Socio-economic drivers of household cooking energy use in Missenyi district, Tanzania

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ABSTRACT

Access to clean cooking energy remains a major development challenge in many developing countries, particularly in rural areas where households continue to depend heavily on traditional biomass fuels such as firewood and charcoal. Despite the implementation of various national policies and programs to promote clean cooking energy in Tanzania, the adoption of modern cooking fuels remains relatively low. This study examined the socio-economic factors influencing household cooking energy choices in Missenyi District, Tanzania. Specifically, the study sought to identify the primary cooking energy sources used by households and determine the socio-economic factors influencing the adoption of different cooking energy options. This study is anchored on the Energy Ladder Theory which explains how households transition from traditional to modern cooking energy sources as their socio-economic conditions improve. A cross-sectional research design was employed, and primary data were collected from 100 households in Kassambya, Nsunga and Kyaka wards using structured questionnaires. Descriptive statistics and a Multinomial Logistic Regression (MNL) model were used to analyze the data. The findings indicate that firewood (39%) and charcoal (29%) remain the dominant cooking energy sources, while liquefied petroleum gas (LPG) (22%), electricity (8%), and biogas (2%) are less commonly used. The regression results further reveal that household income, education level, age, household size, gender, and marital status significantly influence household cooking energy choices. Higher-income and better-educated households were more likely to adopt cleaner cooking fuels such as LPG and electricity, whereas lower-income and larger households relied predominantly on traditional fuels, particularly charcoal and firewood. The study concludes that socio-economic characteristics play a significant role in determining household cooking energy choices in rural Tanzania. It recommends strengthening household income-generating opportunities, expanding access to affordable clean cooking technologies, improving rural energy infrastructure, and implementing awareness programs that promote the health, environmental, and economic benefits of modern cooking energy. These interventions are essential for accelerating the transition towards sustainable and clean cooking energy in Tanzania.

Keywords: Cooking Energy, Household Energy Use, Multinomial Logistic Model, Sustainable Development Goals (SDG)

I. INTRODUCTION

Access to clean cooking energy is essential for human well-being, sustainable development, poverty reduction, and improved health outcomes. It significantly influences household livelihoods (Matavela et al., 2022; Kitole et al., 2023). As of 2021, approximately 2.4 billion people globally lack access to clean cooking energy, with 40% of these people residing in sub-Saharan Africa and 55% in developing Asia (International Energy Agency IEA et al., 2023). The global push for cleaner cooking solutions is aligned with the 7th Sustainable Development Goal (SDG), which aims to achieve universal access to sustainable modern energy by 2030 (United Nation Development Program [UNDP], 2020; Utouh & Kitole, 2024; Mhagama & Heriel, 2023). In sub-Saharan Africa, the challenge is particularly acute, with around 700 million people relying on traditional biomass, such as firewood and charcoal, for cooking (Anteneh, 2019; Onyeneke et al. 2019) Despite international and local efforts to promote cleaner alternatives, biomass use continues to rise due to persistent poverty, lack of infrastructure, and deep-rooted cultural preferences. Economic and political instability further complicates the region's ability to transition to modern cooking energy (IEA et al., 2023).

In Tanzania, the situation mirrors these broader trends, with the majority of households still using firewood (63.5%) and charcoal (26.2%) as their primary cooking fuels. In response, the Tanzanian government has launched the National Strategy for Clean Cooking Energy (2024-2034), aiming to increase the use of clean cooking energy from 10% to 80% by 2034. However, significant obstacles remain, including the high cost of clean energy alternatives, limited public awareness, and insufficient infrastructure (Citizen, 2021). To achieve universal access to affordable, reliable, sustainable, and modern energy by 2030, the government has implemented several measures, including expanding electricity access, establishing the Tanzania Rural Electrification Expansion Programme (TREEP), and promoting solar home systems and mini-grid markets (Rugaimukamu et al., 2023; Omari et al., 2020).

