DEMAND AND SUPPLY DYNAMICS OF WOOD ENERGY IN SCHOOLS IN TRANS-NZOIA COUNTY, KENYA

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N50/24869/2011

A Thesis Submitted in Partial Fulfillment of the Requirements for the Award of a Degree in Masters in Environmental Science in the School of Environmental Studies of Kenyatta University

MARCH 2016
DECLARATION

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

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DEDICATION

This work is dedicated to my parents Mary and Charles, and my brothers Joe, Alex, Oscar and Edwin.
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This thesis could never have been achieved were it not for the guidance and support of the following persons:

First to the Almighty God for the gift of life, good health and the wisdom that enabled me carry out the study successfully.

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## ACRONYMS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>KNBS</td>
<td>Kenya National Bureau of Statistics</td>
</tr>
<tr>
<td>NEMA</td>
<td>National Environment and Management Authority</td>
</tr>
<tr>
<td>GoK</td>
<td>Government of Kenya</td>
</tr>
<tr>
<td>RETAP</td>
<td>Renewable Energy Technology Assistant Program</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nation Development Programme</td>
</tr>
<tr>
<td>KFS</td>
<td>Kenya Forest Services</td>
</tr>
<tr>
<td>BTUs</td>
<td>British Thermal Units</td>
</tr>
<tr>
<td>SMEs</td>
<td>Small and Medium Enterprises</td>
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<tr>
<td>LPG</td>
<td>Liquid Petroleum Gas</td>
</tr>
<tr>
<td>GHGs</td>
<td>Green House Gases</td>
</tr>
<tr>
<td>NGOs</td>
<td>Non-Governmental Organizations</td>
</tr>
<tr>
<td>GACC</td>
<td>Global Alliance for Clean Cookstoves</td>
</tr>
<tr>
<td>MoE</td>
<td>Ministry of Energy</td>
</tr>
<tr>
<td>MoEd</td>
<td>Ministry of Education</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nation Environment Programme</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel for Climate Change</td>
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<td>FAO</td>
<td>Food and Agriculture Organization</td>
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ABSTRACT

In Kenya, the transition from National to County level energy planning has experienced various challenges, one of them being the lack of reliable baseline data upon which such plans can be based. This is evident because the last comprehensive biomass study done by the Ministry of Energy was in 2002, which is too old for effective and efficient biomass energy planning. This study provides this data by analyzing the demand for and supply of fuelwood in secondary schools within the County of Trans-Nzoia. Furthermore, the study highlighted the important role that the wider adoption of energy-efficient institutional stoves would play in the sustainable management and conservation of forestry resources in the County. A questionnaire survey with 65 randomly selected schools, actual weighing of the daily fuelwood consumption estimates and general site observations were carried out. From the study, the mean daily fuelwood consumption was 159.2±91.75 kg per school and 0.524 kg per student. As it will be discussed later in the thesis, these consumption rates varied when considering the type of cookstove used and the number of students being cooked for. *Eucalyptus species*, *Grevelea robusta*, *Acacia species* and *Croton species* were the commonly harvested tree species for fuelwood, with farmlands and forests being the main areas of harvest. In these schools, parents supplied majority of the fuelwood as fees in kind. Regarding improved cookstoves adoption rates, 68% of the sampled schools had adopted the stoves. However, only 26% of these schools used them exclusively, while 42% combined them with either a traditional or semi-improved cookstove or both. On the benefits of using an improved cookstove, a typical school saved about 0.34 kg per student daily and 91.8 kg per student annually. This fuelwood saving was equivalent to a financial saving of Ksh.138 per student annually. The results present a potential baseline data that could be used for energy planning and forest resource management purposes in Trans-Nzoia County.
CHAPTER ONE: INTRODUCTION

1.1 Background of the study

In Kenya, biomass energy accounts for approximately 68% of the total national energy consumption. Other sources of energy are petroleum 22%; Electricity 9% and others 1% (wind and solar) (Ministry of Energy [MoE], 2002). The major consumers of biomass energy are households, communal institutions (like schools, Prisons, hospitals) and Small and Medium Enterprises (SMEs) like restaurants.

The demand for biomass energy has an annual growth of about 2.7% while the sustainable supply is growing at a slower rate of 0.6% (Helio International, 2009). This demand especially for firewood and charcoal exerts a lot of pressure on our available forest resources (UNEP, 2007; KIPPRRA, 2010) considering that Kenya has a low forest cover of about 5.9% which is below the minimum 10% of forest cover (KFS, 2012a). In addition, Kenya has a wood deficit of about 57.2% (Mugo and Gathui, 2010). The wood demand and consequently forest resource pressure is elevated due to inter alia the increasing population, inefficient combustion of wood devices being used (Kituyi, 2000; Waithera, 2008; RETAP, 2008) and lack of access to alternative cleaner energy sources. The high poverty level estimates ranging between 32% and 42% of Kenya’s total population living below a dollar per day (World Bank, 2013) is also an issue. This enhances the continued use of wood fuel because people cannot afford the conventional energy sources (NEMA, 2011).

Most official Kenya’s biomass energy studies done in the past have focused on household energy demand and supply dynamics, giving little attention to other large-scale biomass energy consumer groups (MoE, 2002; O’keefe et al., 1984). These groups include education institutions, notably schools- both primary and secondary- and also colleges. A few studies (Kituyi and Kirubi, 2003; Kituyi et al., 2001; Ngeywo, 2008; RETAP, 2007, 2010) have focused on biomass energy in these types of institutions in Kenya. This interest has been motivated by the fact that over 40,000 education institutions rely entirely on fuelwood for cooking and water heating purposes (RETAP, 2010). Most of these institutions rely on traditional cookstoves that are inefficient (5-10%), leading not only to high fuelwood
demand—hence pressure on the dwindling forest resources but also to emissions of products of incomplete combustion. This is happening at a time when energy-efficient biomass stoves specially built for institutions are widely available and distributed by many vendors in both rural and urban areas in Kenya. In fact, the uptake of these improved institutional stoves on the Kenyan market has been growing steadily since mid-90’s. However, the potential market is still huge since only 59% of potential educational institutions have adopted such energy efficient stoves (RETAP, 2010).

It is unlikely that the pressure by schools on forest resources for energy will reduce anytime soon. This is because of the current yearly increase in number of schools (in 2007-32600 schools while in 2011-35900 schools) (KNBS, 2013a) due to population growth in Kenya. Urgent policy and technical interventions are therefore necessary. As the country has moved from national to County-level planning and management of local resources, there is need for reliable data for planning. The data is important for sustainable use of the available energy resources, especially forest resources, within each County. High quality data and a clearer understanding of the fuelwood demand and supply dynamics is therefore critical for the energy sector. This is particularly relevant for the educational institutions that consume biomass energy in bulk.

1.2 Problem statement
Among the functions already devolved from National to County level planning and management include energy, natural resources and the environment. Furthermore, the County integrated development plan was to be finalized by mid-2014 to allow sector development plans to be cascaded. County energy development plans required a comprehensive analysis of baseline supply-demand dynamics for all classes of consumers of all available energy resources within the County. The available data on supply-demand dynamics particularly of fuelwood in schools was old and focused on national aggregates from surveys involving a small sample of schools. Such data was too coarse to inform County level planning. Data and knowledge on fuelwood consumption trends and patterns by schools is required for
efficient access, utilization, planning and management of wood resources at the County level.

The primary focus of this research was to fill this important knowledge gap on harvesting and utilization of biomass energy by local schools in Trans-Nzoia. This is important for developing an effective and long-term plan for wood energy at the County-level. The study also examined the adoption rates of improved cook stoves by a critical sector like schools and quantified the corresponding environmental and financial savings. This would be relevant for biomass policy at both County and national levels.

1.3 Research questions
1. What are the current fuelwood consumption rate and patterns by different types of schools in Trans Nzoia County? and how were the consumption rates influenced by enrolment and stove type?
2. Where are the most commonly-used tree species harvested from and who supplies them to schools?
3. What is the current adoption rate of energy-efficient institutional cookstoves in Trans Nzoia County, and what are the environmental and economic benefits of their adoption in schools?

1.4 Objectives of the study
The main objective of this study was to characterize the fuelwood demand and supply dynamics in schools sector in Trans-Nzoia County of Kenya. Specifically, the study intended:
1. To determine the fuelwood consumption rates and patterns by schools.
2. To determine fuelwood where and who supplies the commonly-harvested tree species for fuelwood.
3. To quantify the adoption rate and the potential benefits of using improved institutional cookstoves in schools.
1.5 Hypothesis
1. The enrolment and type of cookstoves used in the schools significantly influences the consumption rates and patterns of fuelwood.
2. The preference of a particular tree species to be supplied for fuelwood in secondary schools is determined by the species’ burning characteristics
3. The wider adoption of energy-efficient biomass stoves by schools will lead to significant economic and environmental benefits

1.6 Justification
In the energy sector, the shift of responsibilities from National to County (local) authorities due to devolution has come with many challenges especially during the early stages of the shift. The lack of adequate and reliable sector data is a challenge in achieving a devolved sustainable energy plan. This was from the discussion with an official in the Ministry of Energy. These data was lacking especially for resources that are often called traditional sources like biomass. Similarly, no budget was allocated for baseline studies to support energy sector development planning in Trans-Nzoia County. This study provides a comprehensive and detailed analysis of fuelwood demand and supply dynamics in secondary schools in Trans-Nzoia County. The data is mandatory if sustainability in energy sector is to be achieved in Trans-Nzoia County. In addition, the research design and methodologies used in this study can easily be adopted by the 46 other counties so as to ensure sustainability of wood energy planning country-wide. Moreover, schools need empirical evidence of social, environmental and economic benefits related to adoption of energy-efficient institutional cookstoves in order to trigger interest and accelerate their large-scale adoption, which this study highlights.
1.7 Conceptual framework for the demand and supply dynamics of fuelwood

The above conceptual framework shows the relationship between the type of stove being used to cook and the number of students being cooked for, and the fuelwood consumption rate and pattern. The fuelwood consumption rate and pattern in turn determines the fuelwood demand, which finally determines the amount of fuelwood supplied in a school. Knowledge on these variables are important for sustainability in fuelwood energy planning for schools in the County as they provide an understanding of both the demand and supply dynamics.

In order to understand the fuelwood consumption rates and pattern, which in turn determines demand and supply, various factors reported to influence the consumption were considered. First, is number of students being cooked for in a school. It is expected that there is a general decrease in the daily fuelwood consumed per student, as the number of students being cooked for increases (RETAP, 2008, 2010; Kituyi, 2000; Ngeywo, 2008). This is attributed to the economies of scale.

Secondly, the type of stove being used for influenced fuelwood consumption. There is a progressive reduction in the amount of fuelwood consumed as one moves up the energy conversion technology ladder i.e. a switch from a traditional stove to an energy-efficient biomass stove. This is due to the varying efficiency levels where the energy-efficient stove-users consume less wood because of the high efficiency as
compared to the traditional stove users who consume more because of their low efficiency (Barnes et al., 1994; Kituyi, 2000).

Another factor considered in this study was the tree species often preferred hence commonly harvested for fuelwood. The choice of a tree species tends to vary with the location of a school in a particular agro-ecological zone and the fuelwood supplied to schools is often obtained from varied forest resources available (Kituyi, 2000).

1.8 Scope and limitation of the study
This study focused on secondary schools in Trans-Nzoia Country since they all had a feeding programme irrespective of whether they were boarding or day schools. This was unlike primary schools where the day schools had a feeding programme for pupils in class eight while the rest had to go home for lunch.

Furthermore, within the secondary schools, the two main parameters considered in the study that influence fuelwood consumption rate were the number of students being fed and the type of cookstoves being used during the cooking process, in the sampled schools. Other factors reported to influence consumption but were not considered in this study included; the type and number of meals being cooked, the type of school i.e. day or boarding, private or public, scarcity or abundance of fuelwood, proximity to fuelwood source, cost of fuelwood, and inter-fuel substitution (Kirubi et al., 2000; Kituyi and Kirubi, 2003; Kituyi et al., 2002; Marufu et al., 1997).

