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Analysis of Cooking Fuels and Cooking Energy Demand in Rural Households

Sophy A. Ogalo[1] K.V. Rop[1]
[1]Strathmore University, Nairobi Kenya
Corresponding Author: ogalosophie@gmail.com

Abstract:- Approximately 92% of rural households in Kenya still rely on traditional biomass as their primary cooking fuel, which poses significant health risks, particularly for young children who are vulnerable to respiratory infections from smoke exposure. The government of Kenya, along with various non-governmental organizations, has been actively working to promote the adoption of cleaner cooking solutions, such as liquefied petroleum gas (LPG) and electricity, aiming to reduce reliance on biomass and improve public health and environmental outcomes. Despite increased electrification rates and population grow th, cooking practices in rural areas continue to depend heavily on biomass, notably firewood and charcoal. This study investigates the demand for cooking energy in rural households in Kenya, examining the energy consumption patterns of various fuels, including firewood, charcoal, LPG, and kerosene. Results show that biomass dominates the rural cooking landscape, leading to high levels of indoor air pollution and contributing to deforestation. Furthermore, the data highlights the benefits of transitioning to cleaner technologies, such as LPG and electric stoves, which offer significantly higher energy efficiency compared to traditional biomass fuels. With increased access to these alternatives, the study suggests that a shift towards cleaner fuels could improve health outcomes, reduce environmental impact, and create a pathway towards sustainable energy use for rural households. Targeted interventions are essential to accelerate this transition and promote sustainable energy practices.

Keywords: *Cooking Energy, Biomass, Clean Cooking, Rural Kenya, Energy Demand*

1. Introduction

Cooking energy is a critical aspect of daily life, with most households in Kenya relying on traditional fuels such as firewood, charcoal, and agricultural residues. These energy sources are deeply entrenched in the cultural and economic fabric of rural communities, primarily due to their availability and low upfront cost. Over 2.5 million rural communities rely on biomass for cooking, which includes animal dung, agricultural waste, and charcoal [1][2]. However, energy poverty significantly affects growth and well-being of rural Kenyans, yet energy is a necessary condition for social and economic advancement. For the vast majority of rural houses, biomass serves as their main energy source. Uncontrolled tree cutting occurs in rural regions due to an overreliance on unsustainable wood fuel, which is made worse by climate and rainfall variation.

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According to UNDP, Kenya's most central source of energy is fuel wood, accounting for over 70% of the total energy requirements for domestic needs [3]. Cooking energy can be classified into traditional which include wood, charcoal and agricultural residues and modern such as petroleum products and electricity. In Kenya majority of the households in rural areas rely completely upon fuel wood as the key source of domestic energy [4] [5]. This has largely been determined by the local availability, opportunity and transaction costs involved in accessing, collecting and utilization of the biomass fuels.

Despite the efforts by the Kenyan government and NGOs to promote cleaner cooking practices through policies and awareness campaigns, biomass remains the predominant cooking energy source in rural areas. This study aims to analyze cooking energy demand trends in rural households, focusing on fuel types, energy consumption, and the potential for transitioning to cleaner energy sources. By understanding these patterns, policymakers can develop targeted strategies to promote cleaner cooking solutions, reduce health risks, and improve energy sustainability for rural communities in Kenya.

The rest of this paper is organized as follows. Section 2 examines the types of cooking energy sources. Section 3 discusses the proportions of cooking fuels used in rural households. Sections 4 and 5 cover cooking fuel trends and energy demand, respectively. Finally, Section 6 concludes the study.

2. Types of Cooking Energy Sources

The primary sources of cooking energy in rural Kenya predominantly revolve around biomass, specifically fuelwood and charcoal. These traditional biomass sources play a crucial role in meeting the energy needs of rural households. Approximately 90% of rural households in Kenya rely on fuelwood as a fundamental energy source for cooking and heating [6].

2.1. Biomass Fuel

Biomass fuel primarily consists of organic materials such as firewood, charcoal, crop residues, and animal dung, which are readily available in rural settings [7][8]. In Kenya, biomass fuel, particularly firewood, is the most preferred and commonly used cooking fuel among rural households due to its affordability and accessibility [9]. The dominance of biomass fuel in rural Kenya is influenced by various factors, including cultural factors & financial constraints that limit the ability of households to afford cleaner alternatives.

