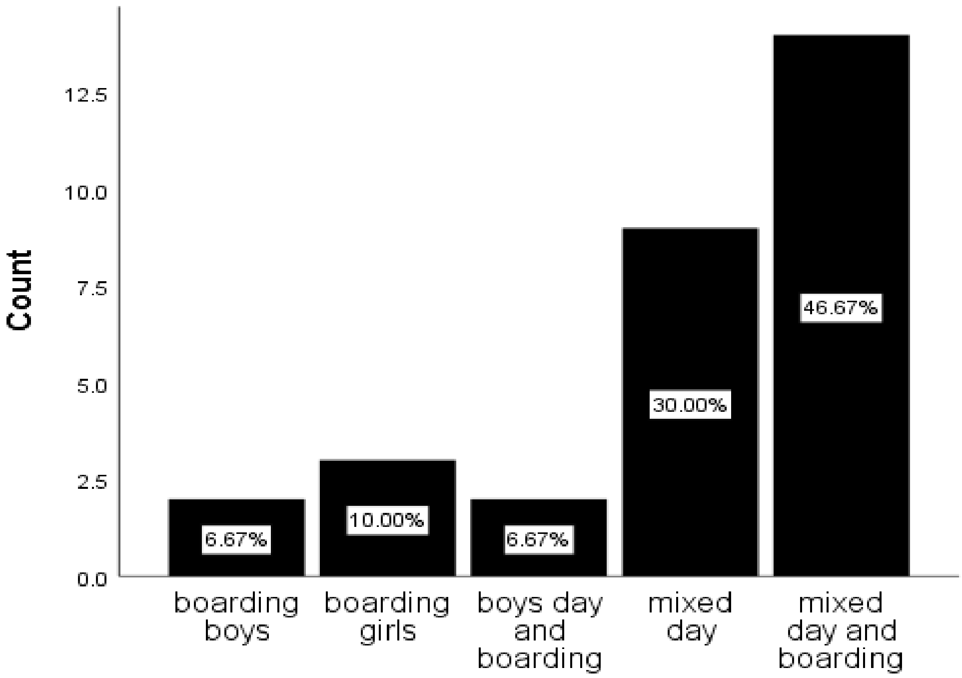

Figure 4.2: School type by percentage in the study area

4.1.1.3 Number of schools established per year in the study area

The study revealed that majority (60%) of the schools in the study area were established between 2006-2015, compounding the fact that majority of the schools in the study area were recently established (Table 4.1). This can be attributed to the increased student enrolment in public schools due to the introduction of Free Primary

Education in 2003 and Free Day Secondary Education in 2008. As a result, there has been an increased demand for energy in schools.

Table 4.1: Number of schools established per year in the study area (N=30)

Year	Frequency	Percent
1965-1975	1	3
1976-1985	3	10
1986-1995	4	13
1996-2005	4	13
2006-2015	18	60

4.1.1.4 Age of the school heads in the study area

An analysis of the socio-economic characteristics of the respondents of the study revealed that, majority (67%) of school heads were between 41-50 years of age (Figure 4.3).

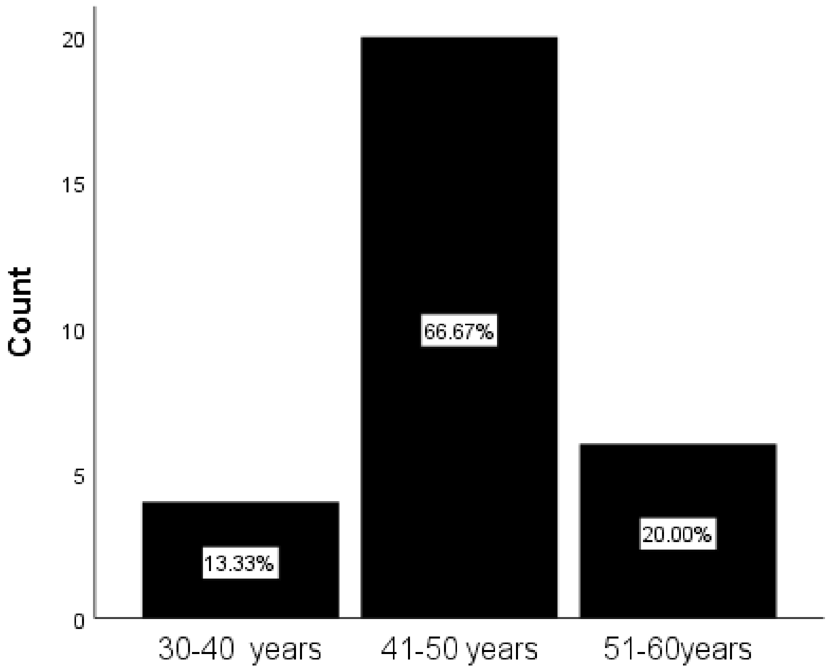

Figure 4.3: Age of school heads in the study area

4.1.1.5 Education level of the school head

In terms of education level, the study results showed that the highest number of respondents (school heads/principals) had a Master's degree making up 15 respondents (50%), with 14 respondents (47%) had Bachelor's degree and 1 respondent (3%) had a PhD (Figure 4.4).

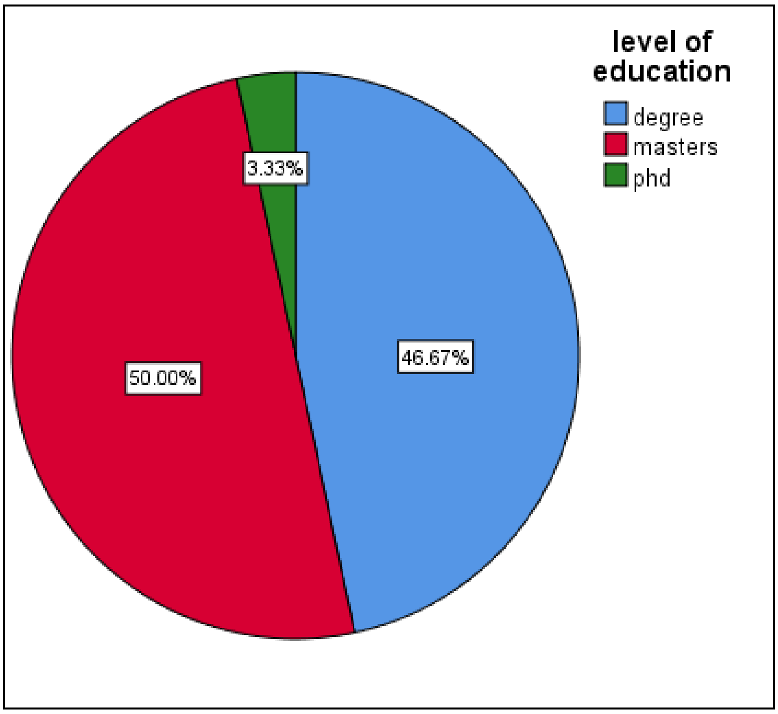

Figure 4.4: Education level of the school heads in the study area

4.1.1.6 Years of service of school head

The study also revealed that the number of years the school heads had served in their stations were between 1 and more than 10 years (Figure 4.5), with 60% having served for between 1 to 5 years, 37% having served for between 6 to 10 years and 3% having served for more than 10 years.

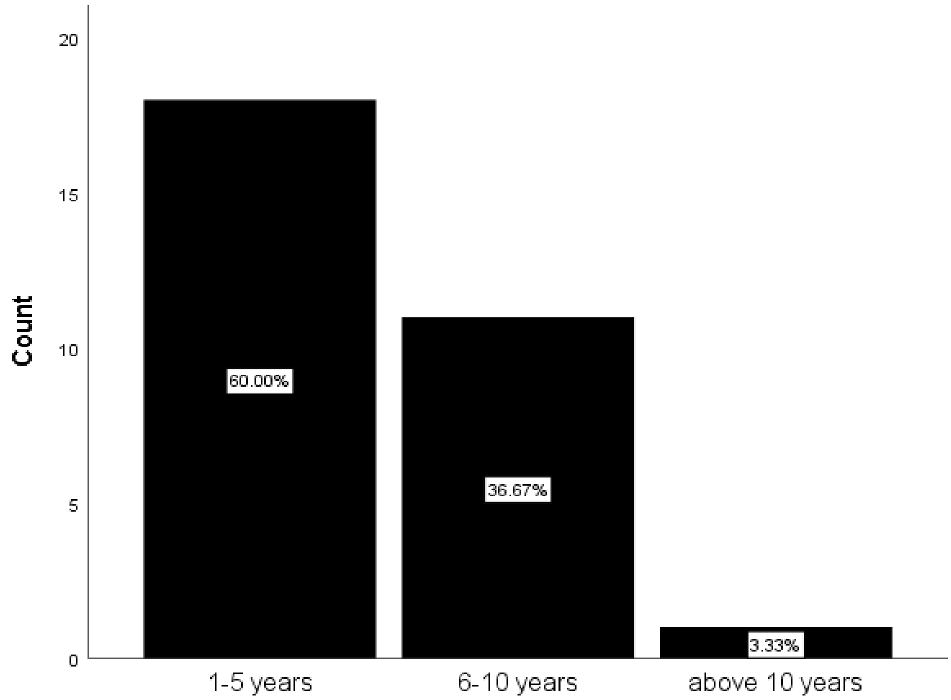

Figure 4.5: Years of service of the school heads in the study area

4.1.1.7 Gender of school head

On the gender composition of the school heads, there were more male (67%) than female (33%).