On limitation, the study did not measure the moisture content in the fuelwood. This had an implication on the estimated weight of the fuelwood and also on the estimated greenhouse gases emission calculation.
CHAPTER TWO: LITERATURE REVIEW

2.1 Fuelwood consumption in Kenyan schools

Educational institutions are one of the sub-sets of service-sector that depend almost entirely on fuelwood. Several studies have been carried out to understand the fuelwood consumption rates and patterns by schools. An example was a study by Kituyi in 2000 that revealed 90 percent of 20,000 schools relied entirely on fuelwood for daily cooking and heating purposes. In 2007, another study by RETAP reported that 75% of the 4215 secondary schools in Kenya, which were boarding type, depended entirely on fuelwood for their daily cooking and water heating purposes. The study reported a consumption estimate of 200- 300 tons of fuelwood annually for a typical boarding school. An exception was a handful of mainly high cost schools that used electricity and LPG. This scenario changed in 2010 according to a study by RETAP that revealed some prominent schools had switched back to using fuelwood. These prominent schools included Kenya High School in Nairobi, which had switched from using steam boilers that relied on oil to fuelwood. Similarly, Lenana High School also switched from LPG to fuelwood. This was done so as to cut on the cost because, after the liberalization of the energy sector in 1994, the prices of petroleum products, including LPG that had been raising sharply.

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 (RETAP, 2007) hence increased deforestation rates. The unsustainable way in which schools are consuming the fuelwood is of major concern. This is because many of the schools in Kenya still use traditional cookstoves and highly inefficient open fire cooking systems, generating a high demand for wood and promoting deforestation (Waithera, 2008; RETAP, 2010).

The limited studies done on overall daily consumption rates of fuelwood in schools ranged between 99.9-178.2Kg. 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 (RETAP, 2007, 2008; Kituyi, 2000; Kituyi and Kirubi, 2003; Ngeywo, 2008).
Unlike in households’ fuelwood supply that is collected mainly as fallen branches from farmlands and trust lands, most of the wood consumed by schools was unsustainably harvested, considering it was harvested in bulk. This exerts tremendous pressure on the existing forest resources including indigenous forests, private and public plantation and farmland trees. Note that Kenya has a low forest cover of 5.9%, which is less than the 10% minimum expected and a wood demand deficit of 57.2% (Mugo and Gathui, 2010).

2.2 Demand dynamics

2.2.1 Factor influencing fuelwood consumption rates in schools

Studies, (Kituyi, 2000; Kituyi and Kirubi, 2003; Ngeywo, 2008; RETAP, 2008, 2010; Marufu et al., 1997) done in Kenya on biomass energy have improved our understanding of factors that affect biomass consumption rates and patterns, fuelwood included. These factors include; stove type, fuel composition and tree species, diet types, demographic factors, cost and distance to the fuelwood source, fuel availability and inter-fuel substitution pattern. This is through their impact on combustion characteristics - the duration of firing sessions, frequency of these sessions and the burning efficiencies (Kituyi, 2000). The study considered stove type, tree species and the number of students being cooked for, specifically in secondary schools.

2.2.1.1 Type of stove

Fuelwood consumption rate was reported to reduce progressively as one moved up the technology ladder from traditional cook stoves to improved, state-of-the art cookstoves (RETAP, 2010) which was attributed to their varying efficiencies. According to RETAP (2008), the increase in rate of deforestation and the unsustainable way in which fuelwood was being consumed in most of the learning institutions was attributed to the use of inefficient stoves as well as open fires. The two types of cookstoves used for fuelwood combustion in schools were traditional stoves and improved stoves and are described below.
Traditional stove basically consists of three stones or bricks positioned in a triangular form around a fire. The cooking pot was usually placed on the stones, while the fuelwood was added from between the stones. These stoves were often built by anyone and did not require any initial training to use them (Karekezi and Ranja, 1997). Traditional stoves are considered versatile because they can burn all kinds of biomass, could be adjusted to fit any size of pot and amount of heat controlled by adjusting the fuelwood supply. Apart from cooking, these stoves could be used for space heating. In addition to the heating purpose, the smoke emitted kept insects away and the area where the stove was fired was an important gathering place (Kuhnhenn, 2003).

Traditional cookstove have several disadvantages. First, they have a low efficiency of between 5-10%, which results in a high demand for fuelwood and long cooking times (Barnes et al., 1993, 1994). Secondly, they emit significant amounts of products of incomplete combustion that pose health threats to the users. Finally, the openness of the stoves could result in accidents, leading to injuries or damages to properties (George, 2002). Many Kenyan schools use these traditional cookstoves for their daily cooking and water heating purposes and their daily mean fuelwood consumption rates is reported to be between 1.4 and 1.7 Kg per student (Kituyi, 2000; Ngeywo, 2008).

Improved stove is a cookstove designed to significantly improve energy efficiency, reduce indoor air pollution and increase ease of use (World Bank, 2012). The cookstove has a large cylindrical stainless steel casing with a brick lining and an inner metal casing. The cooking pot fits neatly into the center of each stove hence completely surrounded by the stove wall. The cookstoves have a higher efficiency of between 35-45%, which is due to their inbuilt characteristics. First, their firebox is small and enclosed hence optimizing combustion. Secondly, the stove is connected to a chimney that helps draw air through the fire and takes all the smoke out of the kitchen. Thirdly, the flue gases transfer heat to the pot as they are forced up the narrow gap between the pot and the stove wall. Fourthly, the stove has a lining made from insulating bricks to minimize heat loss. Lastly, it has a door that allows the cook to control the airflow. These cookstoves have reported a daily mean fuelwood
consumption rate of between 0.35- 0.55 Kg per student (Kituyi, 2000; Ngeywo, 2008) in schools where they are being used.

2.2.1.2 Tree species

The characteristics and quality of wood as a fuel vary widely and often depended on the type of wood and the pre-treatment process (Vos, 2005). Tree species with dense wood provide the best firewood releasing more British Thermal Units (BTUs) per volume of wood than species with less dense or lighter-weight wood. A study done by Kituyi (2000), showed that depending on the Agro-Ecological Zone (AEZ) a school was located, the type of tree species commonly-used for fuelwood varied. According to the study, learning institutions located in the savanna and highland zones used eucalypts tree mainly *E. saligna* for their fuelwood but if this was unavailable, piles of cypress, pine and jacaranda logs were used. Coastal and arid and semi-arid zones used neem and acacia trees most respectively.

Another study done by RETAP (2010), showed that exotic tree species like grevillea, eucalyptus, pine and cypress were the main sources of fuelwood in the sampled learning institutions. This was because they are widely grown and readily available as they grow faster than the indigenous trees such as croton and acacia that were also found in use in some learning institutions. The study also revealed that most schools used eucalyptus more than pine and cypress because of its high calorific value.

Unlike households who showed a wide range of species, schools’ choices were limited to mainly a single species per school in the different zones studied (Kituyi, 2000). The study showed that a tender to supply fuelwood was awarded to vendors who could deliver the preferred species even if the source was across a different Agro-Ecological Zone. In addition, the source of mainly *eucalyptus species* was from farmlands while cypress, pine and jacaranda were from forests and saw mills.

From the above studies, it was evident that tree species is an important parameter to consider when studying factors that influence fuelwood consumption and the species
type varied from one school to another hence the need to determine the type of tree species commonly-used for fuelwood by schools within Trans-Nzoia County.

2.2.1.3 Enrolment

Enrolment, which is the number of students registered in a school hence the number of students being cooked for daily is an important parameter when studying fuelwood consumption patterns. A study by RETAP (2010) showed that schools with high number of students had a low fuelwood consumption rate per student compared to those with fewer students. This was attributed to economies of scale where the more the number of individuals being cooked for, the lower the consumption rate per individual/student. In addition, another study by Kituyi (2000) made an observation that collective cooking to serve many people (commercial enterprises and academic institution) demands less fuelwood consumption per student, than cooking for smaller groups like in households.

The results from a study by Ngeywo (2008) proved that, as the number of students enrolled in an educational institution increased, the fuelwood consumption rate per student decreased. For example, in Alliance Girls, where the enrolment 773 students and a daily consumption of 279.5 kg reported a daily consumption rate of 0.26 Kg per student. On the other hand, in Buruburu Girls, the daily consumption rate was reported to be 0.50kg per student, yet it had an enrolment of 550 students and consumed 274Kg of fuelwood daily. Another school, Nembu Girls with an enrolment of 380 students and a daily consumption rate of 218Kg had a daily consumption of 0.57Kg per student. From this result, it is evident that schools with low enrolment consume fuelwood per student, than those with higher enrolment. This was attributed to savings associated with collective use of resource thus conforming to the findings of Marufu et al., (1997) and Kituyi et al., (2001).

Since the amount of fuelwood consumed per student in schools was important in determining the consumption patterns, there was need to determine the minimum number of students in a school above which fuelwood consumption rate did not show a significant change. This would help reduce wastage of fuelwood by schools
with few students especially for the new upcoming learning institutions in the County.

2.3 Supply chain for fuelwood to schools

2.3.1 Sources

Kituyi (2000) classified forestry resources in Kenya into three, namely; indigenous forests, plantation forests and farmland trees. According to the classification, the indigenous forest resources include closed broad-leaved forests, open broad-leaved forests, the coniferous forests, bamboo forests and mangrove forests. Plantation forests are those trees planted in a large area of land for commercial wood production. The choice of species in such plantations depended on the end-use objectives, the effectiveness of regeneration and relative susceptibility or resistance to insects, diseases and damage by wild herbivores. The farmland trees were those planted in farms and settlements.

Fuelwood used in households, academic institutions and Small and Medium Enterprises was often sourced from available forestry resources within their surroundings (Kituyi, 2000). Depending on the agro ecological zone in which a school is located, fuelwood could be sourced from natural forests, public and private tree plantation and farmlands (Kituyi, 2000). The choice of a source was also influenced by the most preferred tree-species for fuelwood. For example, the source of mainly *Eucalyptus species* was from farmlands and private plantations while cypress, pine and indigenous tree species were reforested areas of natural forests (Kirubi et al., 2000). In some schools where they were very strict on the type of tree species they would like, fuelwood suppliers would source the preferred tree species outside their Agro Ecological zone (Kituyi et al., 2001).

2.3.2 Suppliers

Fuelwood is an important source of livelihood despite it being associated with environmental degradation and other negative social effects like respiratory diseases. This was for the people involved in the production, transportation and supply of fuelwood for commercial purposes (KFS, 2009). In Kenya, there has been
large-scale production of *Eucalyptus species* in both private and public plantations solely for commercial purposes like for biomass, saw mills, construction materials and power poles (MoE, 2002).

### 2.3.3 Policy/Regulations and strategies for wood energy

Kenya has formulated and effected several policies to address the various energy issues with an aim of boosting its development challenges. These include the National Energy Policy, which advocates for adequate, quality, cost effective and affordable supply of energy to meet consumer needs while protecting and conserving the environment (MoE, 2004). The policy further promotes the planting of fast maturing trees for fuelwood production and scaling up of efficient fuelwood technologies. The Environment Management and Co-ordination Act (EMCA) in 1999 Section 49 also promotes the conservation and tree planting for renewable sources of fuel wood energy. Such policies would go along way to ensure sustainability in the energy sector if fully reinforced.

### 2.4 The adoption rate and role of improved institutional cookstoves in the sustainable consumption of fuelwood

#### 2.4.1 Adoption rates of improved cookstoves in Kenyan schools

The commercialization of energy-efficient biomass cookstoves in Kenya began in the 1980s when it became clear among development agencies that the prevailing technologies for fuelwood and charcoal were extremely wasteful. This was believed to result in significant deforestation around the country among other factors (UNDP, 2013). Several NGOs and private sector companies have been in the forefront in promoting the adoption of energy-efficient cookstoves in Kenya. This was done through financial support schemes, training, research and development of technology and quality improvement and control. The success of improved cookstove adoption is evident, as Kenya has experienced a near-exponential uptake. This is from less than 5 % in the mid-1980s to 13% in 1997 (Kituyi, 2000) and 59% in 2010 (RETAP, 2010) by education institutions.
However, compared to the number of schools and the fact that Kenya was one of the two countries; Sri-lanka, who first commercialized the energy-efficient cookstoves in the 1980s, the rate of their uptake is very slow (RETAP, 2007, 2010; Waithera, 2008). Various barriers had been identified that hindered faster adoption rates. They include; lack of finances, low awareness of financing schemes, lack of permanent kitchens and few students which does not justify investing in improved cookstoves. In addition, the lengthy procurement decision making process in schools and availability of few manufacturers who can make quality cookstoves due to the seasonal purchasing trends have been reported to contribute to the current slow adoption rate (RETAP, 2007, 2010). Moreover, public schools that cannot afford a one-pay-off for the cookstoves whose price range USD 1200-2500 depending on the size, contributed too to the slow adoption rates.