2.2. Liquefied Petroleum Gas (LPG)

LPG has emerged as a cleaner cooking fuel alternative in rural Kenya, offering a more sustainable and environmentally friendly option compared to traditional biomass fuels like firewood and charcoal. The adoption of LPG for cooking in rural areas is influenced by various factors, including awareness campaigns, affordability, accessibility, and government policies aimed at promoting clean cooking practices [10] [11]. Efforts to raise awareness about the safe use of LPG and address financial barriers have been identified as crucial strategies to encourage wider adoption and sustained use of LPG in rural households [11].

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2.3. Kerosene

Kerosene has historically been a commonly used cooking fuel in rural Kenya, with many households depending on it for their cooking needs. However, the use of kerosene for cooking has been declining in recent years due to various factors. Economic factors, including increasing fuel costs and associated health expenses, have influenced the declining use of kerosene in rural households.

The Ministry of Energy of Kenya has been implementing policies to promote the use of cleaner cooking fuels and reduce dependence on traditional fuels like kerosene. These policies include initiatives to increase access to LPG, promote renewable energy sources for cooking, and enhance energy efficiency in households. The government aims to significantly increase the use of LPG for cooking by 2030, with the objective of improving health outcomes, reducing environmental impact, and fostering sustainable energy use in rural communities [12][13][14].

2.4. Electricity

In rural Kenya, electricity is not widely used as a source of cooking fuel compared to other energy sources like kerosene, firewood, and charcoal. Rural households in Kenya mainly rely on kerosene and electricity for lighting, while firewood remains the primary source of energy for cooking [15]. The limited use of electricity for cooking in rural areas can be attributed to various factors, including accessibility, affordability, and infrastructure challenges.

However, there is potential for increased adoption of electricity as a cooking fuel in rural Kenya through electrification initiatives. The Government of Kenya has been implementing rural electrification programs to extend electricity access to underserved communities. These initiatives play a crucial role in promoting sustainable energy use, enhancing human development, and spurring economic growth in rural areas.

3. Cooking Technologies used in Rural Households

Cooking technologies used in rural households in Kenya encompass a diverse range of traditional and modern methods. Traditional cooking practices in rural Kenya often involve the use of three-stone fire cook stoves that utilize biomass fuels like firewood and charcoal. These stoves are commonly used for preparing staple dishes such as ugali(a starchy meal) [16]. There are several cook stove technologies for each of the cooking energy sources in use in rural households.

3.1. Traditional Three Stone Cooking Fire

A three-stone cooking fire stove shown in figure 1(a) is one of the simplest and oldest methods of outdoor cooking, prevalent in the rural households in Kenya. Firewood, dried cow dung, crop residues & agricultural wastes are some of the most used sources of cooking fuels used with the technology.

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Figure 1: (a) 3-Stone Cooking Fire (b) Improved Firewood Stove. *Source: [17]*

Improved version of the traditional 3 stone fire stove that saves energy also exists as shown in figure 1(b) which uses less firewood than the open version.

3.2. Charcoal Stove

A charcoal stove is designed specifically for burning charcoal as a fuel source as shown in figure 2. Both traditional and improved versions of the charcoal stoves exist. The stoves are popularly known as 'Jiko' in Kenya.

3.3. Kerosone Stove

These kerosene stoves with wick-type burner, contain a refillable fuel tank at the bottom to hold kerosene which is used as fuel to cook as seen in figure 3.

3.4. LPG Stove

LPG stoves as shown in figure 4 typically feature one or two burners, offering quick and controllable heat, which is highly valued for reducing cooking time and improving indoor air quality.



Figure 2: Ordinary Jiko *Figure 3: Kerosene Stove* *Figure 4: 6kg LPG Cylinder*

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4. Percentages of Cooking Fuels used in Rural Households

Energy is a basic living resource as well as an industrial need. The definition of rural residential energy usage often includes cooking, lighting, appliances, and other home requirements. The economy and wellbeing of rural populations are significantly impacted by the use of energy in rural areas. At the moment, over 2.64 billion individuals in developing countries depend primarily on conventional biomass fuels for heating and cooking with 82% residing in rural areas [18]. Nearly 400 million people in China, one of the world's most populous developing country, rely significantly on conventional biomass energy, the most of whom live in rural areas [19]. Over 70% of energy use is still fuelwood and straw, with only a small portion coming from high-quality modern energy sources. This system of energy consumption increases CO_2 emissions, which affects the environment and human health [5,6].