4.2 Sources of Energy Used in Public Schools

4.2.1 Types of energy sources used

The study findings revealed that public secondary schools in the study area use eight (8) different sources of energy to meet daily energy needs (Table 4.2). Firewood was the most popular source of energy (100%), followed by electricity (60%), LPG gas (43%), batteries (dry cells) (33%), solar power (26%), charcoal (23%), generator (13%) and kerosene (13%).

Table 4.2: Types of energy sources used in schools in the study area (N=30)

Energy source	Frequency	Percent
Firewood	30	100
Electricity	18	60
LPG gas	13	43
Batteries (dry cells)	10	33
Solar power	8	27
Charcoal	7	23
Generator	4	13
Kerosene	4	13

In many school large heaps of wood and logs were observed outside the kitchens (see plate 4.1). The respondents confirmed that the firewood (mainly from indigenous trees) had been cut down to be used for cooking.

Plate 4.1: Heap of logs and firewood outside Kathekani secondary school kitchen

4.2.2 Type of use of the energy source in schools in the study area

From the study (Table 4.3), it is clearly shown that different types of energy sources had multiple uses in schools in the study area. Firewood was shown to be the most preferred energy source for cooking at 100% followed by charcoal at 23%, 57% of the respondents reported that they used LPG-gas for performing practical/experiments in the school laboratory, some of the respondents (27%) indicated that they used solar power for lighting. The findings of the study revealed that electricity was used for lighting at 60% as well as for teaching and learning/ICT at 30%. It was also shown in the study that batteries (dry cells) were used for conducting practical/experiments at 17% and for security at 17%. Other usages of these energy sources are reported in Table 4.3.

Table 4.3: Type of use of the energy source in schools in the study area (N=30)

Energy source	Type of use	Frequency	Percent
Firewood	Cooking	30	100
	Heating	3	10
Charcoal	Cooking	7	23
	Heating	2	7
Electricity	Charging	8	27
	Cooking	1	3
	Lighting	18	60
	Performing practical	3	10
	Refrigeration	1	3
	Security	7	23
	Teaching/ICT	9	30
LPG gas	Heating	2	7
	Cooking	3	10
	Lighting	1	3
	Performing practical	17	57
Solar power	Charging	3	10
	Lighting	8	27
	Security	4	13
	Teaching/ICT	5	17
Kerosene	Cooking	2	7
	Lighting	2	7
	Lighting firewood	1	3
Generator	Charging	2	7
	Lighting	4	13
	Performing practical	1	3
	Security	2	7
	Teaching	2	7
Batteries (dry cells)	Lighting	4	13
	Performing practical	5	17
	Security	5	17

Further analysis revealed that five different types of energy sources were commonly used for cooking in schools in the study area (Table 4.4). Overall, firewood was shown to be used by all (100%) the schools but some schools also used other forms of energy including charcoal, LPG-gas, kerosene and electricity (23%, 10%, 7% and 3% of schools respectively).

Table 4.4: Five commonly used energy sources for cooking in schools in the study area (N=30)

Type of use	Energy source	Frequency	Percent
Cooking	Firewood	30	100
	Charcoal	7	23
	LPG gas	3	10
	Kerosene	2	7
	Electricity	1	3

4.2.3 Duration of use of the energy source(s) in schools in the study area

An attempt was made to establish the number of years a particular energy source has been in use in the study area. The focus was to reveal the energy sources that have been predominantly used over the years.

When asked how long they have been using their mentioned type of energy source in the schools, the respondents indicated that on average; firewood was used for more than 13 years, batteries (dry cells) for 5 years, electricity for 4 years, charcoal for 4 years and LPG-gas at 3.6 years (Table 4.5). For the other types of energy sources, it was found that they have been in use for less than 2 years on average, these include; petrol/diesel, solar power, and kerosene (Table 4.5).

Table 4.5: Average number of years of use of energy source in schools (N=30)

Energy source	Average use in years	Percent
Firewood	13.77	46
Electricity	4.47	15
LPG gas	3.57	12
Batteries (dry cells)	5.33	18
Solar power	1.20	4
Charcoal	3.80	13
Petro/diesel	1.83	6
Kerosene	1.03	3

4.2.4 Estimated quantity of firewood, charcoal, electricity and LPG-gas spent in school per term (2017) in the study area

An attempt was made to establish the quantity of firewood, charcoal, electricity and LPG-gas spent in school per term as reported by the respondents'/school heads (table 4.6). The quantity was based on number of tonnes for firewood used, 90kg bags for charcoal, units (kWh) for electricity and 6kg cylinders for LPG-gas. It was evident from the study that schools spent a lot of firewood per term. The study findings indicated that on average one school spends 10 tonnes of firewood per term, electricity at 1649.8 units, charcoal at 3.4 bags and LPG- gas at 3 cylinder per term (Table 4.6). The study noted that school terms vary in terms of length, climatic conditions and activities. These factors were reported to be influencing demand on fuel/energy in schools in the study area.

Table 4.6: Estimated quantity of firewood, charcoal, LPG-gas and electricity spent in school per term (2017) in the study area

School Name	Type of school	Firewood (tonnes)	Charcoal (90kg bag)	LPG-gas (6kg cylinder)	Electricity (units)
1.Ititi	Mixed day and boarding	6	0	1	0
2.Kamulalani	Mixed day and boarding	14	0	0	230
3.Nzoila	Mixed day	5	0	2	0
4.Yumbuni	Mixed day and boarding	1	0	2	0
5.St. Lucy Kalimani	Mixed day	2	0	0	83
6.Mavindini	Mixed day and boarding	20	0	0	0
7.Yikitaa	Mixed day and boarding	3	0	1	0
8.Kitenge'i	Mixed day	3	0	4	1000
9.Molemuni girls'	Girls boarding	5	0	2	2000
10.Joanna chase	Boys boarding	5	8	12	5000
11.Mbeetwani	Mixed day	20	0	0	0
12.Kithing'iisyo	Mixed day and boarding	30	0	4	1105
13.Kasue girls'	Girls boarding	36	5	4	5250
14.Ngwata	Mixed day and boarding	16	0	0	2000
15.Iiani	Boys day and boarding	10	0	0	1000
16.Kiuani	Mixed day and boarding	2	0	1	923
17.Ivingoni	Mixed day and boarding	10	3	0	1000
18.Komboyoo	Mixed day	10	0	0	0
19.Mwitasyano	Mixed day	1.5	0	0	0
20.Misuuni	Mixed day and boarding	10	0	0	1330
22.Matulani	Mixed day and boarding	10	0	4	0
22.Miangeni	Mixed day and boarding	3	1	0	150
23.Silanga	Mixed day	5	0	0	120
24.Kyusyani	Mixed day and boarding	3	2	0	0
25.Darajani boys'	Boys day and boarding	32	0	1	3800
26.Tsavo West	Mixed day	5	0	0	0
27.Muthingiini	Boys boarding	15	2	2	706
28.St. Mary's Komboyoo	Girls boarding	10	0	0	1500
29.Kathekani	Mixed day and boarding	5	3	0	2500
30.Canaan	Mixed day	5	0	0	0
Average		**10.1**	**3.4**	**2.9**	**1649.8**

4.2.5 Per Capita energy usage by school per term (2017) in the study area

This sub section sought to investigate the per capita energy usage by school per term in order to establish how much energy a student consumes per term. The per capita energy usage by school was calculated by dividing the quantity of energy used by the student enrolment in the period under consideration.

The study found that the highest Per Capita usage for firewood was at 260Kgs/ student, charcoal at 2.6 Kg/student, LPG-gas at 0.26Kg/student and electricity at 17.78kWh/student (Table 4.7). It emerged from the study that schools with lower student enrolment had a higher Per Capita usage compared to those with higher enrolment.

Table 4.7: Per Capita energy usage by school per term (2017)

School Name	Type of School	Student enrolment	Per Capita usage by school per term (2017)			
			Firewood (Kgs /student)	**Charcoal** (Kgs/student)	**LPG-gas** (Kgs/student)	**Electricity** (kWh/student)
1.Ititi	Mixed day and boarding	165	40	0	0.04	0
2.Kamulalani	Mixed day and boarding	247	60	0	0	0.93
3.Nzoila	Mixed day	92	50	0	0.13	0
4.Yumbuni	Mixed day and boarding	190	10	0	0.06	0
5.St. Lucy Kalimani	Mixed day	72	30	0	0	1.15
6.Mavindini	Mixed day and boarding	182	110	0	0	0
7.Yikitaa	Mixed day and boarding	135	20	0	0.04	0
8.Kiteng'ei	Mixed day	213	10	0	0.11	4.70
9.Molemuni	Girls' boarding	270	20	0	0.04	7.4
10.Joanna Chase	Boys boarding	280	20	2.6	0.26	17.78
11.Mbeetwani	Mixed day	78	260	0	0	0
12.Kithing'iisyo	Mixed day and boarding	326	90	0	0.07	3.39
13.Kasue Girls'	Girls' boarding	425	90	1.1	0.06	12.35
14.Ngwata	Mixed day and boarding	333	50	0	0	6.01
15.Iiani	Boys day and boarding	316	30	0	0	3.16
16.Kiuani	Mixed day and boarding	310	10	0	0.02	2.98
17.Ivingoni	Mixed day and boarding	210	50	1.3	0	4.76
18.Komboyo mixed	Mixed day	181	60	0	0	0
19.Mwitasyano	Mixed day	210	10	0	0	0
20.Misuuni	Mixed day and boarding	344	30	0	0	3.87
21.Matulani	Mixed day and boarding	308	30	1.2	0.08	0
22.Miangeni	Mixed day and boarding	179	20	0.5	0	0.84
23.Silanga	Mixed day	168	30	0	0	0.71
24.Kyusyani	Mixed day and boarding	85	40	2.1	0	0
25.Darajani	Boys day and boarding	389	80	0	0.02	9.77
26.Tsavo West	Mixed day	91	60	0	0	0
27.Muthingiini	Boys boarding	287	50	0.6	0.04	2.46
28.St.Mary's Komboyo	Girls' boarding	246	40	0	0	6.10
29.Kathekani	Mixed day and boarding	240	20	1.1	0	10.42
30.Canaan	Mixed day	120	40	0	0	0