2.4.2 Benefits associated with adopting of improved cookstoves

Even with the slow adoption rate, the energy-efficient cookstoves have reported major public and private benefits (social, environmental or economic) associated with them.

2.4.2.1 Social benefits of adopting improved cookstoves

Burning of solid fuels including fuelwood has been associated with smoke and other air pollutants produced due to the incomplete combustion of fuelwood (Jetter & Kariher, 2009; Ellegård, 1997). These pollutants have health impacts to the fuelwood users including chronic respiratory diseases, difficulty in breathing and stinging eyes. In addition, WHO identifies smoke from burning of solid fuel among the top 10 health risk (WHO, 2002; Jetter & Kariher, 2009). Improved cookstoves could reduce the amount of indoor air pollution in the kitchen due to its high efficiency by minimizing the production of products of incomplete combustion. Moreover, they have chimneys, which vent the smoke away from the cooking area. This decreases the exposure to harmful pollutants hence improved health for the wood users (World Bank, 2005; Zuk et al., 2005; GACC, 2010).
2.4.2.2 Environmental benefits of improved cookstoves

The use of fuelwood comes with high environmental costs, these include forest loss and climate change impacts. In areas where the wood is scarce yet the demand is high, there is considerable pressure on the forestry resources (IEA, 2002). Moreover, the use of traditional cookstoves demands more fuelwood hence leads to massive forest loss. This is due to their low combustion efficiency (Waithera, 2008). The climate change impact of fuelwood combustion is due to inefficient combustion conditions. This results into production of products of incomplete combustion like CH$_4$ and N$_2$O. These products are important GHGs with high global warming potentials (IPCC, 2001). Energy efficient improved cookstoves have high efficiency hence they consume less fuelwood (Ngeywo, 2008; Kituyi et al., 2001; RETAP, 2008). This implies that less forest would be destroyed hence improved cookstoves play an important role in curbing deforestation. Moreover, improved cookstoves efficiently combust fuelwood hence minimizes the production of products of incomplete combustion like Methane, Nitrous Oxide and carbon particulates. These products would have otherwise had some climate change impacts (World Bank, 2012).

2.4.2.3 Economic benefits of improved cookstoves

The use of improved cookstoves is associated with high efficiency hence reduced demand for fuelwood (Ngeywo, 2008). This is very important for learning institutions since they consume the fuelwood in bulk. The amount of fuelwood saved due to the switch to using an improved cookstove will lead to monetary benefits (Ngeywo, 2008; RETAP, 2008; Kituyi et al., 2001). The significant fuelwood saving means that the amount of money allocated for fuelwood purchase would reduce, hence the extra money could be used for other development projects in the school. A study by UNDP in 2013 promoted the use of improved cookstoves through highlighting the significant monetary savings that would be accrued by the schools due to reduced expenditure on fuelwood purchase.
2.5 Literature gaps

Over the years, biomass resource mapping and planning have been constrained by inadequate and unreliable data at both national and local level. This is evident because the last comprehensive biomass study in Kenya was done by the Ministry of Energy was in 2002. This is almost a decade years ago, yet biomass planning requires quality and reliable data for its effective and efficient planning. Furthermore, the same study did not include learning institutions in the biomass energy mapping exercise, yet these institutions are among the bulk users of fuelwood.

However, one of the roles of the devolution to County government is planning for energy resources within the county. The role of energy planning had encountered challenges among them being lacks baseline data upon which their energy planning activity could be based. There is need to effectively engage schools in County energy resource planning because they are among the bulk users of wood for energy. This could be achieved by having a clear understanding of the demand dynamics (influence of enrolment, stove type, the cost and commonly-used tree species) and the supply dynamics (commonly-harvested tree species for wood energy, areas where the wood is harvested from and fuelwood suppliers) of wood energy. This study provides a detailed wood resource base analysis for sampled secondary schools in Trans-Nzoia County. The information if used would ensure sustainability in the biomass energy sector at the County level.
CHAPTER THREE: MATERIALS AND METHODS

3.1 Study site

The study was carried out between July 2013 and February 2014 in Trans-Nzoia County, which is one of the fourteen (14) counties in the Rift Valley. It comprised of three districts namely; Trans-Nzoia West, Trans-Nzoia East and Kwanza. The County borders Uganda to the West, Bungoma and Kakamega Counties to the South, West Pokot County to the East and Elgeyo Marakwet and Uasin Gishu Counties to the south. The County lies approximately between latitudes of 0° 52’ and 1° 18’ North of the equator and longitudes 34° 38’ and 35° 23’ east of the great meridian. Trans-Nzoia County covers an area of 2,495.6 km² this represents 0.42% of the Rift Valley Province (District Development Plan, 2012).

Trans-Nzoia County was chosen owing to first, the County has eight gazetted forest areas e.g. Sikhendu, Saboti, Sosio, Kitale, Kimothon, Kipyogot, Suam and Kapolet and public and private forest plantations (KFS, 2012b; DDP, 2012). Secondly, the researcher was conversant with the geography of the study area, which was important during the study.

Figure 3.1: Map of Trans-Nzoia County
(Source: KFS, 2012b; DDP, 2012).
3.2 Site stratification and sampling design

The study site was stratified through a combination of cluster and simple random sampling techniques. The three former districts: Trans-Nzoia West, Trans-Nzoia East and Kwanza Districts were the clusters. The cluster sampling technique was important for this particular study in determining whether the proximity of the selected schools to a forest resource especially the indigenous and private/public plantation forest resources, influenced their choice of fuelwood source. In addition, cluster sampling is appropriate when doing institutional surveys (Ahmed, 2009; Nachmias & Nachmias, 1996; Saifuddin, 2009). Within each cluster, the sampling units were randomly selected using simple random sampling technique. There are two ways of drawing a sample, with and without replacement. *With replacement* means that once an individual is selected to be in a sample, that individual is placed back in the population to possibly be sampled again. *Without replacement* means that once an individual is sampled, that individual is not placed back in the population for re-sampling (Kothari, 2004; Frerichs, 2008). The latter was used during the sampling process within the three clusters.

Trans-Nzoia County had 460 primary schools, 174 secondary schools and 32 tertiary colleges of which, only secondary schools were considered for the study (MoEd, 2013). It was observed that all the secondary schools in the region whether of day or boarding type cooked for all their students. This was not the case for primary schools where only boarding schools cooked for all their students while the day school cooked for only class eight students in particular those who are able to pay the feeding fee.

Using the formula shown below adopted from Kothari (2004), a sample size of 62 was calculated then changed to 65 secondary schools.

\[ n = \frac{z^2 \cdot p \cdot q \cdot N}{e^2 (N - 1) + z^2 \cdot p \cdot q} \]
Where:
- n - Desired sample size
- Z - Standard normal variant at 1-\(\alpha\) confidence level (\(\alpha=0.05\))
- p - Proportion of the population with the trait of interest (p=0.5)
- q - (1-p)=0.5
- N - Population size (N=174)
- e - Margin of error (e=10%)

\[
n = \frac{1.96^2 \times 0.5 \times 0.5 \times 174}{0.1^2 (174-1) + (1.96^2 \times 0.5 \times 0.5)}
\]

Simple random sampling was done by obtaining a list of all the secondary schools for each cluster, with each school being assigned a number ranging 1-55, 1-79 and 1-40 for Trans-Nzoia East, Trans-Nzoia West and Kwanza, respectively. The numbers were written on separate slips of paper then placed in a large container. The slips were then mixed thoroughly before a sample was drawn from the container. The slip selected represented the school that was included in the study. After each pick, the slips were thoroughly mixed before the next pick was done. The process was repeated until the desired number of schools was attained for each cluster.

**Table 3.1:** Sample size distribution within each cluster

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Total number of secondary schools</th>
<th>Population ratio</th>
<th>No of schools visited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans-Nzoia East</td>
<td>55</td>
<td>0.32</td>
<td>21</td>
</tr>
<tr>
<td>Trans-Nzoia West</td>
<td>79</td>
<td>0.45</td>
<td>29</td>
</tr>
<tr>
<td>Kwanza</td>
<td>40</td>
<td>0.23</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>174</td>
<td></td>
<td>65</td>
</tr>
</tbody>
</table>

**3.3 Research Instruments**

The data collection tools adopted in this study was similar to those used in previous studies that were looking at biomass consumption rates and patterns and technologies used in combusting biomass. These studies include Kituyi *et al.* (2001), Kirubi *et al.* (2000) and Ngweyo (2008).
3.3.1 Questionnaires

In this study, a questionnaire was one of the tools used to collect data relevant to the study. This is because it is among the most common tools for big enquiries and one is able to do a pilot survey to identify the questionnaire’s weakness before the official data collection begins (Kothari, 2004). Appendix I shows a sample of the questionnaire used during the study and it was divided into three major sections. The first section had questions on the type of school i.e. day, boarding or mixed day and boarding; the number of students being cooked for and the total school enrolment over the years. The main respondent for this section was the bursar who is usually responsible for school record keeping. The second section was on the type of tree species frequently delivered for fuelwood; their daily and annual fuelwood consumption; cost per ton; the frequency of delivery; the sources of the fuelwood; name and contact of fuelwood suppliers; and the number of meals being cooked per day. The third section had questions on the type of cookstove used; number of cookstoves; the year of installation and the cost of the energy-efficient cookstoves and the general change in fuelwood consumed after the adoption of these cookstoves. The bursar and the cooks were the main respondents for the second and third sections of the questionnaire.

The questionnaire was pre-tested in three secondary schools prior to the actual exercise to eliminate any gaps that would otherwise emerge in the course of the study.

3.3.2 Interview schedules

The interview schedules were administered to the fuelwood supplier and representatives of the different Government Ministries at the County level. In the ministry of Education, the District Education Officer was interviewed. Interview schedules were used because the researcher was able to obtain in-depth data required to meet the supply dynamics objectives and address some of the policy level gaps in the study (Mugenda and Mugenda, 1999). The National Environment and Management Authority (NEMA) officer-in-charge for Trans-Nzoia District was also interviewed. In addition, the lead forester with the Kenya Forestry Service in Trans-
Nzoia County was also interviewed. They represent the different government ministries and are directly or indirectly involved in the fuelwood energy dynamics in one way or the other. A sample of the interview schedules for each respondent above is presented in Appendix ii, iii, iv and v.

3.3.3 Observation
Observation was also employed especially in ensuring that the information given by the respondents was reliable hence enhancing the accuracy of the study (Mugenda and Mugenda, 1999). This included information on the type of tree species frequently delivered which the researcher expected to find in the schools’ fuelwood store; the type and number of cookstoves used; and reading and recording of the daily consumption estimates.

The daily fuelwood consumption was obtained by the actual weighing of an estimate of the fuelwood to be used within 24hrs. The cook was requested to put aside the fuelwood he/she uses from morning when he/she starts to cook breakfast to evening after he/she has finished all his/her cooking activities for the day. Kituyi, 2000; Marufu et al., 1997; and Ngeywo, 2008, have used this technique before. The fuelwood was then weighed (Using an Accu-Weigh Universal Hanging Scale, with 200kg max weight) by first tying a rope on a cross bar in the kitchen or fuelwood store, then the wood was stacked into a sack and hooked onto the weighing balance. The weight was then recorded and the process repeated until all the fuelwood put aside was weighed.

In addition, general information on how the energy-efficient cookstoves were being used by the cooks was best obtained through the researcher observing the process during the school visits.

The researcher herself administered all these data collection tools.

3.4 Reliability of the data collected
Reliability is the measure of the degree to which a research instrument yields consistent results or data (Mugenda and Mugenda, 1999). This is very important in limiting biasness and errors in the results collected. The technique was used in a
study by Waithera (2008) to highlight some of the measures taken during data collection so as to ensure reliability of the data.

To ensure reliability of the data collected during the study several measures were exercised. First, when visiting the school, the most knowledgeable person was chosen to answer specific questions. The person was determined by asking the school head about the sub-ordinate staff responsible for a specific task/duty. The questions in the questionnaire were adopted to suit a specific respondent. Secondly, prior to the interview or filling in the questionnaires, the respondents were given five minutes to go through the interview schedules and the questionnaires. Thirdly, some of the respondents especially cooks were not fluent in English and preferred use of Kiswahili. The researcher had to translate the questions into Kiswahili so that the respondent could understand and answer them correctly. Fourthly, on questions about the type of tree species frequently delivered for fuel, the respondents were allowed to use their mother-tongue in listing the tree species which they were familiar with rather than the common or scientific names. Fifth, probes were used during the interview and questionnaire session. This enabled the researcher seek clarity in some issues raised by the respondent and also invoke the memory of the respondent in recalling information that might be relevant for the study. Lastly, the respondents were encouraged to answer the questions freely.