A 2019 report by Kenya Continuous Household Survey Programme (KCHSP) revealed that, firewood remained the most common source of cooking fuel at 84.3% the rural areas. Electricity represented only 0.2% of the households' cooking energy source. Kerosene was used by 2.3% of the rural households while charcoal and Liquefied petroleum gas (LPG) represented 8.9% and 2.5 % respectively [22] as shown in Table 1. . The figures have been truncated to one decimal point, ideally the figures should add up to 100%. A comparison of these various types of fuels used in rural, urban and national level is illustrated in figure 5.

In table 1, "National" represents the average percentages of households using each type of cooking fuel across both rural and urban areas in the entire country. This national figure is calculated by combining data from both rural and urban households to give an overall view of fuel usage patterns across all households in the country.

Table 1: The Percentage of Households by Primary Source of Cooking Fuel

	Firewood	Electricity	LPG	Biogas	Kerosene	Charcoal	Animal dung	Agricultural Crop Residue	Other	Number of households
Rural	84.3	0.3	2.5	0.2	2.3	8.9	0.0	0.3	0.9	6,442,000
Urban	16.1	2.0	27.6	0.2	29.0	21.9	0.1	0.0	2.4	4,972,000
National	54.6	1.0	13.4	0.2	14.0	14.6	0.1	0.2	1.6	11,415,000

Source: Author modified from [22]

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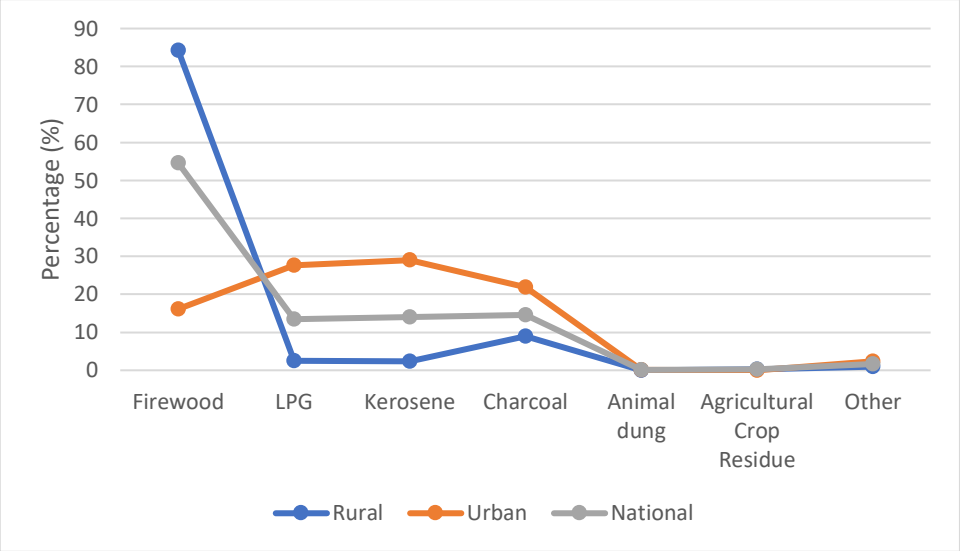

Figure 5: Comparison of Various Cooking Sources of Fuel

Previous studies and surveys by KNBS and CCAK have shown that the most common cooking fuel sources in the rural households are Fuelwood, Charcoal, LPG, Kerosene and Crop Residues as shown in Table 2 [8] [9] [10].