Household energy consumption in Tanzania, as in many developing countries, covers a range of activities, including cooking, lighting, space heating/cooling, and powering appliances (Abubakar et al., 2024). Despite the national efforts to promote clean cooking energy, many households in Missenyi District continue to rely on traditional fuels, which pose significant health risks due to indoor air pollution and contribute to environmental degradation, and therefore deepening the climate challenges in the area which also affects efforts to address the clean energy agenda (Kitole et al., 2024). Identifying the factors that influence household energy choices is crucial for informing policies and interventions aimed at promoting sustainable energy use. This study seeks to understand the factors influencing the choice of cooking energy sources in Missenyi District, Tanzania, where access to modern cooking energy remains a significant challenge. The study aims to provide insights that could help encourage cleaner and more sustainable cooking practices, aligning with national and global goals for energy sustainability.

1.1 Statement of the Problem

Access to clean and modern cooking energy remains a significant development challenge worldwide, particularly in developing countries where the majority of households continue to depend on traditional biomass fuels such as firewood and charcoal. According to the International Energy Agency (IEA et al., 2023), approximately 2.4 billion people still lack access to clean cooking energy, with sub-Saharan Africa accounting for the largest proportion of this population. The continued reliance on traditional cooking fuels contributes to indoor air pollution, respiratory illnesses, environmental degradation, deforestation, and greenhouse gas emissions, while also imposing substantial economic and time burdens on households, particularly women and children who are primarily responsible for fuel collection and food preparation. In Tanzania, despite various government initiatives aimed at promoting clean cooking energy, including the National Clean Cooking Energy Strategy (2024–2034), the majority of households still rely on firewood and charcoal as their principal cooking fuels. Although programmes such as the Tanzania Rural Electrification Expansion Programme (TREEP) have improved electricity access in many rural areas, the adoption of modern cooking fuels remains considerably low because of high equipment and fuel costs, inadequate supply infrastructure, low household incomes, and limited public awareness regarding the health and environmental benefits of clean cooking technologies (Omari et al., 2020; Rugaimukamu et al., 2023).

Previous empirical studies have identified several socio-economic factors that influence household cooking energy choices. For example, Mangula et al. (2019), Kitole et al. (2023), Mhagama and Heriel (2023), Kamuzora (2024), Debebe et al. (2023), and Egunjobi (2020) reported that household income, education level, household size, age, gender, and marital status significantly affect the adoption of modern cooking energy. However, these studies were conducted in different geographical settings with varying socio-economic conditions, levels of infrastructure development, and cultural practices. Consequently, their findings cannot be directly generalized to all rural districts of Tanzania.

Missenyi District presents unique socio-economic and geographical characteristics that may influence household cooking energy decisions. The district is predominantly rural, with agriculture serving as the primary economic activity, while access to modern energy infrastructure remains relatively limited. Despite these conditions, there is limited empirical evidence specifically examining the socio-economic determinants of household cooking energy choices within the district. This knowledge gap limits the ability of policymakers and development partners to design context-specific interventions that effectively promote the adoption of clean cooking energy. Therefore, this study was undertaken to examine the socio-economic determinants of household cooking energy choices in Missenyi District, Tanzania. The findings are expected to provide empirical evidence to support the implementation of Tanzania's National Clean Cooking Energy Strategy, contribute to the achievement of Sustainable Development Goal 7, and inform policies aimed at increasing the adoption of affordable, reliable, and environmentally sustainable cooking energy technologies in rural communities.

1.2 Research Objectives

i. To identify the major cooking energy sources used by households in Missenyi District.
ii. To examine the socio-economic factors influencing household cooking energy choices in Missenyi District.

II. LITRATURE REVIEW

2.1 Theoretical Review

2.1.1 Energy Ladder Theory

This study is anchored on the Energy Ladder Theory which explains how households transition from traditional to modern cooking energy sources as their socio-economic conditions improve. The theory, developed by Leach (1992) and further advanced by Hosier & Dowd (1987) proposes that households move progressively from traditional biomass fuels such as firewood and agricultural residues to transitional fuels such as charcoal and kerosene, and ultimately to modern fuels including liquefied petroleum gas (LPG), biogas and electricity as income and living standards increase.

The theory suggests that household income is the principal determinant of cooking energy choice because improvements in purchasing power enable households to acquire cleaner, safer, and more efficient cooking fuels. However, subsequent empirical studies have demonstrated that household energy transition is influenced by multiple socio-economic and institutional factors beyond income alone. Factors such as education, household size, accessibility of energy sources, fuel prices, cultural preferences, and availability of energy infrastructure also shape household cooking energy decisions (Kitole et al., 2023; Ang'u et al., 2023; Debebe et al., 2023).