3.5 Data analysis and interpretation

Quantitative data was analyze using Microsoft Excel and XLSTAT while the qualitative data analysis was done using interview summary sheet technique so as to achieve the set out objectives and ensure their relevance to education, wood energy planning and forest management and conservation strategies. Different parameters were analyzed as shown below.

3.5.1 Fuelwood consumption rate:
The per student fuelwood consumption estimates were calculated for each school during the study period using the following expression adopted from that of Kituyi (2000).

\[
\text{Consumption rate } C_r = \frac{C_w}{p} \hspace{1cm} (i)
\]
Where:
- \( C_W \) is the daily fuelwood consumption in Kg per school
- \( P \) is the total number of students in a school

The consumption rates were reported as kilograms per student per day (Kg Cap\(^{-1}\) Day\(^{-1}\)) and as kilograms per student per year (Kg Cap\(^{-1}\) yr\(^{-1}\)).

The average fuelwood consumption rates for schools in a given in two categories. Firstly, the average consumption rate, which is irrespective of the type of cookstove and number of students being fed. Secondly, the average consumption rate, which considers the type of cookstove being used and lastly the number of students being cooked for as factors influencing the consumption rate.

### 3.5.2 Fuelwood saved

In order to obtain the amount of fuelwood saved due to using an improved cookstove, the following expression adopted from Kituyi (2000) was used:

\[
C_{r \text{ saved}} = C_{r \text{ (traditional)}} - C_{r \text{ (improved)}} \quad \text{(ii)}
\]

Where
- \( C_{r \text{ (traditional)}} \) is the average per student fuelwood consumption by traditional cookstove users
- \( C_{r \text{ (improved)}} \) is the average fuelwood consumption per student by improved cookstove users

The fuelwood saved was reported as Kg/cap/day and Kg/cap/yr.

### 3.5.3 GHG emission avoided estimates

Using the formula below adopted from Ngeywo, 2008, an estimate of the amount of GHG emission avoided was calculated.

\[
E \text{ avoided} = C_{r \text{ saved}} \times EF \quad \text{.............................. (iii)}
\]

Where \( E \text{ avoided} \) was the amount of trace gas emission avoided, \( C_{r \text{ saved}} \) was the average per student fuelwood consumption calculated from equation (ii) above and \( EF \) was the emission factor of the specific trace gas. These emission factors were
obtained from various published literature, which indicate the mass of pollutant released per unit of fuelwood consumed. Table 3.2 below shows the different emission factors.

**Table 3.2:** Emission factors of the atmospheric Carbon and Nitrogen compounds from domestic combustion of fuelwood

<table>
<thead>
<tr>
<th></th>
<th>EF&lt;sup&gt;1&lt;/sup&gt;</th>
<th>EF&lt;sup&gt;2&lt;/sup&gt;</th>
<th>EF&lt;sup&gt;3&lt;/sup&gt;</th>
<th>EF&lt;sup&gt;4&lt;/sup&gt;</th>
<th>EF&lt;sup&gt;5&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH&lt;sub&gt;4&lt;/sub&gt;</td>
<td>3.20</td>
<td>2.00&lt;sup&gt;A&lt;/sup&gt;</td>
<td>9.40&lt;sup&gt;B&lt;/sup&gt;</td>
<td>5.00</td>
<td>2.00</td>
</tr>
<tr>
<td>N&lt;sub&gt;2&lt;/sub&gt;O</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.15&lt;sup&gt;C&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup>Baillis *et al.*, 2003  
<sup>2</sup>Brocard *et al.*, 1998  
<sup>3</sup>Smith *et al.*, 2000  
<sup>4</sup>IPCC default factors  
<sup>5</sup>Delmas *et al.*, 1995

<sup>A</sup> Used for calculation of minimum emission estimates  
<sup>B</sup> Used for calculation of maximum emission estimates  
<sup>C</sup> Used for calculation of emission estimates without range

All the factors are reported in g of pollutant per Kg of fuel. Assumptions made were trees absorbed the CO<sub>2</sub> released and the moisture content of the firewood is at 30%

**3.5.4 Financial Savings (Kenyan shillings per year)**

The monetary savings by a school due to the switch from a traditional cookstove to an improved cookstove was a product of the average annual per student fuelwood rate in tons obtained from equation (ii) and the cost of a ton of fuelwood. The equation was as below:

\[
\text{Money saved} = C_r \text{ saved} \ast \text{ cost per ton } \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (iv)
\]

The cost of a ton of fuelwood was obtained during the study and an average of it was calculated.

**3.5.5 Species identification**

In order to identify the preferred/commonly-used tree species, which were given in local language during the study, the researcher used a handbook from the Vi Agroforestry (Vi-skogen) to obtain the English and Scientific names. The handbook (Maundu and Tengnas, 2005) contained names of trees and shrubs found in Kenya,
with their names in different tribal languages in Kenya of which Luhya language was among them. The researcher looked up the names in Luhya language and matched it to the corresponding Scientific and English names.

3.5.6 Interview schedule data analysis

The data from the interview schedules was analysed using interview summary sheet technique. This involved rereading the written down interview notes and writing a summary of what each interviewee said.
CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. General observation
4.1.1. Sample type and distribution in clusters
The 65 secondary schools, in Trans-Nzoia County were distributed unevenly among the clusters with Trans-Nzoia West cluster having the most number of secondary schools (see Table 3). Majority of the schools in this cluster were located far from Mt Elgon and were close together and with a high enrolment unlike those close to the mountain. This was likely due to the poor infrastructure in areas close to the mountain.

Secondary schools in Trans-Nzoia County were found to be in three categories: day schools, boarding schools and mixed day and boarding schools. In day schools, students were from within the school’s neighborhood and return home in the evening, while the boarding schools are those that offer accommodation to the students for about 270 school-going days each year. In mixed day and boarding schools both boys and girls are admitted and only a proportion of the student body is resident within the school. Table 4.1 shows the distribution of the schools in the County’s clusters according to their categories.

Table 4.1: Sample distribution across the clusters

<table>
<thead>
<tr>
<th></th>
<th>Trans-Nzoia West</th>
<th>Trans-Nzoia East</th>
<th>Kwanza</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day schools</strong></td>
<td>18</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td><strong>Boarding schools</strong></td>
<td>7</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td><strong>Mixed day and boarding school</strong></td>
<td>4</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Categorizing the sampled secondary schools further in terms of gender, 8% were girls schools, 5% boys schools while the remaining 87% were mixed boys and girls.

4.1.2. Catering Arrangements
All the school categories were found to have a feeding programme. In day schools, students paid a fee so as to be included in this feeding programme with those unable to pay being excluded. All students in boarding schools were included in the feeding
programme and the required fee was usually included in the total school fees paid at the beginning of the school term.

In all day schools, students were served tea during the 10am tea break and a mixture of maize and beans (*githeri*) during the 1pm lunch break. Those students who did not eat *githeri* were usually served a special diet of maize flour paste (*ugali*) and kales (*sukuma wiki*) or rice for lunch. Students in boarding schools had four meals a day; breakfast at 7am, tea at 10am, lunch at 1pm and supper at 6pm. Tea and porridge were served alternately for breakfast and at morning break while lunch, was either *githeri* or rice and beans stew or *ugali* and *sukuma wiki*. For super, *ugali* and *Sukuma wiki* was the most commonly served meal. Special meals such as beef and eggs were often prepared in some schools during the weekends. In boarding and mixed day and boarding schools, only students who were asthmatic and those who were sick were provided with hot water for bathing. This information above and what is shown in Table 4.2 was important for partially explaining the fuelwood consumption patterns and rates. This was because the type of food being cooked and the number of meals cooked influences the amount of fuelwood consumed (Kituyi and Kirubi, 2003).

**Table 4.2:** A typical school-catering programme for an average boarding and day secondary school in Trans-Nzoia County

<table>
<thead>
<tr>
<th>Meal sessions</th>
<th>Boarding school</th>
<th>Day school</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakfast</td>
<td>Tea/Porridge</td>
<td>-</td>
</tr>
<tr>
<td>Tea break</td>
<td>Tea</td>
<td>Tea/Porridge</td>
</tr>
<tr>
<td>Lunch</td>
<td><em>Githeri</em>/ Rice + Beans/ Rice+ Vegetables</td>
<td><em>Githeri</em></td>
</tr>
<tr>
<td>Supper</td>
<td><em>Ugali</em>+ Vegetables</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Ugali</em>+Beans</td>
<td></td>
</tr>
<tr>
<td>Weekends (Lunch)</td>
<td>Rice+Eggs/ Rice+beef/ <em>Ugali</em> + Beef+vegetables</td>
<td></td>
</tr>
</tbody>
</table>

**4.1.3. Commonly used types of biomass energy in study area**

Fuelwood was the most common type of fuel, where 93% of the sampled schools used it for cooking and heating water. Apart from fuelwood, other types of fuel found in use were maize cobs and charcoal, although these were only used to
supplement fuelwood and also in preparing the special meals for teaching staff and students with special dietary needs. This information was important especially for County energy planning since it shows what type of fuel is on demand to ensure planning for its sustainable supply. This was also important for the Kenya Forestry Services during their planning.

Table 4.3: Fuel types commonly used by schools in Trans-Nzoia County

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Trans-Nzoia West (%)</th>
<th>Trans-Nzoia East (%)</th>
<th>Kwanza (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firewood</td>
<td>93.1</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Charcoal</td>
<td>3.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maize cobs</td>
<td>3.4</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

4.2 Fuelwood consumption rates and patterns

At the time of this study, all the sampled secondary schools (n=65) were found to depend on fuelwood for their heating and cooking purposes with only 3% of them using maize cobs or charcoal as an additional fuel source for heating and cooking. The overall daily fuelwood consumption per school varied between 48 and 384 kg determined by the size of school, with a mean school consumption of $159.2 \pm 91.75$ kg in the studied secondary schools. The daily consumption rate ranged between 0.12 -1.67 kg per student and yielded a weighted mean consumption rate of 0.524 kg per student daily. This value was irrespective of the number of meals being cooked per day, the type of meal being prepared, the type of school, the type and number of cookstoves used per school. This value fell within the per student consumption range (0.37-0.66 kg per student daily) reported in other studies (see Table 4.4). Despite the difference in the consumption rate, which was likely due to the different fuelwood measurement conditions, the fuelwood value from this study could be used in estimating the average fuelwood demand in the whole County with a known number of students.
The average consumption value per student per daily was expected to change when these parameters that influence fuelwood consumption were considered.

Table 4.4: Reported consumption rates (kg/cap/day) for schools in Kenya

<table>
<thead>
<tr>
<th>Daily per student consumption (kg cap(^{-1}) day(^{-1}))</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 (overall)</td>
<td>RETAP, 2008</td>
</tr>
<tr>
<td>0.46 (Improved Stoves)</td>
<td></td>
</tr>
<tr>
<td>0.88 (Traditional Stoves)</td>
<td></td>
</tr>
<tr>
<td>0.66 (overall)</td>
<td>RETAP, 2007</td>
</tr>
<tr>
<td>0.57 (improved stoves)</td>
<td></td>
</tr>
<tr>
<td>0.96 (traditional stoves)</td>
<td></td>
</tr>
<tr>
<td>0.34 &amp; 0.49</td>
<td>Kituyi and Kirubi, 2003</td>
</tr>
<tr>
<td>0.54</td>
<td>Kituyi et al., 2001</td>
</tr>
<tr>
<td>0.64 ± 0.41</td>
<td>Ngeywo, 2008</td>
</tr>
<tr>
<td>0.52</td>
<td>This study</td>
</tr>
</tbody>
</table>

3.5.7 Influence of enrolment on fuelwood consumption rate
Studies done (Kituyi, 2000; RETAP, 2008, 2010; Ngeywo, 2008) highlighted the importance of enrolment in education institutions when studying fuelwood consumption patterns. The same was considered during this study for all the sampled schools within the County and the results tabulated in table 4.5.