Table 2:Cooking fuel sources

Fuel	KIHBS 2005/2006	KIHBS 2015/2016	CCAK 2018/2019
Firewood	87.7	84.3	86
Charcoal	7.7	8.9	7
Gas/ LPG	2.7	2.5	6
Kerosene	0.7	2.3	0.7
Electricity	0.4	0.3	0
Biomass Residue	0.2	0.3	0
Grass	0.1	0	0
Biogas	0	0.2	0
Other	0.4	0.9	0.2

Figure 6 illustrates the distribution of cooking fuel sources in rural households in Kenya across three different periods: KIHBS 2005/2006, KIHBS 2015/2016, and CCAK 2018/2019 represented by the inner, middle, and the outer doughnut respectively. For easy visualization purposes, only three major fule sources, namely firewood, charcoal, and LPG, have been labelled in figure 6. It can be seen in figure 6 (inner doughnut) that the majority of rural households in 2005/2006 data relied heavily on firewood and charcoal due to their accessibility and affordability, while LPG and kerosene use were minimal. The middle doughnut in figure

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6 shows that firewood and charcoal remained the dominat sources of fuel in rural communities without a a shift in LPG and other sources of fuel. A noticeable but gradual shift can be seen in the outer doughnut of figure 6 where, even though firewood and charcoal remain dominant, there is a slight increase in the use of LPG. This shift indicates a growing interest in alternative energy sources. Also, there was a decline in kerosene as awareness of clean cooking solutions grows.

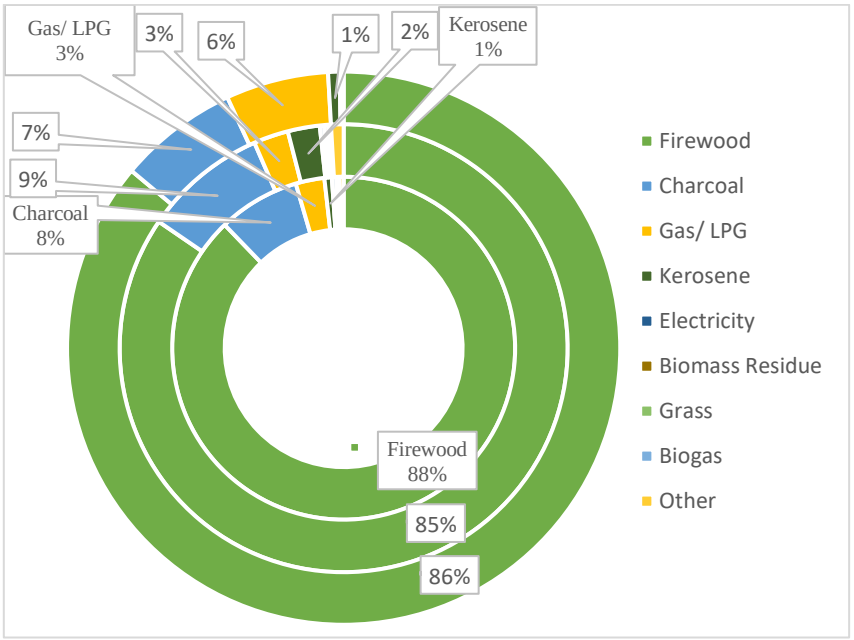

Figure 6: Comparison of Fuel Sources Percentages from the Three Surveys

The bar graph in figure 7 provides a comparative analysis of cooking fuel sources in rural Kenyan households across three survey periods. By plotting these data points side-by-side, we can clearly see that fuelwood and charcoal were consistently the dominant fuel sources across all three surveys, reflecting the prevalence in their use in rural households. However, the data reveal slight increases in the use of cleaner fuels like LPG and biomass residues from 2005 to 2019, indicating a gradual shift toward more sustainable energy sources. This gradual shift underscores the need for more initiatives to promote sustainable cooking solutions in rural communities in Kenya.