4.2.6 Monetary value of the energy sources (using market price) in the study area

Estimation of the monetary value for the selected energy sources in the study was based on the energy quantity used in the various schools in the study area. The valuation was done through the market price method (MPR) using the cost value. This involved the consideration of the prevailing sale prices for each energy source in relation to the specified quantity at the study site. The monetary estimation involved the multiplication of the total energy quantity used from each school with the current market price to compute the gross value. The prevailing market prices at the time of analysis was as shown: firewood Kshs. 4000/ tonne, charcoal kshs.1000/ 90kg sack, LPG-gas Kshs. 900 for refilling 6kg cylinder, electricity; first 50kWh:2.50, 50kWh to 1500kWh:12.75, thereafter (1500kWh and above): 20.57 Kshs. The study noted that the price of firewood was highly dependent on the tree species. In this study therefore, the price of firewood used represent the average market price of firewood in the study area.

The findings of the study established that the highest monetary value of the estimated cost of the energy sources were Kshs, 144,000 for firewood, Kshs. 95,359 for electricity, Kshs. 10,800 for LPG-gas and Kshs. 8,000 for charcoal (Table 4.8).

Table 4.8: Monetary value (using current market price) of the estimated cost (in Kshs in '000') of the energy sources in the study area

		Estimated energy cost by school per term (2017)			
School Name	Type of School	Firewood	Charcoal	LPG-gas	Electricity
1.Ititi	Mixed day and boarding	24	0	.9	0
2.Kamulalani	Mixed day and boarding	56	0	0	2.420
3.Nzoila	Mixed day	20	0	1.8	0
4.Yumbuni	Mixed day and boarding	4	0	1.8	0
5.St. Lucy Kalimani	Mixed day	8	0	0	.54575
6.Mavindini	Mixed day and boarding	80	0	0	0
7.Yikitaa	Mixed day and boarding	12	0	.9	0
8.Kiteng'ei	Mixed day	12	0	3.6	12.2375
9.Molemuni	Girls' boarding	20	0	1.8	28.5065
10.Joanna Chase	Boys boarding	20	8	10.8	90.2165
11.Mbeetwani	Mixed day	80	0	0	0
12.Kithing'iisyo	Mixed day and boarding	120	0	3.6	12.30125
13.Kasue Girls'	Girls' boarding	144	5	3.6	95.359
14.Ngwata	Mixed day and boarding	64	0	0	28.5065
15.Iiani	Boys day and boarding	40	0	0	12.2375
16.Kiuani	Mixed day and boarding	8	0	.9	11.25575
17.Ivingoni	Mixed day and boarding	40	3	0	12.2375
18.Komboyo mixed	Mixed day	40	0	0	0
19.Mwitasyano	Mixed day	6	0	0	0
20.Misuuni	Mixed day and boarding	40	0	0	16.445
21.Matulani	Mixed day and boarding	40	0	3.6	0
22.Miangeni	Mixed day and boarding	12	1	0	1.397
23.Silanga	Mixed day	20	0	0	1.0175
24.Kyusyani	Mixed day and boarding	12	2	0	0
25.Darajani	Boys day and boarding	128	0	.9	65.5325
26.Tsavo West	Mixed day	20	0	0	0
27.Muthingiini	Boys boarding	60	2	1.8	8.489
28.St. Mary's Komboyo	Girls' boarding	40	0	0	18.6125
29.Kathekani	Mixed day and boarding	20	3	0	38.77915
30.Canaan	Mixed day	20	0	0	0

4.2.7 Total Cost of energy bills in schools for the previous years (2015-2017)

Results in the last 2 years (between 2015-2017) revealed that electricity had been the most expensive energy source followed by firewood (Table 4.9).

Table 4.9: Total amount of money (in Kshs in '000') spent on energy bills by schools in the study area in the previous years (2015 to 2017)

School Name	Type of school	Electricity	Firewood	Charcoal	LPG-gas	Total
1. Ititi	Mixed day and boarding	0	250	0	2.5	**252.5**
2.Kamulalani	Mixed day and boarding	19	203	0	0	**222**
3.Nzoila	Mixed day	0	26	0	6	**32**
4.Yumbuni	Mixed day and boarding	0	48	0	0	**48**
5.St. Lucy Kalimani	Mixed day	14	25	0	0	**39**
6.Mavindini	Mixed day and boarding	0	150	0	0	**150**
7.Yikitaa	Mixed day and boarding	0	36	0	9	**45**
8.Kitenge'i	Mixed day	93.1	25.5	0	36	**154.6**
9.Molemuni girls'	Girls boarding	240	215	0	6	**461**
10Joanna Chase	Boys boarding	920	200	49	93	**1262**
11.Mbeetwani	Mixed day	0	195	0	0	**195**
12.Kithing'iisyo	Mixed day and boarding	258	565	0	22.6	**845.6**
13.Kasue girls'	Girls boarding	925	1010	15.4	35.8	**1986.20**
14.Ngwata	Mixed day and boarding	360	360	0	0	**720**
15.Iiani	Boys day and boarding	182	110	0	0	**292**
16.Kiuani	Mixed day and boarding	66	39	0	10.5	**115.5**
17.Ivingoni	Mixed day and boarding	60	90	9	0	**159**
18.Komboyoo	Mixed day	0	135	0	0	**135**
19.Mwitasyano	Mixed day	0	41.5	0	0	**41.5**
20.Misuuni	Mixed day and boarding	200	188	0	10.8	**398.8**
21.Matulani	Mixed day and boarding	0	108	0	30	**138**
22.Miangeni	Mixed day and boarding	18	54	2	0	**74.9**
23.Silanga	Mixed day	16.6	86	0	0	**102.6**
24.Kyusyani	Mixed day and boarding	0	28.5	10.5	0	**39**
25.Darajani boys	Boys day and boarding	505	564	0	28	**1097**
26.Tsavo West	Mixed day	0	37	0	0	**37**
27.Muthingiini	Boarding boys	152.130	184.90	1.95	17	**355.98**
28.St. Mary's Komboyoo	Girls boarding	243	325	0	0	**568**
29.Kathekani	Mixed day and boarding	450	210	16.2	12.2	**688.40**
30.Canaan	Mixed day	0	0	0	0	**0**
Total		**4721.83**	**5509.40**	**104.05**	**319.40**	**10655.58**

4.2.8 Source of initial capital for installation of energy source(s) in school

According to the respondents (school heads), a significant proportion of the energy sources/technologies were installed using school fees as the initial capital, these include energy saving stoves at 87% and electricity at 47%. The study reports that solar power was installed through government support at 23% and school fees at 6.6% (Table 4.10). Other sources of capital include B.O.M, NGO support and fundraiser as reported by the respondents.

Table 4.10: Source of money for installation of the energy source(s) (N=30)

Energy source/technology	Source of money for installation	Frequency	%
Electricity	B.O.M	1	3
	Government support	7	23
	NGO support	1	3
	School fees	14	47
Solar power	Government support	7	23
	NGO	1	3
	School fees	2	7
LPG-gas	Fundraiser	2	7
	Government support	3	10
	School fees	10	33
Generator	B.O.M	1	3
	Fundraiser	1	3
	School fees	4	13
Batteries	Government support	3	10
	School fees	10	33
Energy saving stove	B.O.M	1	3
	Fundraiser	2	7
	Government support	7	23
	School fees	26	87

4.3 Determinants for choice of the energy source

The study sought to investigate the determinants for choice of energy source(s) used by the schools in the study site as presented in the following sub-sections.

4.3.1 Reasons for choice of energy source in use

Respondents (school heads) were interviewed on the major reason for choosing energy sources in the school. As shown in Table 4.11 below, the highest number (47%) indicated that it was due to high cost of other energy sources, 33% stated that they were aware of environmental conservation, 20% attributed it to lack of alternative energy source for the school, another 20% stated that it was highly suitable, while only 17% of the respondents said it was easily available.

Table 4.11: Reasons for choice of energy source in the study site (N=30)

Reason for choice of energy source	Frequency	Percent (%)
High cost of other energy sources	14	47
Awareness of environmental conservation	10	33
Highly suitable (suitability)	6	20
Lack of alternative energy source	6	20
Easily available (availability)	5	17
Government grant	2	7
Frequent power blackouts (unrealiability)	1	3
Influenced by other schools	1	3
Own interest	1	3

4.3.2 Reasons for choice/preference of each type of energy source in use

Further analysis was deemened necessary to reveal the the main reason for choice and/or preference of the commonly used energy source for cooking in the schools. The results indicated that firewood was mostly prefered at 100% as it was percieved to be highly suitable for cooking compared to other sources of energy, charcoal at 23% was less expensive, schools prefer use of LPG-gas because it's more efficient and affordable energy as represented by 10%. kerosene at 7% was prefered as an alternative energy and faster to use, and elecctricity at 3% was prefered since it's easy and faster in use (Table 4.12).