Table 4.5: Effect of school enrolment on per student consumption rates

<table>
<thead>
<tr>
<th>Enrolment range</th>
<th>n (no of schools)</th>
<th>Minimum consumption (Kilograms per student daily)</th>
<th>Maximum Consumption (Kilograms per student daily)</th>
<th>Mean Consumption (Kilograms per student daily) (mean ±sd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-250</td>
<td>30</td>
<td>0.22</td>
<td>1.67</td>
<td>0.72 ±0.372</td>
</tr>
<tr>
<td>251-350</td>
<td>18</td>
<td>0.19</td>
<td>1.35</td>
<td>0.55 ±0.329</td>
</tr>
<tr>
<td>351-Above</td>
<td>17</td>
<td>0.12</td>
<td>1.69</td>
<td>0.44 ±0.223</td>
</tr>
</tbody>
</table>

From the study, schools with enrolment above 350 had the lowest mean consumption of 0.488 ±0.384 kg per student daily as compared to those with
students below 350. Schools with students ranging 100-250 had the highest mean consumption rate of 0.72 ±0.372 kg per student daily, yet they had the least number of cookstoves. In addition, such schools relied on the traditional and semi-improved cookstoves and were day schools. The difference between the two consumption rates was statistically significant at p=0.006 at 95% confidence interval. This supports the fact that there is indeed some actual fuelwood savings per student. The lower consumption rate is attributed to economies of scale in schools with many students than in those schools with few students.

The scatter diagram (Figure 4.1) illustrates further how enrolment influences fuelwood consumption using the per student fuelwood consumption rates of all the schools sampled.

From Figure 4.1 above, the fuelwood consumption rate per student decreased with an increase in the number of students. This implies that secondary schools with few numbers of students consumed more fuelwood per student than those with larger enrolment. This knowledge could be used by the education sector as criteria for registering new schools where only school managers who demonstrated their ability to enroll more than 250 students were considered. This was the enrolment level beyond which the fuelwood consumption per student did not change significantly.
The result from this study supports findings from previous studies by Kituyi (2000), Marufu et al. (1997) Ngeywo (2008); RETAP (2010) on economies of scale in the context of school-level biomass use. A meaningful functional relationship between the two parameters may be derived with longer-term monitoring data from every institution, as opposed to the single measurements carried out in this study.

4.2.1 Influence of type of cooking stove on fuelwood consumption

Another important factor that was considered to influence fuelwood consumption patterns was the type of cookstove used in the sampled secondary schools. The types of cookstoves found in the sampled secondary schools were the traditional, the semi-improved and the improved institutional energy saving cookstoves, all of which are described below.

4.2.1.1 Traditional cookstove (TC)

The cookstove had three stones of the same height arranged in a triangular format and the cooking pot balanced on them over the fire. Construction was easy and it requires very little cash to construct. A detailed description of the characteristics of a traditional cookstove is in Chapter 2. A photo of a traditional 3-stone cookstove in one of the sampled schools was as shown in Plate 4.1. From the study, 18% of the sampled schools (n=65) used traditional cookstoves exclusively, with 41% of them combining it with either improved or semi-improved cookstoves. Although the percentage of schools using traditional cookstoves entirely was low, those combining it with others stoves was very high. The main reason being the side-dishes that these schools cook with the other stoves.

The fuelwood mean consumption rate for schools using these tradition cookstoves was $0.80 \pm 0.419$ Kg per student daily (see Table 4.6 below). The main reason given by schools using a traditional stove as their main stove was they couldn’t afford to purchase the improved institutional cookstove because it was expensive.
4.2.1.2 Semi-improved Cookstove (SIC)

Semi-improved cookstoves were partially enclosed, made of either metal, mud or bricks and were fixed on the ground, just like most improved cookstoves. Some were fitted with chimneys that released smoke to the atmosphere and use slightly less wood compared with traditional cookstoves. They were locally made and the cost depended on the cost of materials and service charge at different locations in the County. The fuelwood consumption rate for semi-improved cookstoves users was $0.61 \pm 0.287$ Kg per student daily. These cookstoves were used as the main stove by 8% of the sampled schools ($n=65$) with 15% combining them with either traditional or improved cookstoves or both. The semi-improved cookstoves were used because the schools would not afford to buy the improved cookstoves yet they were keen to reduce their fuelwood consumption. The semi-improved cookstove offered them a cheaper option to achieve fuelwood saving although not at an optimum level. The different semi-improved cookstove models found in some of the sampled schools in the County were as presented in Plate 4.2 below.
4.2.1.3 Improved institutional cookstove (IC)

This type of cookstove was made of a stainless steel outer casing, an inner lining made of insulating bricks that minimizes heat loss, and was fitted with a chimney that released smoke to the atmosphere. The cooking pot was placed in the pot socket and was easily removed after cooking. These types of cookstoves were either fixed on the ground or portable. A detailed description of the characteristics of an improved institutional cookstove is in Chapter 2.

From the study, 26% of the sampled schools were using improved cookstoves alone, with 41% combining it with either traditional or semi-improved cookstove. The reason for the combination was that they cooked small amounts of side dishes, which could not be cooked in the big pots of improved stoves. The fuelwood consumption rate for schools using improved cookstoves was $0.46 \pm 0.211$ Kg per student daily. The main reason given by schools for using this stove during the survey was its low fuelwood consumption. Schools reported to have had a reduction in the amount of fuelwood they purchased after their adoption of the improved cookstoves. Plate 4.3 shows two different models of improved cookstoves taken during the study.
Plate 4.3: Improved single-burner (left) and double-burner (right) institutional cookstoves in one of the surveyed schools

Table 4.6 collates the overall fuelwood consumption rates based on the discrete cookstove types and their stove combinations in sampled schools in Trans-Nzoia County.

Table 4.6: Fuelwood consumption rates influenced by type of stove or stove combinations

<table>
<thead>
<tr>
<th>Cookstove type</th>
<th>n=65 (no of samples)</th>
<th>Consumption rate (kg cap⁻¹ day⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC</td>
<td>17</td>
<td>Mean (± sd)</td>
</tr>
<tr>
<td>SIC</td>
<td>5</td>
<td>0.46 ± 0.211</td>
</tr>
<tr>
<td>TC</td>
<td>12</td>
<td>0.61 ± 0.287</td>
</tr>
<tr>
<td>IC &amp; SIC</td>
<td>4</td>
<td>0.80 ± 0.419</td>
</tr>
<tr>
<td>IC &amp; TC</td>
<td>21</td>
<td>0.54 ± 0.364</td>
</tr>
<tr>
<td>SIC &amp; TC</td>
<td>4</td>
<td>0.62 ± 0.366</td>
</tr>
<tr>
<td>IC &amp; SIC &amp; TC</td>
<td>2</td>
<td>0.36 ± 0.122</td>
</tr>
</tbody>
</table>

IC- Improved cookstove; SIC- Semi-Improved cookstove; TC- Traditional cookstove

When considering schools using single stoves, improved institutional cookstove users had the lowest per student fuelwood consumption of 0.46kg. The traditional and semi-improved cookstove users, each student consumed 0.80kg and 0.61kg of...
fuelwood daily respectively. These findings imply that the traditional cookstove users had the highest consumption rate. The fuelwood consumption rate difference between the traditional and improved cookstove users was statistically significant at p=0.008 and 95% confidence interval. This showed that there was some saving by switching from a typical traditional to an improved cookstove. This fuelwood consumption rate reported by this study was in concurrence with the previous studies by Kituyi (2000), RETAP (2007, 2008), and Ngeywo (2008) as shown in table 4.4 above. This makes the rate reliable and could be used for policy formulation purposes.

When considering the cookstove combination (see table 8 above), schools that combined the three types of cookstoves had the highest daily consumption pattern of 1.02 ± 0.248 kg per student as compared to the other cookstove combinations. The low fuelwood consumption of 0.36 ± 0.122 kg per student per day for schools that used both Semi-improved and traditional cookstove was an anomaly. This was because, first, the four schools were hardly two years old and cooked only a single meal daily (lunch). Secondly, these cookstoves were managed well hence the very low consumption rate. Figure 4.2 shows the various cookstoves combinations used within the County. This information could be used by the County for strategic planning especially in promoting the use of improved cookstoves in the County.

![Stove combination vs % No. of Schools](image)

**Figure 4.1:** Cookstove combination in Trans-Nzoia County
In general, institutions using improved institutional cookstoves consumed 1.7 and 1.3 times less fuelwood per student, than the users of the more common traditional and semi-improved cookstoves respectively. The figures indicated that there would be a reduction in fuelwood consumed by schools when they switched to using improved cookstoves alone.

4.3 Preferred tree species and their sources

4.3.1 Preferred tree species for fuelwood

The survey revealed a wide variety of tree species used by secondary schools for fuel in various parts of the County. All the secondary schools reported using a particular tree species more often than the other due to their burning characteristic or their availability. The preferred tree species was always in the fuelwood store or fuelwood yard most of the year. Despite schools having a preferred tree species for fuelwood, these schools resorted to using other tree species in the absence of the preferred species.

Various fuelwood-use patterns were observed across the County and each cluster showed unique combinations. The preferred trees species for fuelwood by secondary schools in Trans-Nzoia County included: *Eucalyptus species, Grevillea robusta* and *Croton species*. Other species listed were as shown in Figure 4.5. The preference of use depended mostly on their availability in the local surroundings and the location of the schools within the County. For example, it was observed that 75% of sampled schools in Trans-Nzoia West and 93% Kwanza clusters listed exotic tree species as their first choice for fuelwood. Unlike the two clusters, Trans-Nzoia East listed both exotic (62%) and indigenous tree species (38%) as their first choice for fuelwood. This was likely because of the availability of these species within the clusters.
Figure 4.3 shows tree species used by sampled schools as either first choice or second and third choice.

Using the Figure 4.3 above, 68% of the sampled secondary schools listed *Eucalyptus species* as their first choice for fuelwood whereas 20% out of the 32% that used other species listed *Eucalyptus species* as their second or third species choice for fuelwood. *Eucalyptus species* was used widely because it was widely grown and readily available as it grew faster as compared to the indigenous species (Mwangi, 2014). In addition, *Eucalyptus species* produces heat of high intensity (the calorific value of Eucalyptus (Dry weight) ranges between 17900-19500 KJ/kg (Jenkin, 1993), it dried faster and could burn even when wet as per the general comments by some of the cooks in the sampled secondary schools. *Grevellea robusta* was the second and third choice tree species by 45% of the sampled schools, followed by *Cupressus lusitanica* by 17% as the exotic species. *Croton spp* and *Acacia spp* were listed by 14% and 22% of the sampled schools as second and third choice used indigenous tree species respectively. The same information was characterized by cluster and presented in Table 4.7 below.

The wider range of species choices noted in secondary schools in the different constituencies within the County could be attributed to, *inter alia*, the prevailing
climatic conditions, the highly varying topography and soil types. It was observed that in Trans-Nzoia West and Kwanza clusters *Eucalyptus species* and *Grevillea robusta* were the first, second and third frequently used tree species for fuelwood. In Trans-Nzoia East, other indigenous species like *Croton species*, *Ficus sycomorus* and *Acacia species* were listed as the schools’ frequently used tree species. Knowing the sources, distribution and demand rates of these species in different areas within the County is important during planning for reforestation activities.

The two main sources of the tree species for fuelwood in Trans-Nzoia County were farmlands and forests but this varied depending on whether it was an exotic or indigenous forest. A more detailed analysis of the sources is on section 4.3.2 below. An interview with fuelwood suppliers revealed that they delivered a wide range of trees species for fuelwood but most of them were exotic species. The suppliers who delivered indigenous species often obtained them from farmlands but those that source their wood from the indigenous forests were restricted to only harvesting the planted exotic species. The indigenous trees species obtained were as dead wood. Private plantations e.g. Kuza farm and public plantations like Agricultural Development Cooperation (ADC) plant *Eucalyptus species* only.
### Table 4.7: Tree species used for fuelwood in Trans-Nzoia County

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Common Names for trees species</th>
<th>1st Choice</th>
<th>% Secondary School Reporting 2nd &amp; 3rd Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trans-Nzoia West</strong></td>
<td>Blue gum</td>
<td>75.9</td>
<td>13.8</td>
</tr>
<tr>
<td></td>
<td>Grevillea</td>
<td>6.9</td>
<td>44.8</td>
</tr>
<tr>
<td></td>
<td>Cypress</td>
<td>-</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>Acacia</td>
<td>3.4</td>
<td>13.8</td>
</tr>
<tr>
<td></td>
<td>Croton/Musine</td>
<td>-</td>
<td>13.8</td>
</tr>
<tr>
<td></td>
<td>Nile tulip/ Nile trumpet/ Siala tree</td>
<td>-</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>Bark-cloth fig</td>
<td>-</td>
<td>17.2</td>
</tr>
<tr>
<td></td>
<td>Mexican weeping pine</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>Water-wood/ Water-berry tree</td>
<td>-</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>Avocado pear</td>
<td>-</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>Podo</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>Bush-willow tree</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nandi flame/ African tulip tree</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td><strong>Kwanza</strong></td>
<td>Blue gum</td>
<td>73.3</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Grevillea</td>
<td>20.0</td>
<td>46.7</td>
</tr>
<tr>
<td></td>
<td>Cypress</td>
<td>-</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>Acacia</td>
<td>-</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>Croton/Musine</td>
<td>-</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>Sycamore tree</td>
<td>6.7</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>Mexican weeping pine</td>
<td>-</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Water-wood/ Water-berry tree</td>
<td>-</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Podo</td>
<td>-</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>East African olive/ Elgon olive</td>
<td>-</td>
<td>13.3</td>
</tr>
<tr>
<td><strong>Trans-Nzoia East</strong></td>
<td>Blue gum</td>
<td>42.9</td>
<td>38.1</td>
</tr>
<tr>
<td></td>
<td>Grevillea</td>
<td>14.3</td>
<td>42.9</td>
</tr>
<tr>
<td></td>
<td>Cypress</td>
<td>-</td>
<td>14.3</td>
</tr>
</tbody>
</table>
4.3.2 Fuelwood sources

Table 4.8 shows the most common sources across the clusters of the five most commonly used tree species for fuelwood.