Furthermore, recent studies have shown that many households practice fuel stacking**,** whereby traditional and modern fuels are used simultaneously rather than completely abandoning biomass fuels. This behaviour reflects the reality that cooking energy decisions are complex and depend on affordability, reliability, convenience, and cooking preferences (Mangula et al., 2019; Mhagama & Heriel, 2023). Consequently, while the Energy Ladder Theory provides an important conceptual foundation, household cooking energy choices should be understood within a broader socio-economic context. The theory is appropriate for this study because it provides a useful framework for examining how household socio-economic characteristics influence the choice of cooking energy among rural households in Missenyi District.

2.2 Empirical Review

2.2.1 Empirical Studies on Major Household Cooking Energy Sources

This objective focuses on identifying the dominant cooking energy sources used by households. Previous empirical studies indicate that traditional biomass fuels continue to dominate household cooking in most developing countries despite increasing promotion of clean energy technologies. Mangula et al. (2019) found that firewood and charcoal remain the principal cooking fuels among rural households in Tanzania due to their affordability and widespread availability. Similarly, Kitole et al. (2023) reported that biomass fuels account for the largest proportion of household cooking energy in urban and peri urban Tanzania, although the use of LPG is gradually increasing among higher-income households.

Comparable findings were reported by Mhagama and Heriel (2023), who observed that charcoal and firewood remain the dominant cooking fuels because many households face financial constraints and limited access to modern cooking infrastructure. Likewise, Debebe et al. (2023) found that households in rural Ethiopia continue relying on biomass fuels despite government efforts to promote cleaner energy technologies. These studies consistently demonstrate that household cooking energy use in developing countries remains dominated by traditional fuels.

Although previous studies have documented household cooking energy sources in various settings, little empirical evidence exists for Missenyi District. Therefore, this study seeks to identify the major cooking energy sources currently used by households within the district.

2.2.2 Empirical Studies on Socio economic Factors Influencing Household Cooking Energy Choices

Previous studies have consistently reported that household cooking energy choices are influenced by several socio economic characteristics. Mangula et al. (2019) found that household income significantly increases the adoption of LPG and electricity while reducing dependence on traditional biomass fuels. Similar findings were reported by Kitole et al. (2023), Ang'u et al. (2023), and Mperejekumana et al. (2021), who concluded that higher household income increases the likelihood of adopting cleaner cooking technologies.

Education has also been identified as an important determinant of household energy choice. Ishengoma and Igangula (2021) and Mangula et al. (2019) found that educated household heads are more likely to adopt modern cooking energy because they better understand the health, environmental, and economic benefits associated with cleaner fuels. Household size has similarly been found to influence cooking energy decisions. Egunjobi (2020) and Kitole et al. (2023) reported that larger households tend to rely on firewood and charcoal because these fuels are relatively cheaper when preparing food for many household members.

Demographic characteristics also affect household cooking energy choices. Mhagama and Heriel (2023) observed that older household heads are more likely to continue using traditional biomass fuels due to long-established cooking practices. Likewise, Qiu et al. (2022) found that female household heads are generally more willing to adopt cleaner cooking technologies because they are more exposed to indoor air pollution during cooking. Kamuzora (2024) further reported that marital status influences household investment decisions regarding modern cooking technologies.

Literatures demonstrate that household cooking energy choices are influenced by multiple socio-economic factors, including income, education, household size, age, gender, and marital status. While previous studies consistently identify these variables as important determinants, they also reveal that the magnitude and direction of their effects vary across countries and regions because of differences in economic development, infrastructure availability, energy markets, government policies, and cultural practices. Most previous studies have been conducted at national, regional, or urban levels, with relatively limited attention given to predominantly rural districts in Tanzania. Consequently, the existing literature provides limited evidence regarding the socio-economic determinants of household cooking energy

choices in Missenyi District, where household livelihoods, access to energy infrastructure, and socio-economic conditions differ from those examined in previous studies.