Table 4.12: Main reason/preference for using the energy source in school (N=30)

Main reason for use	Energy source	Frequency	Percent
Highly suitable for cooking compared to other energy sources	Firewood	30	100
Less expensive	Charcoal	7	23
Efficient and affordable	LPG gas	3	10
Alternative and faster to use	Kerosene	2	7
Easy and faster to use	Electricity	1	3

4.3.3 Forms of modern energy technologies acquired by Public Secondary Schools in Mtito Andei Division

Further, the study sought to find out whether the selected schools had employed the use of modern energy efficient technologies which would help in conserving the environment and in reduction of energy bills by limiting energy usage in particular since this was the focus of the study.

For the purposes of this study, the term adoption of energy technology refers to the choice of the school head to accept, acquire and use a new energy innovation/technology that is available in the market in order to reduce energy bills and to save the environment. To arrive at this, the study relied on the questionnaire item on choice of energy source that asked the respondents of the study to indicate the energy technology adopted in school. The analysis was done for solar power, energy saving stoves and energy saving bulbs.

The findings of the study indicated that 87% of the respondents (school heads) had energy saving stoves followed by solar power at 27%, and energy saving bulbs at 10% (Table 4.13).

Table 4.13: Forms of modern energy technology used by schools in Mtito Andei Division (N=30)

Energy technology	Frequency	Percent
Energy saving stoves	26	87
Solar power	8	27
Energy saving bulbs	3	10

It was observed that some schools had installed solar power and energy saving stoves as shown in the Plates 4.2 and 4.3 below.

Plate 4.2: Solar panels fitted on rooftop of Yikitaa secondary school building

Plate 4.3: A school cook preparing a meal using energy saving stove

4.3.4 Reasons for acquisition of modern energy technologies in schools

An analysis for the reasons for the acquisition of modern energy technologie was conducted to establish why the school heads deemed it necessary to acquire these technlogies. The results of the analysis were as shown in Table 4.14 below.

As shown in Table 4.14, the highest number (47%) indicated that it was due to high cost of other energy sources, 33% stated that they were aware of environmental conservation, 20% attributed it to fuel problem for the school, another 20% stated that it was highly suitable for cooking, while only 17% of the school heads said it was easily available.

Table 4.14: Reasons for acquisition of modern energy technology in Public secondary schools in the study area (N=30)

		Type of modern energy technology					
		Energy saving stoves		Energy saving bulbs		Solar power	
		Count	Row N %	Count	Row N %	Count	Row N %
Reason for acquisition of Modern energy technologies in schools	Awareness of environmental conservation	10	33	0	0	0	0
	High cost of other energy sources	14	47	0	0	0	0
	Easily available	0	0	5	17	0	0
	Frequent power blackouts	0	0	0	0	1	3
	Fuel problem	6	20	0	0	0	0
	Government grant	0	0	2	7	0	0
	Highly suitable for cooking	6	20	0	0	0	0
	Influenced by other schools	0	0	0	0	1	3
	Own interest	0	0	0	0	1	3

4.3.5 Determinants for adoption of modern energy technologies in schools

Further, the study sought to establish the relationship between selected variables such as; age of school head, school type (i.e. boarding or day school), education level of school head and length of service to the reasons for adoption of modern energy technologies in the study area. The choice for these variables of study was informed by their perceived relevance to the study topic as they directly touch on the respondents (school heads) of the study, they also formed the basis of influence to the choice of energy technology adopted by a school and the Pearson correlation test revealed a positive significant relationship between the tested variables.

The factors determining the choice of energy technology such as age of school head, school type (i.e. boarding or day), education level of school head and length of service were subjected to Pearson correlation analysis against reasons for adoption to ascertain the influence of these factors on the choice of the energy technology.

The Pearson correlation analysis was done on solar power, energy saving stoves and energy saving bulbs (energy technologies) against the reasons for their choice. The outcome of the analysis is shown below.

4.3.5.1 Age of school head and adoption of energy technology

To determine the influence of age (chronological age of school head) on adoption of modern energy technology it was hypothesized that the factor (age) did not influence energy adoption (HO: There is no statistically significant correlation between reasons for adoption of modern energy technology and age of the school head). Since p-value is $0.000<0.05$, we fail to accept HO and conclude that there is statistically significant correlations between reasons for adoption of modern energy technology and age of the school head. Implying that there was a strong positive Pearson correlation relationship between the two variables at 0.825 (Table 4.15).

It emerged that the older heads of schools were more adoptive to modern energy technologies than the younger heads of schools in the study area. It was further revealed by the respondents (school heads) of the study that younger heads of schools were mostly allocated the recently founded schools where financial resources are limited hence the hinderance to adoption of modern energy technologies. Older heads of schools were allocated the well-established schools where financial resources can cater for the adoption of modern energy technologies.

Table 4.15: Correlations between reason for adoption of energy technology and the age of the school heads in the study area (N=30)

		Reason for adoption	Age of school heads[years]
Reason for adoption of modern energy technology	Pearson Correlation	1	.825**
	Sig. (2-tailed)		.000
	N	46	30
Age of school heads[years]	Pearson Correlation	.825**	1
	Sig. (2-tailed)	.000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

4.3.5.2 School type and adoption of energy technology

The term school type in this study referred to whether a secondary school was boys boarding, girls' boarding, day school or mixed day and boarding.

It was hypothesized that the factor (school type) did not influence modern energy technology adoption (HO: There is no statistically significant correlation between school type and reasons for adoption of modern energy technology by the school head). After subjecting the factor (school type) to Pearson correlation test, it emerged that it strongly influences adoption of energy technology. Since p-value was 0.000<0.05, we fail to accept HO and conclude that there is statistically significant correlations between school type and reasons for adoption of modern energy technology by the school head. Implying that there is a strong positive Pearson correlation relationship between the two variables at 0.716 (Table 4.16).

It can be drawn from this analysis that boarding schools were more adoptive to energy technologies compared to day schools due to the number of times cooking was done in such schools as well as the high need to provide lighting to the students during the night hence the need to cut down energy costs.

Table 4.16: Correlations between school type and reason for adoption of energy technology in the study area (N=30)

		School type	Reason for adoption
School type	Pearson Correlation	1	.716**
	Sig. (2-tailed)		.000
	N	30	30
Reason for adoption	Pearson Correlation	.716**	1
	Sig. (2-tailed)	.000	
	N	30	46

**. Correlation is significant at the 0.01 level (2-tailed).

4.3.5.3 School head education level and adoption of energy technology

To determine the relationship of education level to the reasons for adoption of modern energy technology, it was hypothesized that the factor (school head education level) does not influence energy adoption (HO: There is no statistically significant association between reasons for adoption of energy technology and level of education of the school head). It emerged from the Pearson correlation test that p-value was 0.000<0.05, hence we fail to accept HO and conclude that there is statistically significant association between reasons for adoption of modern energy technology and level of education of the school head. Implying that there is a strong positive Pearson correlation relationship between the two variables at 0.808 (Table 4.17). This analysis implied that, the more educated a school head was, the more likely one embraced modern energy technologies compared to the less educated.

Table 4.17: Correlations between reason for adoption of energy technology and level of education of the school heads

		Reason for adoption	Level of education
Reason for adoption	Pearson Correlation	1	.808**
	Sig. (2-tailed)		.000
	N	46	30
Level of education	Pearson Correlation	.808**	1
	Sig. (2-tailed)	.000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

4.3.5.4 Length of service of school head and adoption of energy source

For the purpose of this study, the term length of service refers to the number of years a school head had served in a school.

To determine the relationship between length of service of the school head to the reasons for adoption of energy technology, it was hypothesized that the factor (length of service) does not influence energy adoption (HO: There is no statistically significant association between reasons for adoption of energy technology and length of service of the school head). Since p-value =0.001<0.05, we fail to accept HO and conclude that there is statistically significant association between reasons for adoption of energy technology and length of service of the school head. Implying that there is a strong positive Pearson correlation relationship between the two variables at 0.778 (Table 4.18).

The analysis implies that school heads who have served for more than five years in their respective work stations are more adoptive to energy technology than their counterparts who have served for less than five years.

Table 4.18: Correlations between reason for adoption of energy technology and years of service of the school head

		Reason for adoption	Years of service [as head]
Reason for adoption	Pearson Correlation	1	.778**
	Sig. (2-tailed)		.001
	N	46	30
Years of service [as head]	Pearson Correlation	.778**	1
	Sig. (2-tailed)	.001	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

4.4 Environmental and socio-economic impacts of energy sources

The study sought to assess environmental and socioeconomic impacts of main energy sources used in public secondary schools in the study area. The focus was to find out the costs/challenges and benefits related to a particular energy source to facilitate comparison between the energy sources, and to provide the respondents of the study with useful information regarding the energy costs and benefits, in order to make an informed decision on the choice of the energy source/technology to adopt in school.