**Table 4.8:** Sources of the five commonly used tree species for fuelwood in secondary schools in Trans-Nzoia County

<table>
<thead>
<tr>
<th>Tree Species</th>
<th>Trans-Nzoia West</th>
<th>Trans-Nzoia East</th>
<th>Kwanza</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue gum</td>
<td>Farmlands/Plantation</td>
<td>Farmlands</td>
<td>Private plantation</td>
</tr>
<tr>
<td>Grevillea</td>
<td>Farmlands</td>
<td>Farmlands</td>
<td>Farmlands/Forest</td>
</tr>
<tr>
<td>Cypress</td>
<td>Farmlands/Plantation</td>
<td>Farmlands</td>
<td>Farmlands</td>
</tr>
<tr>
<td>Acacia</td>
<td>Farmlands</td>
<td>Farmland/Forest</td>
<td>Farmlands</td>
</tr>
<tr>
<td>Croton species</td>
<td>Farmlands</td>
<td>Farmlands</td>
<td>Farmlands</td>
</tr>
</tbody>
</table>

From this study, the most common sources of trees for fuelwood supplied to Trans-Nzoia County secondary schools were as shown in Figure 4.4 with farmland trees being listed as the major source of fuelwood by 88% of sampled secondary schools. Forests, school compound and private and public plantations were listed as the other sources of trees for fuelwood by 14%, 5% and 5% of sampled schools respectively. About 3% of the sampled schools did not know where their fuelwood came from; their concern was more about the availability of the fuelwood in fuelwood stores/yards for use. It would be important for schools to know where their fuelwood came from especially by the school managers/bursar.
Farmlands were the main source of fuelwood in schools within the County because most was supplied as school fees in kind by parents who had trees in their farms but lacked solid cash. This highlights the importance of agroforestry in fuel supply. Another reason was that where school administration was responsible for supplying fuelwood, they asked around for anyone with trees in their farms so as to purchase from them.

4.3.3 Fuelwood suppliers
The fuelwood acquisition system usually enables the school management to select the preferred species. About 52% of sampled schools listed parents as their main suppliers of fuelwood. The fuelwood was supplied as fees in kind by parents who had trees in their farms yet they did not have cash to pay school fees for their children in that particular school. Most schools that allowed that were located in a rural setting and parents were always given the first priority to supply the fuelwood.

The conversion of the amount of fuelwood delivered into its equivalent monetary value depended on transportation mode. A 5-ton pick-up and carts delivered most of the fuelwood, which was easy for the bursar to determine the equivalent monetary value. In one school, there was a large wooden box constructed near the fuelwood yard, which was used to measure the quantity of fuelwood supplied. This was then
used to value the fuelwood in monetary terms. This mode of fee payment was not the most preferred because schools needed cash to enable them implement other development projects. However, the mode was used as a goodwill gesture by the school administration so as to enable parents with no financial resources to pay fees. A major challenge of this model was to give equal opportunities to all parents who wished to pay fees by supplying fuelwood without leading to excess fuelwood supply in the school. To overcome this, priority to supply fuelwood was given to parents who had not supplied fuelwood before.

On the other hand, about 28% of the sampled schools gave tenders to independent candidates who delivered the fuelwood for use. The tendering procedure involved sending out tender notices and the candidate who could deliver the preferred species and the quantity of fuelwood at a competitive price was awarded the contract for one year. It was noted that if the preferred species was unavailable, most schools opted for the species available except for the few National schools that were very specific on the type of tree species to be delivered for fuelwood.

In 3% of sampled schools, the school administration was responsible for supplying fuelwood. The school’s bursar and one teacher were responsible for asking around the village whether there was a farmer who wanted to sell trees. They would visit the farmer to value the tree before it was cut and transported to the school for use as fuelwood.

For the 17% schools that listed both tender and parents as fuelwood suppliers, parents were usually given the first priority and if the fuelwood delivered was not enough, then the tender person supplemented it. It was also noted that parents could supply any type of tree species as fuelwood; the parents were the ones who supplied the avocado tree for fuelwood.
In order to understand the fuelwood supply chain for schools in the County, interviews were carried out with two of the fuelwood suppliers in each cluster within the County. A supplier to be interviewed was chosen depending on the number of schools he supplied fuelwood to and also the source of firewood to ensure each source was included.

The interviews revealed that depending on the sources of the fuelwood, suppliers were limited to which type of species to harvest. For those whose source of fuelwood was indigenous forests like Teldet or Kimothoni forest, they were only allowed to harvest exotic species. The exotic species were often planted as part of the on-going reforestation programme to increase Kenya’s forest cover to a minimum of 10%. The indigenous species harvested were mainly from deadwoods in the forest. This was as per the regulations in the Forest Policy that prohibited the harvest of live indigenous species. Suppliers from private and public plantation were limited to *Eucalyptus species*, which was the main tree species being grown in these plantations.

To ensure sustainability of their fuelwood sourced from indigenous forests, fuelwood suppliers from indigenous forests had a programme with the Kenya Forest
Service (KFS) where they replanted both exotic and indigenous species after cutting at a 2:1 ratio. Meanwhile, suppliers sourcing their fuelwood from farmlands and private and public plantations were not involved in replanting activities, as this was the responsibility of the farm and plantation owners to ensure its sustainability.

The cost of fuelwood per ton was determined by the purchase price at the source, transport cost and labor for those involved in the logging and loading of the fuelwood into trucks. This price was also influenced by the tender agreement between the school and the fuelwood suppliers. The cost of the fuelwood also varied with the season, whereby fuelwood delivered during rainy season was more expensive (due to transport costs) than that delivered during the dry season. That was why most schools preferred purchasing their fuelwood supplies at the beginning of the year because most of the school fees was paid during the beginning of the year and school budgets were also done at this time.

The suppliers were also required to have fuelwood movement/transport permit, which was obtained from the forestry department offices within the County. The process for obtaining the permit from the government was not tedious, a supplier was required to pay a particular amount i.e. some paid 2000/- per week, others paid 450/- per trip while for others, the amount was included in the total purchase cost at the source (in forest sources). This could be a policy concern for the County government to have a uniform rate for all the suppliers that will ensure accountability at the forestry sector.

Some of the adjustments that the suppliers proposed were; i). Increase in forestry resource cover because of the increase in demand for forestry products especially from other bulk users like saw millers; ii). Some suppliers especially those near forest resources and were supplying fuelwood to nearby schools did not see the need to have a movement permit. This was because they didn’t transport the fuelwood over long distances; iii). Localization of the movement permit process at resource point could ensure easy accessibility. The second proposal was unrealistic because it would be very difficult for the forest service to identify where each fuelwood supplier was coming from. It would also create a loop for these fuelwood suppliers
who were closer to the forestry resources to engage in illegal business of buying for other suppliers fuelwood.

4.4 Adoption rate of improved cookstove in secondary schools

The study revealed that 68% of the sampled secondary schools had adopted the energy-efficient cookstoves, with the number of schools purchasing these stoves varying each year. Figure 8 below shows the adoption rate of improved cookstoves irrespective of their number and their stove combinations. This figure was significant especially in illustrating how schools within the County had been taking up the improved cookstoves over the years and also enabled prediction of the number of schools likely to adopt the stoves the following year.

![Figure 4.5: The adoption rate of improved cookstoves in secondary schools in Trans-Nzoia County.](image)

From the field survey, it was observed that although some of the sampled schools had adopted these improved cookstoves, they also used other types of cookstoves i.e. semi-improved and traditional cookstoves on the side. Figure 4.7 shows (in percentage) the number of schools and the varied stove type and stove combinations.
Figure 4.6: Distribution by stove type adopted by a school

In Figure 9, only 26% of the sampled schools had fully adopted use of improved institutional cookstoves. About 42% of the sampled schools had partially adopted these improved institutional cookstoves. From the study, 8% of the sampled schools used semi-improved cookstoves while 18% used traditional cookstoves.

The interview revealed that the partial or lack of adopting improved cookstoves in some of the sampled schools was due to i) Lack of finances to adoption and/or fully shift to improved cookstoves; and ii) Lack of awareness of the existence of other improved cookstove designs suitable for cooking small meals for few individuals. This was because most of the traditional or semi-improved cookstoves were only used to cook meals for teachers and students on special diet. The latter is happening yet the improved cookstoves manufacturers have tailored a two to four burner improved cookstoves as shown in Plate 4.3 above to suit these special needs in schools.

Two main reasons being lack of knowledge on the existence of such stove design and financial constraints. The former can be addressed by creating awareness on the availability of financial loan schemes where a school can pay for the cookstove in termly installments. This was a model used by RETAP, which extends credit to schools by paying the stove manufacturers upfront, then allowing schools to pay in
termly installments over 2 years. With reference to the RETAP’s policy brief (2008), the RETAP financial model could only be successful if schools set aside funds to support them in purchasing the stoves. The funds should never be considered as grants but as credit. In addition, tax incentives can be considered so as to motivate schools to purchase more stoves at a subsidized price.

Considering the varied nature of schools in each cluster within the County, it was important to show how the adoption rates of these improved cookstoves differed across the three clusters. Figure 4.8 illustrates the adoption rate of the improved cookstoves per cluster and also highlights the percentage that had fully adopted the improved cookstoves per cluster.

Trans-Nzoia West cluster had the lowest adoption rate for ICs, yet it was a cluster that had more schools than the other two clusters. As per the comments from the school bursars, the main reason for not adopting the stoves was that they were very expensive. From the desk study, an improved cookstove could cost between USD 700 to USD 2500 depending on the capacity. Another factor is the type of institution. Most boarding and mixed day and boarding secondary schools had the highest adoption rate of improved cookstoves although these types of schools were few as compared to the number of day schools present in the County. This pulls
down the overall adoption rate of improved cookstoves. It is important to remember that most schools within the County had not fully adopted improved cookstoves. The low rate of improved adoption in Trans-Nzoia County can be due to the lack of substantive policy on improved cookstoves and biomass energy.

Considering the type of learning institution, the table 4.9 below shows the varied adoption rate of improved cookstoves by the different school types in the County.

**Table 4.9: Improved cookstove adoption by school-type**

<table>
<thead>
<tr>
<th>Category of Institution</th>
<th>Adoption rate of improved cookstoves (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fully adopted</td>
</tr>
<tr>
<td>Day</td>
<td>12.9</td>
</tr>
<tr>
<td>Boarding</td>
<td>52.9</td>
</tr>
<tr>
<td>Day/Boarding</td>
<td>23.5</td>
</tr>
</tbody>
</table>

Day schools had the least full adoption rate of these improved cookstoves. This was likely due to first, lack of finances since most of them are public schools, attributed to the free secondary education policy hence the schools are left with too little to invest in other projects like purchasing improved cookstoves. Secondly, the poverty levels in rural areas where most of parents pay their fees in kind through fuelwood hence schools lack solid cash to purchase these improved cookstoves.