2.2.1 Research Gap

Although previous studies have substantially contributed to understanding household cooking energy choices in Tanzania and other developing countries, several knowledge gaps remain. First, many studies have focused on urban areas or national datasets, while evidence from rural districts remains limited. Second, existing studies report varying effects of household income, education, household size, and demographic characteristics on cooking energy choices, suggesting that these relationships are context-specific. Third, few studies have simultaneously examined the combined influence of socio-economic factors on household cooking energy choices within the context of Missenyi District. Therefore, there is insufficient empirical evidence to inform district-level implementation of Tanzania's National Clean Cooking Energy Strategy and other clean energy initiatives in rural communities. This study addresses this gap by analyzing the socio-economic determinants of household cooking energy choices in Missenyi District using a Multinomial Logistic Regression model. The findings provide context-specific evidence that can support policymakers and development partners in designing effective interventions aimed at promoting the adoption of clean and sustainable cooking energy in rural Tanzania.

III. METHODOLOGY

3.1 Research Design

The study employed a cross-sectional research design to gather data from households in Missenyi District, using stratified sampling to ensure a representative analysis of factors influencing household energy use (Kitole & Genda, 2024; Dimoso & Andrew 2021) Data were collected through field surveys in the selected villages, chosen for their accessibility and suitability for studying household cooking energy use. A total of 100 households were sampled, ensuring an appropriate balance between size and representativeness. The sample was calculated using Yamane's (1967) formula, commonly used for large populations, based on a total population of 97,919 households in the selected wards. This method ensured that the sample size was both efficient and reliable, allowing for the generalization of findings to the broader household population with confidence (Creswell, 2014; Cohen et al., 2018)

3.2 Study Area

This study was conducted in three wards of Missenyi District, located in the Kagera Region of Tanzania: Kassambya, Nsunga, and Kyaka. These wards encompass the villages of Bunazi, Nsunga, Kyaka, Mabuye, and Kassambya. Missenyi District spans 1,425 square kilometers and has a population of approximately 245,394, according to the National Bureau of Statistics (NBS, 2022). The main economic activities in the district include agriculture, livestock farming, fishing, and trade (Merumba et al., 2022; Jamaldin, 2024). Notably, Missenyi District has one of the highest per capita GDPs in the region, reflecting economic growth from TZS 2,767,397 in 2013 to TZS 3,068,050 in 2014, though it dropped slightly to TZS 2,677,439 in 2015 (NBS, 2022). Despite its economic development, financial services in the district are limited with only three banks (NMB, NBC, and CRDB) located in Bunazi, the district headquarters (Stanslaus & Mmari 2021)

Figure 2
Map of Missenyi district
Source: Missenyi District Council (2024)

3.3 Target Population

The target population comprised all households residing in the selected wards of Missenyi District. According to the National Bureau of Statistics (NBS, 2022), the selected wards contained approximately 97,919 households. Since cooking energy decisions are generally made at the household level, households constituted the appropriate unit of analysis.

3.4 Sample Size Determination

The sample size was determined using Yamane's (1967) sample size determination formula, which is appropriate for large finite populations

$$n = \frac{N}{[1 + N(e)2]}$$

Where:
n = required sample size;
N = target population size;
e = acceptable sampling error (0.10).

$$n = \frac{97919}{1 + 97919(0.1)2}$$
$$n = 100$$

Substituting the study population into the formula yielded a sample size of approximately 100 households, which was considered adequate for generating reliable estimates while remaining manageable within the available financial and logistical resources.

3.5 Sampling Procedure

A multistage sampling procedure was employed. In the first stage, Kassambya, Nsunga, and Kyaka wards were purposively selected because they represent the major rural settings within Missenyi District where dependence on traditional cooking energy remains common. In the second stage, villages within the selected wards were identified. Finally, households were selected using stratified random sampling to ensure that households from different geographical locations were adequately represented. This sampling strategy improved representativeness while minimizing sampling bias.

3.6 Data Collection Methods

Primary data were collected between 2024 through structured questionnaires administered directly to household heads or adult household members responsible for cooking decisions. The questionnaire collected information on household demographic characteristics, socio-economic conditions, and primary cooking energy sources. Before the main survey, the questionnaire was pre-tested in a community with similar socio-economic characteristics to assess clarity, consistency, and reliability. Necessary modifications were made before administering the final questionnaire. Trained research assistants assisted in data collection to ensure consistency and improve data quality.

3.7 Measurement of Study Variables

The dependent variable was household cooking energy choice, categorized into four mutually exclusive alternatives: electricity, charcoal, biogas, and liquefied petroleum gas (LPG). Independent variables included household income, household size, age of the household head, sex of the household head, education level and marital status.