4.4.1 Energy sources challenges and benefits comparison and analysis

During the survey, respondents were interviewed on the challenges and benefits encountered with regard to the energy source used. From the responses, 90% of the respondents indicated that scarcity of firewood was the main challenge in using it, 23% indicated that scarcity of charcoal was a major challenge faced in schools, 17% said the most experienced challenge associated with LPG-gas was that it was expensive to maintain, 53% reported that the main challenge faced when using electricity was frequent power blackout, 27% reported that solar power was being affected by weather especially during the cold months of the year. Other challenges pointed out by the respondents were that some energy sources were not environmentally friendly, and had high installation cost and that there was lack of technical skills to maintain the technologies and lack of funds to pay energy bills among others (Table 4.19).

Table 4.19: Challenges in utilizing different energy sources in schools in the study area (N=30)

Energy source	Challenge	Frequency	Percent
Electricity	Affected by weather	2	7
	Expensive to maintain	3	10
	High installation cost	13	43
	Power blackouts	16	53
Solar power	Affected by weather	5	17
	Expensive to maintain	2	7
	High installation cost	8	27
	Lack of Technical skills	2	7
	Theft	1	3
Firewood	Affected by weather	6	20
	Lack of funds	3	10
	Expensive to maintain energy saving stove	1	3
	Not suitable	4	13
	Scarcity of firewood	27	90
Charcoal	Affected by weather	1	3
	Not suitable	1	3
	Scarcity of charcoal	7	23
LPG gas	Expensive to maintain	5	17
	High installation cost	1	3
	Not readily available	1	3
	Not suitable	2	7
Generator	Expensive to maintain	3	10
	High installation cost	3	10
	Lack of technical skills	1	3
	Power blackouts	1	3

From the survey, it was also established that a number of benefits existed with regard to energy source used. 27% of the respondents interviewed acknowledged that solar power conserves the environment, 23% asserted that its clean energy while another 23% indicated that the running cost of solar power was low after installation. Electricity was reported to be clean energy at 47% and that it conserves the environment at 33%. The findings of the study showed that the main benefit associated with firewood was low running cost after installation of energy saving stoves which was reported at 30%. Other benefits mentioned by the respondents include: easy and fast in use and alternative energy source among others (Table 4.20).

Table 4.20: Benefits of utilizing different energy sources in schools in the study area (N=30)

Energy source	Benefit	Frequency	Percent
Electricity	Clean	14	47
	Conserves environment	10	33
	Easy and fast in use	19	63
	Low running cost after installation	11	37
Solar power	Clean	7	23
	Conserves environment	8	27
	Easy and fast in use	2	7
	Low running cost after installation	7	23
Generator	Easy and fast in use	2	7
	Low running cost after installation	1	3
	Saves time	2	7
	Alternative source	1	3
Firewood	Clean	2	7
	Easy and fast in use	12	40
	Low running cost after installation of energy saving stove	9	30
	Saves time	6	20
	Readily available	3	10
Charcoal	Easy and fast in use	4	13
	Low running cost	4	13
	Readily available	1	3
LPG gas	Clean	4	13
	Conserves environment	3	10
	Easy and fast in use	15	50
	Low running cost after installation	4	13

4.5 Cost benefit analysis

This section sought to conduct the cost benefit analysis of solar power and firewood by using the benefit cost ratio (BCR) and net present value (NPV) approaches to facilitate comparison between the two energy types. These two energy types were selected for analysis since they relatively have positive or negative impact on the environment and data on the costs and benefits was available. The essence of BCR and NPV was to express the relation of discounted benefits to discounted costs as a measure of the extent by which a project's benefits either exceed or fall short of their associated cost. A complete benefit-cost analysis was needed to provide schools with economic and environmental justification of the energy type to be used in the institution.

This benefit cost analysis compares the discounted costs and benefits of solar power and firewood projects for the same period of time (2017). The costs and benefits of the components involved in the analysis are summarised (Table 4.21). The valuation of the costs and benefits was based on the market price method (MPR) using the prevailing market price in Mtito Andei town in the study site as well as the financial data from the schools.

The study established that Kshs. 8,148,000 was the total present value of costs of firewood and Kshs. 1,584,000 was the cumulative present value of benefits of firewood at a discount rate of 13%. The study noted that Kshs. 5,511,000 was the total present value of costs of solar power and Kshs. 6,606,700 was the total present value of benefits of solar power at a discount rate of 13% (Table 4.21).

Table 4.21: Cost benefit analysis summarised

Energy type	Element	Monetary value (Kshs)
Firewood	**Present value of costs at 13% discount rate**	
	(i) Cost of installation of energy saving stoves	4,296,000
	(ii) Cost of buying firewood from vendors	3,168,000
	(iii) Cost of loss of tree cover	Not valued
	(iv) Annual cost of repairing energy saving stoves	384,000
	(v) Cost of repainting sooty kitchen per year	300,000
	(vi) Cost of health bills for the school cook	Not valued
	Total costs	**8,148,000**
	Present value of benefits at 13% discount rate	
	(i) Reduced expenditure on buying firewood by 50% after installation of energy saving stoves	1,584,000
	(ii) Reduced indoor air pollution	Not valued
	Total benefits	**1,584,000**
Solar power	**Present value of costs at 13% discount rate**	
	(i) Cost of installation of solar panels	5,160,000
	(ii) Cost of maintenance	351,000
	Total cost	**5,511,000**
	Present value of benefits at 13% discount rate	
	(i) Avoided cost of buying firewood	3,168,000
	(ii) Avoided loss of tree cover	Not valued
	(iii) Avoided cost of repainting the kitchen walls	300,000
	(iv) Avoided cost of repairing energy saving stoves	384,000
	(v) Savings from electricity bill	2,754,700
	Total benefits	**6,606,700**

Further analysis aimed at comparison of benefit-cost ratios for solar power and firewood was conducted. The first benefit-cost analysis compares solar power benefits with the costs. As noted in Table 4.22 below, solar power had a BCR of 1.19. This ratio revealed that the solar benefits exceeded the costs when compared at a discount rate of 13%. The second benefit-cost analysis compared firewood benefits with costs. As noted in Table 4.22, firewood had a BCR of 0.19. This ratio revealed that the costs of firewood exceeded the benefits when compared at a discount rate of 13%.

Table 4.22: Comparison of Benefit-Cost Ratios for solar power and firewood

	Energy type	
	Solar power	Firewood
Benefit-cost comparison	$\frac{6,606,700}{5,511,000}$	$\frac{1,584,000}{8,148,000}$
Benefit-cost Ratio	1.19	0.19

The study found the NPV for solar power to be positive at 1,095,700 which signifies a better investment, while the NPV for firewood was negative.

4.6 Summary of chapter key findings

This chapter dealt with results of the study. The following is a summary of the key findings of this study in line with the objectives of the study.

The study found that schools use eight different types of energy sources namely firewood, charcoal, electricity, LPG-gas, kerosene, generator, batteries and solar power. Overall, it was found that firewood was the most common source of energy and was used for cooking in all schools in the study area. It was noted that schools use large quantities of firewood for cooking.

The study found that the main reasons (determinants) for the choice of the energy sources used in schools in the study area included: high cost of other energy sources, awareness of environmental conservation, lack of alternative energy source, suitability of the energy source and availability.

In analysing the reasons for choice of modern energy technology in school against the selected school head factors using the Pearson correlation analysis, it emerged that age of school head, school type, education level of school head and length of service of school head strongly correlated with the reasons for the choice of modern energy technology. Implying that these selected school head factors strongly influenced the acquisition of modern energy technology in schools.

Benefits with regard to energy sources include: environmental conservation, clean energy, easy and fast in use especially for solar power and electricity. Challenges in utilisation of energy source include: scarcity of firewood and charcoal, frequent power blackouts for electricity, high installation cost and lack of technical skills especially for solar power.

A comparison of the benefit-cost analysis of solar power and firewood established that solar power had a BCR of 1.19 while firewood had a BCR of 0.19. The NPV for solar power was positive while that of firewood was negative in this study.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Introduction

This chapter discusses the research findings in line with the objectives of the study. It covers each of the objectives at a time and the corresponding research question.

5.2 Energy Sources in Schools

5.2.1: Types of energy sources used in schools in the study area

From the study it was established that schools use eight different sources of energy. Overall, it was noted that firewood was the most popular energy source in all (30) public secondary schools in the study area. This collaborate with the study by Moronge (2015) whose findings show that firewood, electricity, diesel, liquefied petroleum gas (LPG) kerosene and charcoal were the main sources of energy for cooking, lighting and laboratories in boarding schools in Thika Sub-County. This shows a high level of dependency on the trees for firewood. It is therefore, evident from the study that schools put a considerable pressure on the indigenous forests due to the continuous demand for firewood.

GoK (2013) and Ifejika *et al.,* (2007) studies in Makueni County, found that firewood use was at 84.8% and charcoal at 11.1%. These findings are in agreement with this study which reports that all (30) public secondary schools in the study site use firewood. This clearly shows that there is heavy dependency on natural forests to provide firewood for schools since it was observed that only one school (Joanna Chase) in the study area used plantation forests where they could get firewood from.

If this study is anything to go by, then the chances of totally replacing firewood with an alternative fuel will remain a mirage.

5.2.2: Type of use of the energy source(s) in schools

From the study, it is clearly indicated that five different types of energy sources are used for cooking. Firewood is shown to be the most preferred energy source for cooking.