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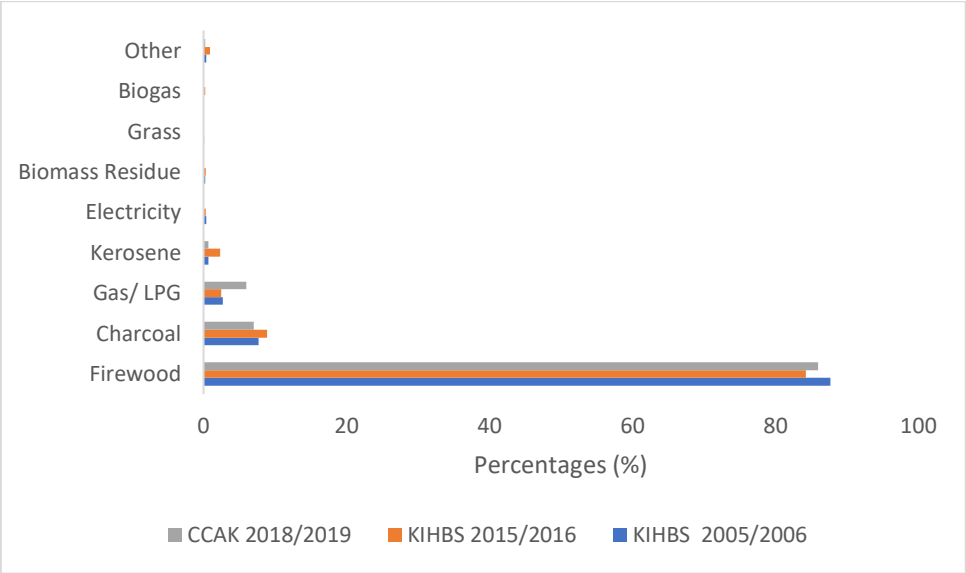

Figure 7: Trends in Cooking Fuel Sources in Rural Kenya

From the reports of Kenya Integrated Household Budget Surveys (KIHBS) by KNBS in 2005 & 2015 and the Kenya Cooking Sector study done in 2019 by CCAK, the data on cooking fuel technologies as used by the rural households was obtained as shown in table 3. The study done by CCAK in 2019 was consistent with the historical data from the KNBS reports, albeit the slight difference in percentages. The difference in the percentages was due to the definitions of improved and ordinary jiko. CCAK grouped the Kenya Ceramic Jiko as an improved jiko, unlike the KNBS survey reports which classified them as ordinary.

Table 3: Main Cooking Fuel Technologies used in the Rural Areas by Percentage

Main Cooking Fuel Technologies in the Rural Area by Percentage			
	KIHBS 2005/2006	**KIHBS 2015/2016**	**Clean Cooking Study Report 2019**
No of households	**5,151,105**	**6,442,000**	**7,419,542**
Technology	**%**	**%**	**%**
Traditional Stone Fire	78	71.7	71
Improved Traditional Stone fire	10.9	12.8	14.9
Ordinary Jiko	4	5.7	0.7
Improved Jiko	3.9	3.7	6.6
Kerosene Stove	2.3	2.2	0.7
Gas Cooker/LPG	0.6	2.4	5.9

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Electric Cooker	0.2	0.1	0
Other	0.3	0.9	0.2

5. Analysis and Discussion of Cooking Energy Demand used in Rural Households

The demand data used in this study for cooking fuels for rural households was adapted from the Kenya Cooking Sector study that was done by the Ministry of Energy through CCAK in 2018. It was a comprehensive report that involved data collection across the 47 counties in the country. The sample size was 1,696 households for the rural areas of Kenya. From the report, the following average annual consumption per household as shown in table 4 was obtained.

Table 4: Average Annual Consumption Per Household Per Year

Energy Sources	kg/yr
Fuelwood	1,362.00
Charcoal	411.00
LPG	47.00
Kerosene	78.00
Crop Residues	421.00
	2,319.00

Fuelwood is the most used at 1,362 kg/yr per rural household as shown in Table 4. Biomass plays a big role in the cooking sector in the households. Some other fuels were not included in the CCAK report as the they were found to be negligible.