Table 1

Description of variables used in the study

Variables	Types of variables	measurements	Expected relationship
dependent variable			
Cooking energy use	Categorical	Categories of household cooking energy use (Electricity, Charcoal, Biogas, and LPG)	
Independent variables			
Household Income	Continuous		positive (+)
Age	Continuous	Age of household head	positive (+)
Sex	Categorical	Sex of the household head	positive (+)
Household size	Continuous	Total number of person in household	positive (+)
Education level	Categorical	Education and awareness on household head	positive (+)
Marital Status	Categorical	Marital status of the household head	positive (+)

3.8 Data Analysis

Data were coded, cleaned, and analyzed using Stata Version 18. Descriptive statistics, including frequencies and percentages, were used to summarize respondents' socio-economic characteristics and the distribution of household cooking energy sources. To identify the socio-economic determinants of household cooking energy choices, a multinomial logistic regression model to analyze the effects of independent variables on the dependent variable, this in this case is the choice of household cooking energy sources. This statistical model is particularly useful when dealing with multiple discrete alternatives. It facilitated the identification and quantification of the factors influencing households' decisions regarding different types of cooking energy sources. This approach is similar to studies conducted by Mangula et al. (2019), Kitole et al. (2023), and Dimoso & Andrew (2021).

The multinomial logit model was chosen due to its capability to utilize the cumulative distribution function of the logistic distribution, making it well-suited for analyzing categorical dependent variables with more than two possible outcomes. It is a robust and effective tool frequently used in studies involving multiple-choice scenarios (Kitole et al., 2023; Kitole and Sesabo, 2022). The model allows for a clear understanding of the relationship between independent variables (such as income, education, household size) and the likelihood of selecting specific cooking energy types. The multinomial logit equation applied to explain the determinants of cooking energy choices among households is expressed as:

$$\log\left[\frac{\pi_j(x_i)}{\pi_k(x_i)}\right]=\alpha_{0i}+\beta_{ij}x_{1i}+\beta_{2j}x_{2i}+\ldots\ldots\ldots..+\beta_{pj}x_{pi}$$

Whereas j = 1,2, …..k

Additionally, the reduced form of the equation is expressed as:

$$\log\left(\pi_j(x_i)\right) = \frac{\exp(\alpha_{0i}+\beta_{ij}x_{1i}+\beta_{2j}x_{2i}+\ldots\ldots\ldots+\beta_{pj}x_{pi})}{1+\sum_{j=1}^{k-1}\exp(\alpha_{0i}+\beta_{ij}x_{1i}+\beta_{2j}x_{2i}+\ldots\ldots\ldots+\beta_{pj}x_{pi})}$$

For j=1,2,…,(k-1), and the parameters α and β will be estimated by the use of maximum likelihood. This Model was Chosen because the dependent variable has more than two unordered categories: firewood, charcoal, and others involved electricity, industrial gas, coal, generator, and solar and was preferred due to its straightforward computational process and its enhanced predictive capability in contrast to the Multinomial probit Model (Mhagama, &Heriel, 2023).

3.9 Ethical Considerations

Ethical principles were observed throughout the study. Respondents were informed about the purpose of the research before participation, and informed consent was obtained from each respondent. Participation was voluntary and respondents were assured that the information provided would remain confidential and would be used solely for academic research purposes. Personal identifiers were excluded during data analysis to protect respondents' privacy.

IV. FINDINGS & DISCUSSION

4.1 Demographic characteristics of Respondents

Understanding respondents' demographic characteristics is essential because household demographic and socio-economic conditions significantly influence cooking energy decisions. Table 2 presents the distribution of respondents according to age, sex, education level and marital status.

Table 2

Characteristics of the respondents

Variable	Categories	Frequency	Percentage
Age level	18-25	23	23%
	26-35	23	23%
	36-45	27	27%
	46 and above	27	27%
	Total	**100**	**100%**
Gender	Male	70	70%
	Female	30	30%
	Total	**100**	**100%**
Education level	primary education	19	19%
	secondary education	47	47%
	certificate/diploma	26	26%
	Bachelor degree and above	8	8%
	Total	**100**	**100%**
Marital status	married	78	78%
	other wise	22	22%
	Total	**100**	**100%**

Table 2 indicates that respondents were fairly evenly distributed across the four age groups. Respondents aged 36–45 years and those aged 46 years and above each accounted for 27% of the sample, while respondents aged 18–25 years and 26–35 years each represented 23%. This balanced age distribution provides adequate representation of economically active households involved in cooking energy decisions. Regarding sex, male-headed households constituted 70% of the respondents, whereas female-headed households accounted for 30%. This reflects the predominance of male-headed households within the study area.