Overall, it was evident from the findings of the study that cooking was the primary use of firewood in all schools in the study area. This is in line with the study findings that on average a school consumes over 10 tonnes of firewood per term. This can also be attributed to the relative high cost of other energy sources. This finding is in consonance with a study by RETAP (2007) which indicated that a typically boarding secondary school in Kenya consumed high amount of firewood in the range of 200-300 tonnes annually.

From the findings of this study, practically nothing is being done by schools to provide other alternatives to cooking other than firewood and charcoal. This is likely to compromise further the tree cover in the study area.

5.2.3: Duration of use of the energy source(s) in the school in the study site

The study established that firewood had been used for more than 13 years on average. For the other types of energy sources, the study found that they have been in use for less than 5 years on average. This revelation affirms the fact that firewood was the most popular source of energy in schools in the study area. The findings imply that most schools in the study area have been using firewood for cooking since their establishment.

The study noted that no school in the study area was using biogas as a source of energy. This can be attributed to the prohibitive high cost of construction that hinders adoption of the technology (Mwakaje, 2012). Biogas plants have a high construction cost (Bond and Templeton 2011) which can be prohibitive for many institutions. Results on the size of land owned by schools indicate that land is enough for establishment of biogas plant. According to Gathu (2014) a quarter an acre is adequate for a biogas plant as such the land size is sufficient for biogas plant construction. This means that land size in this case is not a limiting factor in biogas adoption in schools. Most likely, the hindering factor for biogas adoption is lack of manure supply because public schools in the study area are not keeping livestock e.g. dairy cows. These results collaborate to those of Wanjugu (2012) who found that land was not a hindrance to biogas technology adoption.

5.2.4 Quantity of firewood, charcoal, electricity and LPG-gas used

The findings of the study showed that on average one school consumed 10 tonnes of firewood per term. It was reported by the respondents that most of the firewood was sourced from the natural forests within the study area. Kituyi (2000) revealed that 90 percent of schools in Kenya relied entirely on fuelwood for daily cooking and heating. This phenomenon compounds the fact that schools put pressure on the existing tree cover in the study area. This further reveal that schools in the study area are not promoting environmental management practices to control destruction of forest resources. As at present, Public secondary schools in the study area continue to cut down endangered indigenous species for firewood in the neighbourhood areas. This situation is anticipated to get worse and the few remaining indigenous trees in the area are likely to become extinct.

Based on the interview with the respondents, the quantity of firewood utilized in school was found to be influenced by a number of factors which included: type of diet, moisture content of the wood fuel, cooking device used, number of times cooking was done in a day and the student population among others.

The statistics shown in Table 4.6 clearly point out that over time, the few remaining indigenous forests are likely to be extinct as the demand for firewood in schools increases due to increased student enrolment and as more schools are being established in the study area.

It is anticipated that reforestation programs would be significant for Kenya to attain the 10 percent forest cover as required by the constitution. Report by KFS (2014) shows that Kenya has hit the 7 percent forest cover; this implies that the country is more likely to reach the 10 percent forest cover. This will only be realised if appropriate measures are put in place to restrain deforestation in various regions of this country.

Forests play a vital role to the environment. Besides being a natural habitat of wide variety of animals and plants, trees also take the carbon dioxide that we exhale and give us the oxygen we need for respiration and as well in controlling soil erosion. Moreover, studies have shown that the loss of tree cover leads to soil erosion. Loss of tree cover has serious impact on the hydrological cycle especially on pollution of water bodies due to siltation which diminishes the quality and quantity of waters available for use (Mugo & Gathui. 2010: IEA, 2006).

5.2.5 Total cost of energy bills in schools for the previous years (2015-2017)

This item of the interview schedule sought to find out the total amount of money (in Kshs) schools spent on energy bills. This was important in understanding the budget allocation towards school energy. It was also useful in determining the cost-effective energy source in the study area.

Results of the analysis revealed that firewood was the less cost-effective energy source followed by electricity, LPG-gas and charcoal. These were the main energy sources reported to be in use for the same period. The high cost of firewood can be attributed to the fact that all (30) schools were using firewood and that of electricity was due to the fact that a significant proportion were using electricity.

5.2.6 Source of initial capital for installation of energy sources/technologies

Results from the survey established that school fees were the chief source of capital for installation of electricity, LPG-gas, generator and energy saving stoves in the study area (Table 4.10). It was evident from the findings of the study that solar power had been installed through government support at 23 percent. This clearly reveals the high cost involved in installation of powerful solar panels that a poor school in the study area cannot afford. In addition, it implies that lack of initial capital was the main hinderance to the installation of such energy technologies in the study area.

5.3 Determinants for choice of the energy source(s)

5.3.1 Reasons for choice of energy source/Technologies in schools

General overview of the respondents' choice for energy sources indicated that schools had reasons for choosing the energy source to be used. For example, the results of the study showed that it was due to high cost of other energy sources, awareness of environmental conservation, lack of alternative energy source for the school, suitability for cooking and availability. It is clear from the findings that the cost of energy source was a prime factor for consideration for its adoption.

The findings revealed that respondents were informed on environmental conservation as far as energy utilization in school was concerned. This revelation is backed up by the fact that the respondents indicated that they were aware of environmental conservation. Further probing revealed that the environmental degradation issues they were aware of included; deforestation, loss of tree cover leading to desertification, global warming, environmental pollution, loss of biodiversity, land degradation among others.

The issue of firewood scarcity in the study area came out clearly during the study, with only 10% of the respondents indicating that it was readily available. This implied that the rest of the respondents agreed with the fact that firewood was a scarce resource in the study area. This reflects that there was massive destruction of trees to provide logs for charcoal burning and firewood to meet the ever-increasing demand in the study area hence bringing in scarcity. As a result, schools will be forced to shift to alternative cost effective and environmentally friendly energy sources in the near future.

Further, the study sought to establish the relationship between selected school head variables to the adoption of modern energy technologies in the study area. The variables under study were; age of school head, school type, education level of school head and length of service. It emerged from the analysis that all these factors strongly correlated with the reasons for adoption of energy technology in schools.

From the analysis, the older school heads are more adoptive than the younger school heads. This may be attributed to the fact that by the time one becomes a school head, one ought to have served for a considerable time in the service. This puts one in a better position to understand the energy needs for a school and as such one finds the relevancy to look for better and less costly alternative energy sources. In addition, their age and long experience in school management was deemed important to capture energy information spanning a period of more than 10 years.

Different school types have varied energy needs. For instance, comparatively the number of times cooking is done in a boarding school differs from that of a day school. Similarly, a boarding school requires more lighting facilities than a day school. This implies that the energy costs for boarding schools is relatively higher compared with day schools. Therefore, this calls for adoption of technologies to save on energy.

Education level of the school head influences adoption of energy technology. This can be attributed to the fact that at higher levels of education school heads are more exposed to environmental issues through various informative forums, conferences and relevant sources. The findings of this study concur with Karanja (1999) who established that without education, respondents may not perceive the importance of technological devices to reduce over-dependence on scarce energy resources. Highly educated people have higher energy saving behaviour and opt for more efficient energy sources (Njenga *et al*., 2009).

From the study, the influence of length of service of the school head to adoption of energy technology can be explained by the fact that after serving in a station for a considerable period of time and through the experiences accrued, school heads are better positioned to understand the energy challenges existing in the school. This motivates them to find alternative ways to overcome the existing energy challenges hence the adoption of modern energy technologies.

5.4 Environmental and socioeconomic impacts of energy sources

5.4.1 Energy sources, benefits and challenges comparison analysis

It is evident from the study that every energy source comes with its own set of benefits and challenges. Information from the study findings reveal that different challenges exist and are encountered by the respondents with regard to the energy source(s) used in the school. The study indicated that scarcity of charcoal was the main challenge for those using it, scarcity of firewood was a major challenge faced in schools. These observations show a potential for massive loss of tree cover in the study area due to existing demand. Respondents reported that the challenge associated with LPG-gas was that its expensive to maintain, they also reported that the predominant challenge faced when using electricity was frequent power blackout, and complained of solar power being affected by weather especially during the cold months of the year. Other challenges pointed out by the respondents include; energy source not environmentally friendly, having high installation cost, lack of technical skills and lack of funds to pay energy bills among others.

The survey also established that a number of benefits existed with regard to energy source used. The respondents acknowledged that solar power conserves the environment, its clean energy and the running cost of solar power was low after installation. Electricity was reported to be clean energy and that it conserves the environment.

Based on the interview with the respondents, it was established that the main benefit associated with firewood was the low running cost after installation of energy saving stoves. Other benefits mentioned by the respondents include; easy and fast in use and alternative energy source among others.

During the survey, school cooks were asked about the health implications of cooking using firewood. Through this, the researcher was able to determine the level of health risk posed to the cooks due to frequent exposure to indoor air pollution. This information was important since the preceding findings of the study indicate that firewood was mostly used for cooking. Additionally, the study established that the average consumption of firewood was at 10 tonnes per school per term. Responses from the cooks revealed that they suffer a great deal of health-related risks including chest pain, coughing, sneezing and running nose, eye problems, persistent headache and heat related challenges due to the prevalent use of firewood. It was noted that these problems were frequently mentioned in cases where cooks worked in poorly ventilated kitchens without or with defective energy saving stoves. It was observed that in some cases freshly cut firewood was used. Respondents reported that the use of freshly cut firewood was not healthier than the use of dry fuel wood as it was too smoky thus presenting more health-related risks. This finding clearly demonstrates that the associated health risks for using a particular fuel is a crucial factor for consideration in adoption and utilization of energy source.