The *jua kali* (micro and small enterprise) sector in collaboration with Kenya’s Ministry of Education had played an important role in promoting these improved energy technologies in schools. This was from my interview with the District Education Officer of Trans-Nzoia County. Through the schools heads annual meeting, the improved cookstove manufacturers were allowed to exhibit them. The manufacturers were also given some time to address school-heads on the importance of using these improved cookstoves. The Ministry of Education and that of Environment have also played a role where during education or environment days held at district and division levels, schools were usually encouraged to use the improved cookstoves so as to reduce their fuelwood consumption and reduce deforestation.
The cumulative number of cookstoves being purchased each year by the sampled schools in the County showed an exponential curve. This was presented in Figure 4.9. These numbers were due to schools adding more of these cookstoves or by a school buying one for the first time. This figure shows a yearly increase in the number of stoves being purchased in the County but from the previous discussion, it was evident that they were often combined with other types of cookstoves. This reduced the environmental, social and economic benefits that would have been accrued from the use of the improved cookstoves.

![Graph showing cumulative number of improved cookstoves purchased per year](image)

**Figure 4.8:** Cumulative number of improved cookstoves purchased per year

### 4.5 Potential savings from adopting improved cookstoves by learning institutions

#### 4.5.1 Fuelwood savings

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

Annually, up to 91.8 kg and 41.04 kg of fuelwood per student could be saved by traditional and semi-improved cookstove users respectively if they switched to using improved cookstoves. This was with an assumption that there are 270 operation schooldays each year. Furthermore, a typical school using traditional or semi-improved cookstove in Trans-Nzoia County, with an average of 300 students could make a saving of about 27.5 tons and 12.3 tons of fuelwood annually respectively if they switched to using an improved cookstove. These figures demonstrated that there was environmental savings in terms of reduced deforestation, associated with the switch to using an improved cookstove. Such figures could be used during the promotion of these stoves at schools level. Moreover, the Ministry of Education could use the data as evidence when formulating policies that require schools to have improved cookstoves.

4.5.2 Financial savings

From the study a ton of fuelwood cost an average of KSh.1500, which translated to Kes. 1.50 per kilogram. Using the values in section 4.6.1. on the amount of fuelwood saved, annually a school would save KSh. 138 per student by switching from using a traditional to an improved cookstove. Similarly, a school that used a semi-improved cookstove would save KSh. 62 by switching to using an improved cookstove.

4.5.3 GHG emission avoided estimates

The GHG emissions are usually due to either combustion or pyrolysis of wood and include CO₂, CH₄ and N₂O. In this study, the CO₂ emission avoided was not calculated with an assumption that the growing vegetation around absorbed it. Estimates of the GHG emissions avoided depended on the actual amount of fuelwood saved by a school when they adopt an improved cookstove. From Section
4.2.2 above, the daily fuelwood saved per student when a school switches from a traditional or semi-improved cookstove to an improved cookstove was calculated to be 0.34 kg and 0.152 kg respectively. These data provided the foundation upon which daily and annual benefits in terms of GHG emissions avoided per student in a school by the cookstove switch may be determined using already published emission factors.

Table 4.10 shows the daily and annual estimates for GHG emissions- avoided per student by a school switching from either a traditional or a semi-improved cookstove to an energy-efficient improved institutional cookstove.

<table>
<thead>
<tr>
<th></th>
<th>Daily (g/person)</th>
<th>Annual (g/person)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CH₄ (min)</td>
<td>CH₄ (max)</td>
</tr>
<tr>
<td>Traditional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cookstove users</td>
<td>0.68</td>
<td>3.196</td>
</tr>
<tr>
<td>Semi-improved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cookstove</td>
<td>0.304</td>
<td>1.429</td>
</tr>
</tbody>
</table>

The minimum and the maximum values for methane in Table 4.10 were considered in determining the overall emission level of methane. This was done so as to accommodate the varied emission factors reported in previous studies. For nitrous oxide, the emission factor was obtained from a single study.

GHGs emissions are associated with climate change impacts. This is because of their global warming potential, based on these gases’ heat absorbing ability relative to that of Carbon Dioxide. The global warming impact is usually calculated over a 20, 100 or 500-year time period. Since the use of improved cookstoves is associated with reduced consumption on fuelwood, there will be GHGs emission avoided because of the avoided burning of fuelwood. Using the 100-years period, the climate change impacts were calculated using global warming potential values of CH₄-25 and N₂O-298 from the IPCC 3rd Assessment Report. The figures in Table 4.11 were
important for the policy makers when developing their climate change mitigation strategies since they could compare the impacts of emissions of different gases.

**Table 4.11**: The Global Warming Commitment attributed to a typical school in Trans-Nzoia County

<table>
<thead>
<tr>
<th></th>
<th>100-years GWP (tCO\textsubscript{2}e)</th>
<th>Total 100-years GWP (tCO\textsubscript{2}e)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CH\textsubscript{4} min</td>
<td>CH\textsubscript{4} max</td>
</tr>
<tr>
<td>Traditional cookstove users</td>
<td>1.56×10\textsuperscript{-5}</td>
<td>7.35×10\textsuperscript{-5}</td>
</tr>
<tr>
<td>Semi-improved cookstove users</td>
<td>6.99×10\textsuperscript{-6}</td>
<td>3.29×10\textsuperscript{-5}</td>
</tr>
</tbody>
</table>

A school switching from a traditional to an improved cookstove avoids emitting GHGs, which would have had a daily global warming impact ranging 3.074×10\textsuperscript{-5} to 8.861×10\textsuperscript{-5} tCO\textsubscript{2}eq per student. For semi-improved cookstove users, GHGs emission of a GWC that ranged from 1.374×10\textsuperscript{-5} to 3.962×10\textsuperscript{-5} tCO\textsubscript{2}eq was avoided daily per student due to the switch to an improved cookstove. Annually, the above values translate to GWC avoided ranging 8.30×10\textsuperscript{-3} to 2.4×10\textsuperscript{-2} tCO\textsubscript{2}eq per student for traditional cookstove users and 3.70×10\textsuperscript{-3} to 1.07×10\textsuperscript{-2} tCO\textsubscript{2}eq per student for semi-improved cookstove users. This gives a central value of 1.62×10\textsuperscript{-2} (16.2 kg) and 7.2×10\textsuperscript{-3} (7.2 kg) tCO\textsubscript{2}eq for traditional and semi-improved cookstove users because of the switch.

For the County of Trans-Nzoia, the data above is important for the climate change adaptation and mitigation plan. In addition, knowledge by schools on how they can contribute to the climate change adaptation and mitigation agenda can trigger wider adoption of these cookstoves.
4.6 Projections on potential fuelwood saving, financial saving and GHGs emission avoided

This study collected information on the previous and the current enrolment levels within the sampled schools. This was important for projecting potential fuelwood and financial savings, and as well as GHG emissions-avoided by schools due to cookstove switch. Using the total enrolment data from the sampled secondary schools as from 2009 to 2013, a strong positive linear correlation of 0.990 was obtained. This means that the number of students enrolled in the schools increased as the years increased. Similarly, there was a 27% increase in the number of secondary between 2009 and 2013 as revealed from the sampled schools. These consistent upward trends in both the enrolment and number of schools will consequently lead to an increase in fuelwood demand by secondary education.

![Enrolment Trend](image)

**Figure 4.9:** The enrolment trend in secondary schools in Trans-Nzoia County

Using the fuelwood consumption per student and the enrolment projections, future fuelwood demand by schools was calculated. A baseline scenario where schools would use a traditional cookstove and that of the switch to using improved cookstoves were used to project the fuelwood saved as shown in Table 4.12.
Table 4.12: Projections on the No. of students and fuelwood demand in secondary schools in Trans-Nzoia County.

<table>
<thead>
<tr>
<th>Year</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Students</td>
<td>19,792</td>
<td>21,980</td>
<td>24,360</td>
<td>26,770</td>
<td>29,180</td>
</tr>
<tr>
<td>Baseline scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(fuelwood demand)</td>
<td>15,833</td>
<td>17,584</td>
<td>19,488</td>
<td>21,416</td>
<td>23,344</td>
</tr>
<tr>
<td>Improved efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>scenario (fuelwood</td>
<td>9,104</td>
<td>10,110</td>
<td>11,205</td>
<td>12,314</td>
<td>13,422</td>
</tr>
<tr>
<td>demand)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuelwood saved</td>
<td>6,729</td>
<td>7,474</td>
<td>8,283</td>
<td>9,102</td>
<td>9,922</td>
</tr>
</tbody>
</table>

A comparative analysis of the significance of the baseline scenario (use of traditional cookstoves) and the improved efficiency scenario of the two fuelwood consumption rates were found to be very significant at $p=0.0000936$. This provides an additional insight that schools will make significant savings on fuelwood by switching fully to using energy efficient improved cookstoves. This will mean that the projected demand for fuelwood will reduce hence reduced forest resource destruction in future. This justifies that improved cookstoves will play an important role in curbing deforestation.

The projected decrease in forest destruction means that the forest ecosystem would continue to provide the ecosystem services to people who depend on it for their livelihoods. Using the above projections, the climate change regulation service for the forest ecosystem was protected, hence the climate change mitigation potential associated with an improved cookstove was demonstrated too. This was due to the fuelwood saved hence GHGs emission avoided, which would have been released to the atmosphere leading to climate change impacts.

Table 4.13 below shows the projected potential financial savings that schools could accrue from the switch from a traditional to an improved cookstove use.
Table 4.13: Potential financial saving projections due to a switch to using an improved cookstove

<table>
<thead>
<tr>
<th>Years</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline scenario (1500/- per ton)</td>
<td>23,749,500</td>
<td>26,376,000</td>
<td>29,232,000</td>
<td>32,124,000</td>
<td>35,016,000</td>
</tr>
<tr>
<td>Improved scenario</td>
<td>13,656,000</td>
<td>15,165,000</td>
<td>16,807,500</td>
<td>18,471,000</td>
<td>20,133,000</td>
</tr>
<tr>
<td>Savings made</td>
<td>10,093,500</td>
<td>11,211,000</td>
<td>12,424,500</td>
<td>13,653,000</td>
<td>14,883,000</td>
</tr>
</tbody>
</table>

The projected financial savings associated with the switch from a traditional cookstove to an improved cookstove was also calculated. The savings were found to be very significant at p=0.000648. This showed that there would be a significant reduction in schools’ expenditure budget due to the reduced fuelwood demand. The money that would have otherwise been spent on fuelwood purchase can be used to finance other projects in the schools.

4.7 Research-into-Use opportunities

The study’s results were very relevant in outlining some opportunities that the County can harness. The following were some of the potential opportunities as demonstrated from this study:

First, the Ministry of Energy is in the process of mapping out renewable energy resources in the Counties in the country in which biomass energy is included; for the purposes of planning. This was from an advertisement on the Daily Nation newspaper of 10th of October, 2014 for a consultant opportunity. This study provides a detailed description of both the demand and supply dynamics of wood energy, which will be relevant for developing a strategic and sustainable energy, plan for secondary schools in Trans-Nzoia County. This information may also reduce the survey-burden for Trans-Nzoia County hence efficient use of resources.
Secondly, identification of reforestation areas to be used by the Ministry of Environment and Natural Resources. This will be through the use of the data on sources of fuelwood for various secondary schools in each cluster within the County from this study. In addition, the study identifies the type of trees species that can be planted more due to their high demand as firewood. This will be a timely opportunity to increase the country’s forest cover to 10 % as per the Millennium Development Goals and in ensuring the sustainability of the firewood sector within the County.

Thirdly, additional financial revenue for secondary school through the available carbon markets under the voluntary carbon markets. This can be achieved through wider adoption of the energy efficient cookstoves by schools within the County. These cookstoves have the potential of avoiding substantial amounts of GHGs emission and hence their climate change mitigation potential. If secondary schools within the County can come up with a plan to demonstrate the sustainability of the avoided GHGs emissions, then they will be eligible of getting carbon credits through this.

Fourth, farmers within Trans-Nzoia County can adopt the new agroforestry technologies being promoted, since the main source of fuelwood is from farmlands. This is one of the climate adaptation strategies. This will ensure farmers get extra earning by harvesting and selling trees for fuelwood while still earning cash from their crops.

Lastly, other counties can adopt the methodology used in this study because a decentralization context was applied. This is unlike previous studies, which had their focus on a national context when developing their methodologies.
CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The main objective of this study was to determine the demand and supply dynamics influencing the harvesting and use of wood energy in Trans-Nzoia County. Using the specific objectives as reference, the following results were obtained and can be used to influence decision making in the County of Trans-Nzoia.