Education levels varied considerably among respondents. Nearly half (47%) had attained secondary education, followed by 26% with certificate or diploma qualifications, 19% with primary education, and only 8% with bachelor's degrees or higher. These findings suggest that although basic education is relatively widespread, relatively few household heads have attained higher education. The majority of respondents (78%) were married, while the remaining 22% were single, divorced, or widowed. Marital status may influence household resource allocation and decision-making regarding investment in modern cooking technologies. Overall, these socio-economic characteristics indicate substantial variation among households, providing a suitable basis for examining factors influencing cooking energy choices.

4.1.1 Household Cooking Energy Sources Used in Missenyi District

The first objective sought to identify the major cooking energy sources used by households in Missenyi District.

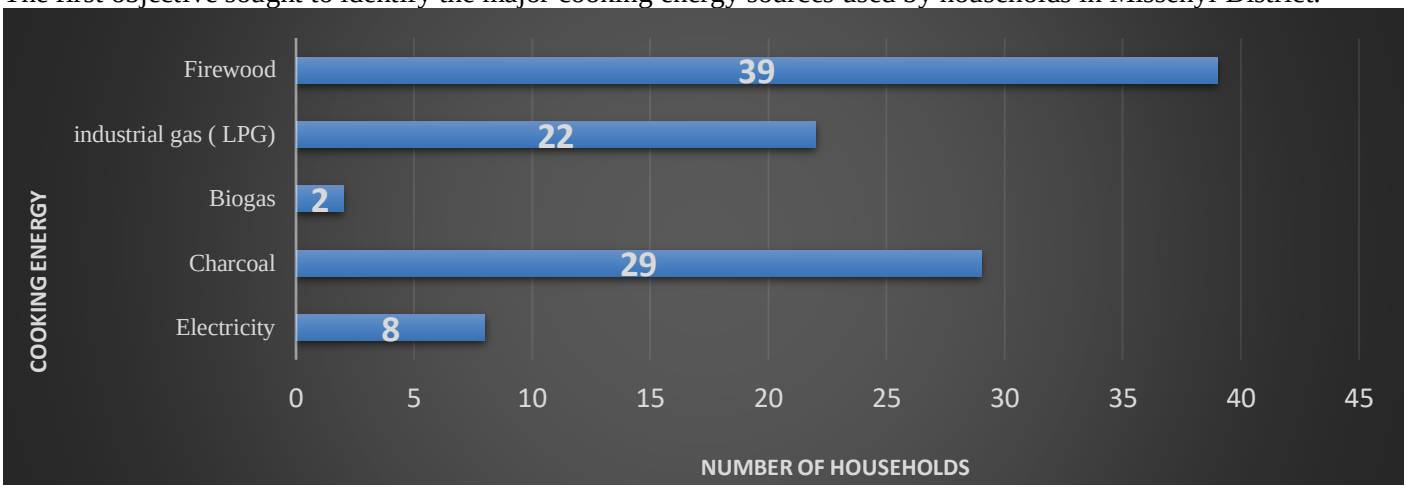

Figure 2
Energy use among households

Figure 2 indicate that firewood remains the dominant cooking fuel, used by 39% of surveyed households, followed by charcoal (29%). Liquefied Petroleum Gas (LPG) accounted for 22%, while electricity and biogas were used by only 8% and 2% of households, respectively. The continued dominance of firewood and charcoal demonstrates that traditional biomass remains the principal source of household cooking energy despite government efforts to promote clean cooking technologies. This finding suggests that affordability, accessibility, and familiarity continue to influence household energy decisions in rural communities. These findings are consistent with Mangula et al. (2019), who reported that firewood remains the primary cooking fuel among rural households in Tanzania. Similarly, Kitole et al. (2023) observed that biomass fuels continue to dominate household cooking despite increasing availability of cleaner alternatives. Comparable findings were also reported by Mhagama and Heriel (2023), who concluded that limited household income and inadequate energy infrastructure continue to constrain adoption of modern cooking fuels in Tanzania. The heavy reliance on traditional biomass has important policy implications because prolonged use of firewood and charcoal contributes to indoor air pollution, forest degradation, greenhouse gas emissions, and adverse health outcomes, particularly among women and children.