Table 5: Table 5: Annual Energy Consumption per Household Source: Modified from [26]

Energy Consumption Per Household Per Year							
Fuel Source	**Fuel technology**	**Average consumption per household**	**% HHs using fuel**	**% HHs using technology**	**Fuel Consumption /Technology**	**% Distribution/ Technology**	**Energy Consumption /household**
		kg	**%**	%	**kg**	**%**	**Tonnes**
Fuelwood	Traditional Stone Fire	1,783.00	97%	71	1,473.73	63.6%	1.47
	Improved Traditional Stone fire			14.9	309.27	13.3%	0.31
Charcoal	Ordinary Jiko	411.00	42%	0.7	39.41	1.7%	0.04
	Improved Jiko			6.6	371.59	16.0%	0.37
LPG	LPG Cooker	47.00	15%	5.9	47.00	2.0%	0.05

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Kerosene	Kerosene Stove	78.00	7%	0.7	78.00	3.4%	0.08
		2,319.00		**100%**	**2,319.00**	**100%**	**2.32**

Table 5 shows the breakdown and calculations for the energy consumption data per household. The average consumption in the initial report was given per fuel type, therefore, a breakdown per fuel technology was necessary for the sake of this study. The technology used in cooking converts fuel into energy, as such, conversion factor like the heating value was used in evaluating the energy content of each fuel.

Table 6 gives more information for the annual energy consumption per household, per capita and for all the households in GJ and in tonnes. The heating values have been used to convert the tonnes of energy to Gigajoules. The conversion efficiency per technology is important in calculation of useful energy. Each household consumes around 40.29 GJ of cooking energy per year, which translates to 299.44 million GJ per year for all the rural households. Energy consumption per capita for the baseline period was calculated and was found to be 8.95 GJ. Fuelwood takes the highest contribution at 5.87GJ
per person. Biogas, electricity and bioethanol were assumed to be zero in the 2019 baseline period.

Table 6: Annual Energy Consumption in GJ

Fuel Source	Fuel technology	Energy Consumption /household	Heating Value	Energy Consumption Per household	Energy Consumption for All Households	Energy Consumption per capita	Conversion Efficiency	Energy Demand All Households
		Tonnes	**GJ/ton**	**GJ**	**Million GJ**	**GJ**	**%**	**kton**
Fuelwood	Traditional Stone Fire	1.47	14.8	21.81	162.11	4.85	17%	10,953.09
	Improved Traditional Stone fire	0.31	14.8	4.58	34.l02	1.02	19%	2,298.61
Charcoal	Ordinary Jiko	0.04	20.1	0.79	5.89	0.18	20%	292.91
	Improved Jiko	0.37	20.1	7.47	55.51	1.66	35%	2,761.74

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LPG	LPG Cooker	0.05	47.3	2.22	16.53	0.49	55%	349.32
Kerosene	Kerosene Stove	0.08	43.8	3.42	25.39	0.76	35%	579.72
		2.32		**40.29**	**299.44**	**8.95**		**17,235.39**

Figure 8 shows the breakdown of the energy consumed per household per technology used in cooking. The pie chart shows that 54% of total cooking energy consumption, equating to 21.81 GJ per year, is used by rural families who depend on traditional three-stone fires for cooking. LPG cookers are not as popular yet in the rural areas representing 6% of total energy at 2.22 GJ per household per year.