The mean fuelwood consumption per school was calculated to be 159.2±91.75kg and a weighted mean of 0.524kg per student per day. Enrolment and type of cookstoves were considered in the study as factors influencing fuelwood consumption. On enrolment, schools with 350 students or more had the lowest daily fuelwood consumption of 0.49±0.384kg per student while those with below 350 students had 0.72±0.372 kg per student per day. Considering the cookstove type, schools that had fully adopted improved institutional cookstoves had a daily per student consumption of 0.46±0.211kg. while the traditional cookstoves users consumed 0.80±0.419kg per student per day.

On specific objective two, eucalyptus spp, Grevelea robusta, Acacia spp and Croton spp were the main tree species most frequently used by sampled schools within the County. Their main source of fuelwood was farmlands with forests being second main source. Those sourcing the fuelwood from forest were restricted on harvesting exotic trees only. Parents were the main suppliers of these fuelwood due to the rural setting of the schools in the County hence fees was paid mostly in kind by supplying fuelwood. Tender was only given when the supply by parents was insufficient to meet the schools’ termly/ annual fuelwood demands. The suppliers needed a movement permit in order to transport the fuelwood from one location to the other within the County.

Specific objective three was achieved, where from the study, the rate of adoption of improved cookstove was found to have weak exponential correlation of r=0.55. Of
concern was that these schools do not realize the fuelwood savings associated with these cookstoves due to their use of various cookstove combinations. This calls for more awareness creation on the environmental and financial savings of improved cookstove use in schools within Trans-Nzoia County.

This study also quantified the fuelwood saving associated with use of improved cookstoves to be 0.34 kg daily per student and an annual saving of 91.8kg per student. Regarding the financial savings, each student would save KSh.138 annually by a school switching from using a traditional to an improved cookstove. GHGs emission avoided due to the switch were also quantified to be having a global warming potential ranging $3.074 \times 10^{-5}$ to $8.861 \times 10^{-5}$ tCO$_2$eq per student. This translates to an annual global warming potential ranging $8.30 \times 10^{-3}$ to $2.4 \times 10^{-2}$ tCO$_2$eq per student. Such figures provide empirical evidence that could be used in promoting the scaling up of the improved cookstoves in schools.

In general, the study had achieved all the laid out objectives and also outlined how the results could be put into use especially for governing natural resources by relevant authorities hence ensuring sustainability in the fuelwood sector.

5.2. Recommendation

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

2. Policies regarding the need for schools to be using the improved institutional cookstoves should be formulated and strictly enforced. This will ensure that the scarce yet important forest resources are used efficiently and sustainably. This will ensure that the forests can continue providing vital ecosystem services to the people who depend on for their livelihood. Furthermore, enrolment should be used as criteria for registering new schools where school managers should demonstrate the ability to enroll more than 250 students. This is the enrolment
beyond which the per student fuelwood consumption does not significantly change.

3. The energy centers existent in some of the counties should be in the forefront in promoting energy related researches within the counties because each County has its own unique scenario. This will ensure that their unique energy needs are addressed hence sustainability in the energy sector.

4. Enhance awareness creation especially for the kitchen staffs on the importance of using the improved cookstoves as instructed by the stove manufacturers. This will ensure that their health is not compromised and also the potential fuelwood savings associated with these cookstoves is realized.

5.3 Areas of further research

1. Further research that will look into the moisture content of fuelwood so that the estimated fuelwood demand for schools, is not an over estimation.

2. Research on tree species that have multipurpose functions should be done. This will ensure that fruit producing trees and indigenous trees are not harvested for fuelwood as found in some clusters in the County.

3. Long-term monitoring of data from every institution would provide a broader overview of the fuelwood demand and supply dynamics hence more accurate data for fuelwood energy planning for schools in the County.

4. Research on factors influencing sustainable use of energy efficient cookstoves by kitchen staff should be carried out. This is important because during the study it was observed that schools used various cookstove combinations yet they had the energy-efficient one.
REFERENCES


## APPENDICES

### Appendix i: Questionnaire for Schools

**Questionnaires for Schools**

<table>
<thead>
<tr>
<th>Interviewers:</th>
<th>Interviewee:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>School:</th>
<th>Cluster:</th>
<th>Type: boarding/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Secondary</td>
</tr>
</tbody>
</table>

1. Enrollment by year

<table>
<thead>
<tr>
<th>Year</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
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<td>2008</td>
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<td>2010</td>
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<tr>
<td>2011</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td></td>
</tr>
</tbody>
</table>

2. Does the school use fuelwood for their heating and cooking purposes? Y/N

3. List sources and species of fuelwood used in order of the most used

<table>
<thead>
<tr>
<th>Species</th>
<th>Frequency/quantity of use</th>
<th>Source</th>
<th>Vendor/supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Total consumption and cost of fuelwood

<table>
<thead>
<tr>
<th>Species</th>
<th>Annual consumption (tons/yr)</th>
<th>Cost of fuelwood (KSh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td></td>
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</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. How often is the fuelwood delivered per term?

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Once a month</th>
<th>Once a term</th>
<th>Annually</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Estimated daily fuelwood consumption for schools (Kgs/day)…………………………

7. Mean per student consumption rate (Kg/cap/day)………………………………………..

8. Which type of cookstove do you use for cooking?

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Number</th>
<th>When installed</th>
<th>Cost (KSh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traditional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Semi-improved</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improved</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9. Why do you use the traditional and semi-improved cookstoves as your main stove?

10. Impact of cookstove change on total fuelwood consumption

<table>
<thead>
<tr>
<th></th>
<th>Direction of change</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semi-improved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved</td>
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</tbody>
</table>
Appendix ii: Questionnaire for fuelwood suppliers.

**Questionnaire for fuelwood suppliers**

<table>
<thead>
<tr>
<th>Interviewer:</th>
<th>Interviewee:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contact:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Where do you get your wood?

2. Do you source different species from different areas? Explain

3. Do you replant the trees that you have cut for fuelwood to ensure sustainability of these sources?

4. How much do you pay for the fuelwood at the source?

5. How much do you charge schools for a lorry/truck of fuelwood? (Tonnage, species)

6. What determines this cost?

7. How does the cost vary across the year?

8. Do you have a permit to sell fuelwood? Y/N

9. Where do you get the get permit from and for how much?

10. What are some of the challenges you experience during the permit application process?

11. What suggestions can you give to make this process easy?
Appendix iii: Ministry of Education interview schedule.

Ministry of Education Interview Schedule

<table>
<thead>
<tr>
<th>Interviewer:</th>
<th>Interviewee:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cluster:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Title:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Has any research been carried out either by the ministry or a student on fuelwood consumption in schools in Trans-Nzoia? If so, when was it done and what were the findings?
2. Are there any policies in the MoE on wood energy usage in schools? What is the MoE’s opinion on wood energy and energy conservation?
3. What is the MoE’s take on wood energy technologies? (funding and awareness creation)
4. The main sources of fuelwood are forests and farmlands, what has the ministry done considering that forest service has forbidden fuelwood from forests?
5. What are the main educational policies especially on upcoming new schools? (in terms of enrolment)
6. What are your recommendations on wood energy use and technologies adoption? There are numerous studies on woodfuel use in schools with cutting edge results. Is the ministry aware of such? Through what process will research influence MoE policy?
7. If the MoE has clear evidence of wood losses from key forestry resources to schools, and the enormous energy-saving potential of improved cookstoves, would it move to influence school managers to change? If so, how?
Appendix iv: Ministry of Energy interview schedule.

<table>
<thead>
<tr>
<th>Ministry of Energy Interview Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviewer:</td>
</tr>
<tr>
<td>Cluster:</td>
</tr>
<tr>
<td>Title:</td>
</tr>
</tbody>
</table>

1. Briefly elaborate the role of MoE in national/regional energy planning
2. Various surveys on woodfuel usage have been conducted in the past by various actors. How have these findings been used if at all?
3. Has any research been done either by the ministry or by other actors on fuelwood consumption in schools in Trans-Nzoia? When was it done and what were the findings?
4. What are the main policies on wood energy usage in schools, if any?
5. How have they been implemented if at all?
6. What has the ministry done with the current fuelwood ban from forests to ensure continued supply of fuelwood in learning institutions? (Is there a conflict between forests and energy?)
7. What has the ministry done to create awareness in schools on different technologies available that are more efficient in terms of reducing emissions and fuelwood consumption?
8. What are your recommendations on wood energy use and technology adoption to learning institutions especially during this period when the country has moved to County governments?
**Appendix v**: National Environment and Management Authority interview schedule.

<table>
<thead>
<tr>
<th>National Environment and Management Authorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviewer:</td>
</tr>
<tr>
<td>Cluster:</td>
</tr>
<tr>
<td>Title:</td>
</tr>
</tbody>
</table>

1. Has NEMA done any studies on how fuelwood consumption has affected environmental management in terms of forest destruction and emissions? When was this done and what were the findings?
2. What are the major policies on wood energy use and their implementation?
3. What are some of the major challenges that you have experienced during the implementation of these policies?
4. In your view, are these policies adequate to cushion forests from the effects of fuelwood consumption in learning institutions?
5. What are some of the management and conservation strategies that NEMA has put in place to ensure wood energy use is in harmony with the environment?
6. How has NEMA involved the learning institutions in environmental protection and conservation?
7. What are your recommendations on wood energy use and environmental protection especially as the country moves to County governments?
Appendix vi: List of traditional, English and Scientific names of tree species.

The table 12 below shows the traditional, English and scientific names of the tree species frequently used by sampled secondary schools in the County. This is because most of the names of these tree species were given in their traditional names by the kitchen staff during the study.

<table>
<thead>
<tr>
<th>Traditional name</th>
<th>English name</th>
<th>Scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue gum</td>
<td></td>
<td>Eucalyptus spp</td>
</tr>
<tr>
<td>Silk-oak</td>
<td></td>
<td>Grevillea robusta</td>
</tr>
<tr>
<td>Mexican cypress</td>
<td></td>
<td>Cupressuslusitanica</td>
</tr>
<tr>
<td>Mexican weeping pine</td>
<td></td>
<td>Pinus patula</td>
</tr>
<tr>
<td>Kumboboso/ Toboswet</td>
<td>Musine/ Croton</td>
<td>Croton megalocarpus</td>
</tr>
<tr>
<td></td>
<td>Broad leaved croton</td>
<td>Croton macrostachyus</td>
</tr>
<tr>
<td>Kukungu/ Kumunyenya</td>
<td>Acacia spp</td>
<td>Acacia etbaica</td>
</tr>
<tr>
<td></td>
<td>White thorn acacia</td>
<td>Acacia seyal</td>
</tr>
<tr>
<td></td>
<td>Red thorn</td>
<td>Acacia lahai</td>
</tr>
<tr>
<td>Kuntuoto</td>
<td>Bark-cloth Fig</td>
<td>Ficus natalensis</td>
</tr>
<tr>
<td>Kumulaha</td>
<td>Bush-willow tree</td>
<td>Combretum collinum</td>
</tr>
<tr>
<td>Kumsiopoo</td>
<td>Bitter leaf</td>
<td>Vernonia</td>
</tr>
<tr>
<td>Kumukhuyu</td>
<td>Sycamore tree</td>
<td>Ficus sycomorus</td>
</tr>
<tr>
<td>Kumusoola</td>
<td>Nile tulip/ Nile trumpet/ Siala Tree</td>
<td>Markhamialutea</td>
</tr>
<tr>
<td>Kumutamaywa</td>
<td>East African olive/ Elgon olive</td>
<td>Oleacapensis</td>
</tr>
<tr>
<td>Kumukomari</td>
<td>East African cordia</td>
<td>Cordia Africana</td>
</tr>
<tr>
<td>Omurembe</td>
<td>Abyssinian coral tree/ Red-hot-poker tree</td>
<td>Erythrina abysinica</td>
</tr>
<tr>
<td>Kumusituli/ Kumuchirisa</td>
<td>Nandi flame/ African tulip tree</td>
<td>Spathodea campanulata</td>
</tr>
<tr>
<td>Kumwandanda</td>
<td>Ozoroa</td>
<td>Ozoioainsignis</td>
</tr>
<tr>
<td>Avocado</td>
<td>Avocado pear</td>
<td>Persea Americana</td>
</tr>
<tr>
<td>Kumusemwa</td>
<td>Water-wood/ Water-berry tree</td>
<td>Syzygium cordatum</td>
</tr>
</tbody>
</table>

Source: Maundu and Tengnas (2005)