4.1.2 Objective Two: Socio economic Determinants of Household Cooking Energy Choices

The second objective examined the socio-economic factors influencing household cooking energy choices using a Multinomial Logistic Regression model.

Table 3
Multinomial logit on determinants of household's cooking energy use

Variables	Electricity	Charcoal	Biogas	Industrial gas (LPG)
Income	0.5217***	-0.4006***	-0.656**	0.2306*
	(0.0146)	(0.0406)	(0.0404)	(0.6606)
Household size	0.2764	0.0855**	0.6346	-0.3848
	(0.1932)	(0.0123)	(0.3280)	(0.24001)
Age				
26-35	0.49472	0.3747***	-0.6193**	0.4316**
	(0.3238)	(0.0455)	(0.1079)	(0.0152)
36-45	0.46747	0.42752**	-0.21973**	0.24151
	(0.2938)	(0.0811)	(0.01890)	(0.0607)
46 and above	0.57894**	0.23086**	-0.18564	0.25193
	(0.1238)	(0.0370)	(0.3753)	(0.50198)
Gender				
Female	-0.77055	-0.06874***	0.00687	-0.13798
	(0.30047)	(0.1795)	(0.21029)	(0.09651)
Education level				
Secondary education	0.25418	-0.10937	0.1875	0.2291
	(0.5456)	(0.17955)	(0.1235)	(0.6376)
Certificate/diploma	0.10579*	-0.12558	0.44155	0.06861*
	(0.03613)	(0.56107)	(0.0371)	(0.07951)

Bachelor degree and above	0.06586**	-0.19331**	0.00138	0.09294**
	(0.01636)	(0.0682)	(0.0081)	(0.02673)
Marital status				
Married	0.17666**	0.25526	-0.7593	0.19626**
	(0.03164)	(0.14008)	(0.472)	(0.01272)
Observation	100			
LR ch2 (40)	111.63			
Prob>Chi 2	0.0000			
Pseudo R2	0.4167			

Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

The overall model was statistically significant (LR $\chi^2 = 111.63$; $p < 0.001$), indicating that the explanatory variables jointly explain household cooking energy choices. The model produced a Pseudo R^2 of 0.4167, suggesting satisfactory explanatory power for household energy choice behaviour. Household Income: Household income significantly influenced cooking energy choices. Higher household income increased the probability of adopting electricity ($p < 0.01$) and LPG ($p < 0.10$) while significantly reducing reliance on charcoal ($p < 0.01$) and biogas ($p < 0.05$). This finding supports the Energy Ladder Theory, which argues that households shift towards cleaner and more efficient energy sources as income increases. The finding is consistent with Mangula et al. (2019), Kitole et al. (2023), Ang'u et al. (2023), and Mperejekumana et al. (2021), who similarly found that household income is among the strongest predictors of clean cooking energy adoption. Higher incomes increase households' purchasing power, enabling them to afford modern cooking appliances and cleaner fuels.

Household Size: Household size positively and significantly influenced charcoal use ($p < 0.05$). Larger households were more likely to depend on charcoal than smaller households. This finding agrees with Egunjobi (2020), Mangula et al. (2019), and Kitole et al. (2023), who observed that larger households often select relatively cheaper cooking fuels because they prepare larger quantities of food and face greater energy expenditure. Age of Household Head: Age significantly influenced cooking energy choices. Household heads aged between 26 and 45 years showed a greater likelihood of using charcoal, while household heads aged 46 years and above were significantly more likely to use electricity alongside charcoal.