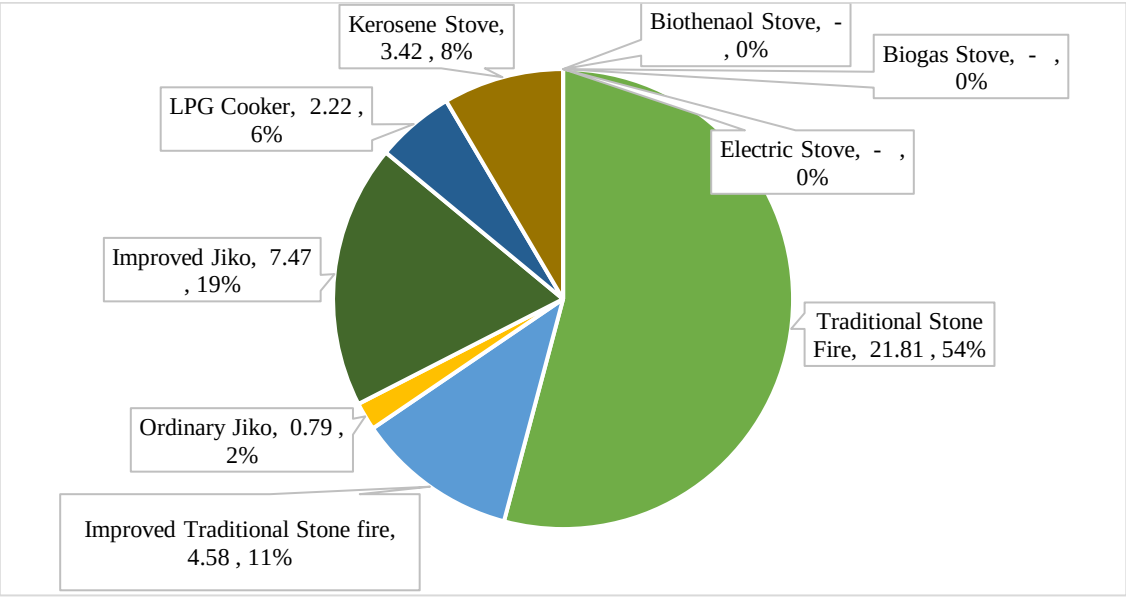

Figure 8: Cooking Energy consumption per household per year

Figure 9 shows the conversion efficiency data. The data on conversion efficiency across various cooking technologies reveals a significant disparity in how effectively each technology uses energy. Traditional stone fires, the most widely used method, have the lowest efficiency at just 17%. This means that a substantial portion of the energy in the fuel is lost as waste heat, rather than being used effectively for cooking. Moving to more advanced cooking technologies, we see a clear increase in efficiency. Among the most efficient technologies, the LPG cooker stands out with a conversion efficiency of 55%, which makes it a much more energy-efficient choice for households that can access and afford it. Electric stoves top the list with an impressive 80% efficiency, followed by bioethanol stoves at 65% and biogas stoves at 55%.

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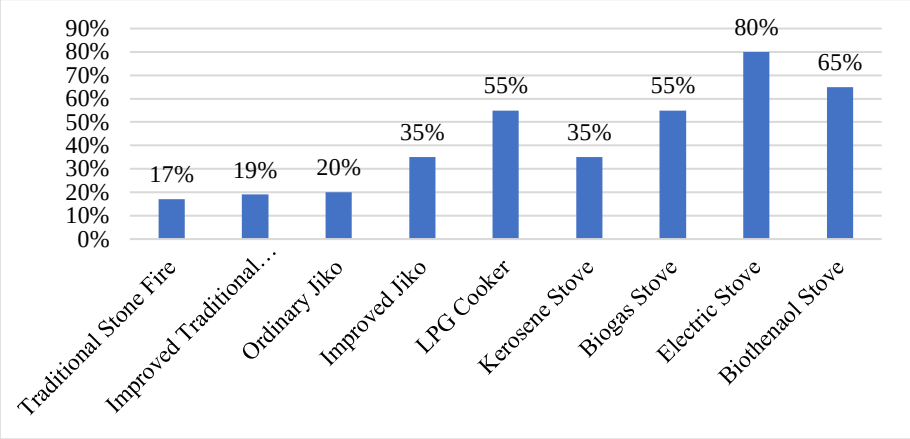

Figure 9: Conversion Efficiency of Cooking Technologies

6. Conclusion

The study of cooking energy demand in rural households in Kenya underscores the critical role of biomass, particularly fuelwood, in the daily lives of these communities. The average consumption of 1,362 kg per household demonstrates the continued dependence on traditional fuel which are associated with low energy conversion efficiencies. The prevalent use of traditional three-stone fires, with an efficiency of just 17%, indicates a substantial loss of potential energy that could otherwise contribute to improved cooking practices.

This analysis highlights the urgent need to transition to more efficient and sustainable cooking technologies. Although LPG cookers currently represent a smaller fraction of the energy landscape, their higher efficiency of 55% suggests that increasing their availability and affordability could significantly enhance energy use in rural areas. Furthermore, emerging technologies such as electric stoves and bioethanol stoves offer even greater potential efficiencies, with rates of 80% and 65%, respectively.

In conclusion, addressing the challenges of cooking energy demand requires a multifaceted approach. Strategies to promote cleaner cooking technologies, raise awareness of energy efficiency benefits, and support rural communities in making this transition are crucial. Such actions will not only improve energy utilization but also contribute to environmental sustainability and better health outcomes for rural households, leading to a more equitable and sustainable energy future.

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