Interestingly, when asked why they preferred using firewood despite being a health risk, majority indicated that firewood produced high heat suitable for cooking tough diet such as githeri (mixture of maize and beans) which is most desired in the study area. In addition, it was affirmed that they are used to cooking with firewood. This concurs with findings by Tee *et al*., (2009) who established that the preference by the population to use fuel wood was due to familiarity with working with the fuels, cost and affordability.

Adopting cleaner cooking methods will, in addition to improving health and reducing illness-related expenditures, improve family livelihoods, stimulate development and contribute to environmental sustainability (WHO, 2003). Environmental issues of school energy are important in that they include, indoor air pollution which is a leading cause of deaths in Sub-Saharan Africa, and emission of greenhouse gases.

5.5 Cost benefit analysis

A comparison of the benefit-cost analyses for solar power and firewood revealed that solar power had a BCR greater than one at 1.19 while firewood had a BCR less than one at 0.19. This revelation clearly points out that solar benefits exceeded the cost as measured in this study. On the other hand, the results indicated that the BCR of firewood was less than one, implying that the costs exceeded the benefits as measured in this study. The NPV for solar power was positive which signified a better investment for schools.

Several opportunities exist in the solar energy technology for rural and education institutions applications including solar photovoltaic water pumping systems, solar chick brooding, solar refrigeration, solar drying, solar water purification, solar air and water heating among others (Iloeje, 2004). However, as alluded by Karekezi and Kithyoma (2003), the renewable energy resource potential in Africa has not been fully exploited, mainly due to the limited policy interest and investment levels. In addition, technical and financial barriers have contributed to the low levels of uptake of (RETs) in the region.

Modern energy sources such as solar power offers various benefits such as saving fuel wood, protecting forests, reducing expenditure on fuels, reducing the time spent on cooking and improving hygienic conditions (Gregory, 2010). Moreover, Murphy (2001) contend that by adopting the modern energy sources women and children in particular will have more time for education. On the other hand, the continued use of biomass especially firewood is said to be one of the main causes of loss of biodiversity and wide scale deforestation in Kenya (Mugo and Gathui. 2010).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter deals with the conclusions and recommendations of the study. The first part deals with the conclusions drawn from the study findings while the second section addresses the recommendations made from the study.

6.2 Conclusions

6.2.1 Energy Sources

The first objective of this study was to document the types of energy sources used in public secondary schools in Mtito Andei Division. From the study, it is apparent that schools use eight different energy sources including firewood, charcoal, electricity, solar power, LPG-gas, generator and batteries. It was found that firewood was the most popular energy source in the study area. The study established that firewood had been in use for more than 13 years on average in all schools in the study site while the other energy sources were found to have been in use for less than 5 years on average.

The study concludes that over-reliance on firewood for cooking in schools has the potential to strain the already diminishing supply from natural forests and further exacerbate desertification, loss of biodiversity and land degradation in the study area.

6.2.2 Determinants for Choice of Energy Source

The second objective of this study was to investigate the determinants for choice of energy source. It was evident from the study that various reasons existed for the choice of energy sources. The study noted that the most prevalent reasons for choice of energy sources/technologies included; high cost of other energy sources, awareness of environmental conservation, lack of alternative energy source for the school and availability of the energy source. Other factors that influenced the choice for modern energy technology include; the age of school head, school type, education level of school head and length of service of school head. The study revealed that the forms of modern energy technologies adopted by the respondents included energy saving stoves, solar power and energy saving bulbs.

The study concludes that these factors played a key role in determining the choice of energy source/technology adopted in the study area.

6.2.3 Environmental and Socioeconomic Impacts of Energy Sources

The third objective of this study was to assess environmental and socioeconomic impacts of major energy sources. The study concludes that economic factors play a major role in determining whether a school acquires a new technology or not. This is because most of the new technologies have a cost implication and only those with money are able to adopt the technologies faster. It can be predicted from the study, that as long as schools in the study area lack capital to install modern energy technologies such as solar power, it should be expected that there will be high deforestation due to persistent use of firewood in schools. The study established that there was scarcity of firewood in the study area which translates to reduced tree cover. Therefore, it can be expected that respondents will be forced to cross over to neighboring Divisions to search for firewood in order to meet their demand, and this is likely to compromise further the tree cover in the county.

The importance of investing in cost effective renewable and environmentally friendly energy sources in overall energy utilization in schools is emphasized in this study. Energy is a key component in school, and schools requires access to reliable, abundant and affordable energy that is environmental efficient. The study found that challenges and benefits existed with regard to the energy source used in school. The study concludes that the school management should consider all the costs/challenges and benefits of the energy source/technology before acquisition. This would foster adoption of environmental efficient energy sources.

It can be concluded that the efforts put in place by schools to reduce firewood consumption are very minimal and cumulatively a lot has to be done to ensure that the natural ecology is not adversely affected by deforestation.

6.2.4 Cost Benefit Analysis

The fourth objective of this study was to conduct a cost benefit analysis of major energy sources used in schools in the study site. Since the solar power BCR was greater than 1 and the NPV was positive, the study concludes that, solar power appears to be a better investment to schools than the use of firewood which was more common in the study area. The results of the financial analysis suggest that, if a school in the study area switches from firewood to solar power alternative, its annual energy net benefit would increase. Benefit cost analysis has been used to compare the benefits and costs of the project.

6.3 Recommendations

The following recommendations were made from the study.

1. Schools should embrace adoption of the energy saving stoves to reduce firewood consumption as such can help to lessen the pressure on the indigenous forest ecosystems in the area.

2. All costs and benefits should be considered before acquisition of energy source/technology, to lessen the prohibitive energy costs and maximize on the benefits and to foster environmental conservation.
3. Advocating, at BOM level, for the establishment of school-based or neighborhood woodlots consisting of fast-growing tree varieties (such as eucalyptus) to address the school wood fuel demands instead of escalating the destruction and loss of indigenous forest ecosystems in the area.
4. Advocating, at BOM level, for the greater use of solar power (for lighting) in line with SDG-7, also in order to cut down on the huge energy bills.
5. The national and county governments should come up with policies such as subsidies, grants and tax relief that will make modern energy technologies affordable and accessible to schools for adoption.
6. Since schools have a greater potential of generating large quantities of human waste due to increased student enrolment, bio-digesters should be introduced to generate biogas energy. This will help to reduce overdependence on biomass and help to save the environment.
7. Advocating, at BOM level, for the compliance by schools of the OSHA (2007) with regard to the provision of essential PPEs for the kitchen staff (e.g. nose masks) in line with occupational health best practises.
8. In depth studies should be done to explore more elaborate evaluation methods/techniques for non-market environmental goods and services, since the study found that some environment costs and benefit were difficult to quantify in monetary terms.

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APPENDICES

Appendix 1: Sample filled school head questionnaire

SCHOOL HEAD QUESTIONNAIRE

COST BENEFIT ANALYSIS OF DIFFERENT ENERGY SOURCES USED IN PUBLIC SECONDARY SCHOOLS IN MTITO ANDEI DIVISION, MAKUENI COUNTY

Informed Consent Form

A research is being undertaken to identify sources of energy, determinants of energy choice and to determine energy costs/benefits by **Arnold Thoya Kazungu,** a Masters student from South Eastern Kenya University, Mtito-Andei Campus. You have been identified as a key stakeholder in this research and therefore a respondent to a few questions. The information you provide will be treated with confidentiality and will be used for academic purposes only.

MODULE A: SCHOOL IDENTIFIFATION AND BACKGROUND DATA

A1. Date of interview	**Day:** 03	**Month:** 10	**Year:** 2017
A2. Name, age and gender of school principal	**Name(optional)** STEPHEN M.	**Age:** 50	**Gender:** MALE
A3. Name of respondent (if not the Principal)	**Name(optional)** N/A	**Designation:** N/A	**Gender:** N/A
A4. Name of school	DARAJANI BOYS HIGH SCHOOL		
A5. Year of establishment	1965		
A6. Type of school	[1] Boarding Girls [5]Mixed boarding [2] Boarding Boys (ticked) / DAY [3] Mixed day and boarding [4] Mixed day		
A7. Name of Zone	[1] Mtito Andei [2] Kambu (ticked) [3] Ngwata [4] Nthongoni		
A8. Current student population in school	Boys: 389	Girls: N/A	

A9. How many teachers do you currently have in your school? 18

A10.How many Non-teaching staff do you currently have in your school? 14

A11.What is the school land size (in acres) 71 ACRES

A12. What is the Principal's highest level of education?

[1] Diploma [2] Degree [3] Masters ✓ [4] PhD

A13.How long have you served as a Principal in this school? 5 YRS

MODULE B: ENERGY SOURCES:

B1. Which source(s) of energy do you use in your school (tick the ones you use)?

[1] Electricity ✓ [6] Kerosene

[2] (LPG) gas ✓ [7] Biogas

[3] Firewood ✓ [8] Generator (petrol or diesel) ✓

[4] Charcoal [9] Batteries ✓

[5] Solar power [10] Others(specify)__________

B2. For how long have you been using this source of energy?

	Energy source	Duration of use (in years)
1	Electricity	8
2	LPG-gas	20
3	Firewood	52.
4	Charcoal	—
5	Solar power	—
6	Kerosene	—
7	Biogas	—
8	Generator (petrol or diesel)	20
9	Batteries	52
10	Others(specify)	—
11		

B3. How do you use this source of energy?