These findings are consistent with Mhagama and Heriel (2023) and Debebe et al. (2023), who reported that older household heads often maintain traditional cooking practices because of long-established behavioural patterns and familiarity with biomass fuels. However, increased economic stability among older households may also facilitate partial adoption of modern cooking energy. Gender: Gender plays a significant role in the use of charcoal, with female-headed households being less likely to use charcoal ($p < 0.01$). Education level is another important factor, with households whose heads have a bachelor's degree or higher being more likely to use electricity and LPG ($p < 0.05$ for both), but less likely to use charcoal ($p < 0.05$). This finding suggests that higher educational attainment is associated with a preference for modern energy sources

This finding agrees with Kitole et al. (2023) and Qiu et al. (2022), who argued that women are generally more aware of the health consequences associated with biomass smoke because they are primarily responsible for household cooking activities. Consequently, female household heads may show greater willingness to adopt cleaner cooking technologies whenever economic conditions permit. Education Level: Education significantly influenced household cooking energy choices. Households headed by individuals with certificate, diploma, bachelor's degree, or higher qualifications were more likely to adopt electricity and LPG while reducing reliance on charcoal.

This finding supports previous studies by Mangula et al. (2019), Ishengoma and Igangula (2021), Kamuzora (2024), and Mperejekumana et al. (2021), which found that education enhances awareness of the economic, environmental, and health benefits associated with clean cooking energy. Educated households are therefore more likely to invest in modern cooking technologies. Marital Status: Marital status significantly influenced household cooking energy decisions. Married households were more likely to adopt electricity and LPG than unmarried households. This finding suggests that married households may possess relatively greater economic stability and stronger household decision-making structures that facilitate investment in improved cooking technologies. Similar observations were reported by Kamuzora (2024), who found that household demographic characteristics significantly influence household energy decisions.

The findings demonstrate that household cooking energy choices in Missenyi District are primarily determined by socio-economic characteristics. Household income and education emerged as the strongest predictors of modern cooking energy adoption, while larger households continued to rely on charcoal because of affordability considerations. Age, gender, and marital status also significantly influenced household energy choices. Despite ongoing government efforts to promote clean cooking energy, firewood and charcoal remain the dominant cooking fuels among rural households, indicating that substantial barriers to clean energy adoption persist. These findings provide empirical

evidence for designing policies that improve household incomes, expand clean cooking energy infrastructure, strengthen public awareness, and increase affordability of modern cooking technologies in rural Tanzania.

V. CONCLUSION & RECOMMENDATION

5.1 Conclusion

This study examined the determinants of household cooking energy use in Missenyi District, Tanzania, with a focus on socio-economic factors such as income, household size, age, gender, and education level. The findings revealed that income and education are critical drivers for the adoption of modern, cleaner cooking fuels such as LPG, while traditional fuels like charcoal remain prevalent among lower-income and larger households. The study also found that female-headed households are less likely to use traditional fuels, highlighting gendered differences in energy preferences. Age was also found to be a significant factor, with older household heads more likely to rely on traditional energy sources. These insights underline the need for targeted interventions to promote the adoption of clean energy sources and reduce the negative health and environmental impacts associated with traditional cooking fuels.

5.2 Recommendations

Given these findings, several policy recommendations are proposed to improve access to and adoption of modern cooking energy sources. Firstly, increasing financial support and credit access for lower-income households can facilitate the transition to cleaner energy sources like LPG. Financial incentives, such as subsidies or low-interest loans for purchasing modern cooking equipment, could make LPG more affordable and accessible, especially for poorer households.

Secondly, awareness campaigns highlighting the health benefits of clean energy and the risks associated with traditional biomass fuels should be strengthened, especially in rural areas. These campaigns should focus on educating households about the long-term health benefits of using modern fuels and how these can contribute to reducing respiratory diseases caused by indoor air pollution. Thirdly, investing in infrastructure to enhance the availability and accessibility of LPG and other modern fuels in rural areas is crucial. The government and private sector should collaborate to develop supply chains for cleaner fuels, particularly in underserved regions where traditional biomass fuels dominate. This includes expanding the distribution networks for LPG and ensuring that refueling stations are easily accessible to rural households.

Lastly, **g**ender-sensitive policies should be developed to support female-headed households in transitioning to cleaner cooking energy. Since women are disproportionately affected by the health risks of traditional biomass fuels, providing targeted support and incentives for female-headed households to adopt modern fuels can lead to improved health outcomes for women and children. Additionally, integrating energy-related training and education into women's empowerment programs can further increase their capacity to make informed energy choices. Therefore, addressing these socio-economic barriers, policymakers can significantly enhance the adoption of cleaner energy sources, contributing to improved health outcomes, environmental sustainability, and economic development in Missenyi District and beyond.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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