(1) Lighting (2) Cooking (3) Teaching and learning/ICT (4) Security (5) Performing laboratory practical (6) Heating (7) Charging (8) Cooling/refrigeration (9) Others (specify)

	Energy source	**Type of use** (indicate the use(s) using the numbers in B3 above)
1	Electricity	Lighting (1)
2	LPG-gas	Performing Laboratory Practicals (5)
3	Firewood	Cooking (2)
4	Charcoal	—
5	Solar power	—
6	Kerosene	—
7	Biogas	—
8	Generator (petrol or diesel)	Lighting (1)
9	Batteries	Lighting (1), 5
10	Others(specify)	Pumping water
11		

B4. What challenges do you face with regard to the energy source(s) used in the school?

[1] Lack of funds to pay energy bills

[2] Scarcity of firewood and charcoal

[3] Lack of technical skills

[4] Not suitable

[5] High installation cost

[6] Not readily available

[7] Affected by weather conditions

[8] Frequent power blackouts

[9] Expensive to maintain

[10] Not durable

[11] Theft

[12] Others(specify)__________

Energy source		Challenges faced in using the energy source (indicate the challenge using the numbers in B4 above)
1	Electricity	~~Lack~~ 1
2	LPG-gas	None.
3	Firewood	2
4	Charcoal	NA
5	Solar power	NA
6	Kerosene	NA
7	Biogas	NA
8	Generator (petrol or diesel)	9
9	Batteries	N/A
10	Others(specify)	NA
11		
12		

MODULE C: DETERMINANTS FOR CHOICE OF ENERGY SOURCE

C1. Has your school adopted any form of low cost energy source?

[1] Yes [✓] [2] No [ ]

If yes, please name the energy source(s) Firewood

NA

C2. What was the major reason for adopting this source of energy?

[1] High cost of other energy sources/cheap

[2] Easily available

[3] Highly effective

[4] Own interest

[5] Fuel problem for the school

[6] Awareness of environmental issues

[7] Influenced by neighbouring schools

[8] Others (specify)

C3. What was the main reason for adopting low cost energy source(s) mentioned in C1 above?

Low cost energy source		Reason for adopting the energy source (indicate the reason(s) using the numbers in C2 above)
1	Energy saving jikos	1
2	Energy saving bulbs	N/A
3	Solar power	N/A
4	Biogas	N/A
5		
6		
7		
8		
9		

MODULE D: ENERGY COSTS/EXPENDITURE AND BENEFITS

D1. In your own opinion, do you think energy is a major budget item in your school?

[1] Yes [✓]   [2] No [ ]

D2. Give an estimate of the quantity of firewood, charcoal and LPG-gas spent in school per term.

[1] Firewood [32] tonnes [2] Charcoal [N/A] sacks
[3] LPG-gas [1] cylinders [4] Electricity [3,800] units

D4. Where do you get the money from to pay for the energy bills?

[1] School fees   [4] NGOs
[2] Government support/capitation   [5] B.O.M
[3] Sponsors/donors   [6] Others (specify)

Energy source		Source of funds (indicate the source(s) of money using the numbers in D4 above)
1	Electricity	1 & 2.
2	Firewood	1 & 2.
3	Charcoal	n/a
4	LPG-gas	1 & 2
5	Generator (petrol or diesel)	1 & 2
6	Kerosene	n/a
7	Biogas	
8	Generator (petrol or diesel)	1 & 2
9	Batteries	1 & 2
10	Others(specify)	n/a
11		

D5. How much money (in Ksh) have you spent in the previous years on energy bills?

Type of energy	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	Total
1.Electricity	160,000	180,000	165,000	150,000	135,000	129,000	12,500	120,000	—	—	—	—	—	1,164,000
2.Firewood	180,000	192000	192000	192,000	191,000	191,000	190,000	185,000	185,900	184,000	160,000	155,000	140,000	2,337,900
3.Charcoal	—	NIL	—	—	—	—	—	—	—	—	—	—	—	
4.LPG-gas	8,000	10,000	10,000	10,000	1000	9000	9000	8800	8,800	8000	8000	7,000	6,000	103,600
5.Petrol/diesel	—	—	—	—	—	—	—	—	—	—	—	—	—	
6.Kerosene	—	NIL	—	—	—	—	—	—	—	—	—	—	—	
7.Batteries	3,000	3,600	3,600	3,600	3400	3,000	3,000	3,000	3000	2,800	2800	2,800	2,600	40,200
8.Others(specify) Generator	88,000	100,000	100,000	105,000	105,000	98,000	98,000	95,000	94,000	94,000	93,000	90,000	90,000	1,240,000

D6. What was the initial cost of installation and maintenance (in Ksh) for the energy type?

Type of energy	Total cost of installation	Maintenance cost per year
Solar power	N/A	N/A
Electricity		
LPG-gas		
Generator	300,000=	120,000=
Batteries	NIL	NIL
Biogas	NIL	NIL
Energy saving jikos	20~~2,000~~1,000	30,000
Others(specify)	—	—

D7. What was the source of the initial capital for the source(s) of energy?

[1] School fees
[2] Government support
[3] Fundraiser
[4] Bank loan
[5] NGO support
[6] B.O.M
[7] Cost sharing with Government
[8] Others(specify)

Source of energy		Source of capital (indicate the source(s) of capital using the numbers in D7 above)
1	Electricity	1
2	Solar power	N/A
3	LPG-gas	1
4	Generator	1
5	Biogas	N/A
6	Batteries	1
7	Firewood	1
8	Charcoal	N/A
7	Others(specify)	—

D8. What benefits do you get when using the mentioned source(s) of energy in the table below?

[1] Low running cost after installation

[2] Clean/no smoke

[3] Easy and fast in use

[4] Saving time

[5] Conserves the environment

[6] Others (specify)

Energy source		Benefits (indicate the benefit(s) using the numbers in D8 above)
1	Electricity	1, 2, 3, ~~4~~, 5
2	Solar power	N/A
3	Biogas	N/A
4	Generator	4
5	Firewood	
6	Charcoal	~~1, 2, 3, 5~~
7	Batteries	1, 2, 3, 5
8	LPG-gas	1, 2, 3, 5
9	Others(specify)	
10		
11		
12		

MODULE E: GENERAL

E1. In your opinion, do you think energy efficiency is related to student performance?

To some extend, yes.

E2. Do you think schools can save much by being energy smart? Yes.

E3. What are your future plans with regard to energy needs in the school?

Installing green energy especially solar power

E4. What do you suggest should be done to promote energy efficiency in schools within Mtito Andei Division?

Putting off energy when not in use.

E5. Do you know any promoters of modern cost-effective energy sources in this division?

[1] Yes [2] No

If yes, name the promoter(s) N/A

E6. Are you aware of the existing environment protection laws in Kenya?

[1] Yes [ ] [2]No [✓]

If yes, which ones?

E7. Is there anything else you would like to say about energy?

Energy is the backbone of Industrialization. The government should extend energy transmission esp. electricity to rural areas

THANK YOU

Appendix 2: Sample filled observation schedule

APPENDIX 2: OBSERVATION SCHEDULE

Sheet No. 1 **School name** KATHEKANI SEC

Division Mtito-Andei **Zone** Mtito-Andei

Type of energy source present: (e.g. firewood, charcoal, LPG-gas, biogas, electricity, solar power)	[1] Firewood [4] Electricity [2] Charcoal [5] Biogas [3] LPG-gas [6] Solar power
Type of kitchen visible, energy efficient devices seen.	-Improved kitchen. -One energy saving stove seen. -Less spacious kitchen -poorly ventilated kitchen.
Method of firewood/charcoal storage	[1] In the open [2] Under a shade [3] In the store
Type of wood used	[1] Hard wood [2] Soft wood [3] Freshly cut/with high moisture content [4] Dry
Other relevant information. -Energy saving stove is in bad state due to poor maintenance leading to poor conservation of energy hence more firewood is used. -More smoke is generated within the kitchen due to presence of poorly fitted chimneys hence posing a health risk to the cooks. -kitchen is sooty and gets hot during cooking.	

Appendix 3: Sample filled interview schedule for school cook

INTERVIEW SCHEDULE FOR SCHOOL COOK

SCHOOL NAME: MUTHINGIINI SEC

1.For how long have you been working in this school? 10 years

2.What is your highest level of education? Class 8

3.which is the most prevalent source of energy for cooking in this school?

Firewood.

4.Do you use modern energy efficient sources for cooking in this school?

Yes. We use Energy Saving stoves.

5.What are the benefits of using the mentioned source(s) of energy?

- Firewood burns fast / easy to start fire when dry.
- Firewood produces hot fire / food is well cooked.
- Less firewood is consumed when using the energy saving stove.
- Fire can be adjusted by increasing or reducing the amount of firewood.
- Easy to prepare large quantity of food; about 90kg at once.

6.What challenges/problems do you encounter when using the mentioned source(s) of energy?

- Scarcity of firewood
- Some tree species produces irritating smoke causing, sneezing, coughing, eye problems and severe headache
- Sometimes the kitchen gets very hot hence posing high risk of suffering from heat related problems.
- Difficult to start fire especially when firewood has high moisture content.
- Splitting of firewood logs increases labour on the cooks.

Appendix 4: Antiplagiarism Report

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