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Determinants of Clean Cooking Fuels in Tanzanian Households

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Determinants of Clean Cooking Fuels in Tanzanian Households

A thesis presented

By

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Dedication

To my beloved family who have always supported me in my academic and life endeavors.

To the millions of people all over the world who are suffering from lack of access to clean cooking fuels and technology, especially women and children.

And most of all, to the Almighty Lord, God our Savior.

This Thesis is dedicated to you.

Acknowledgement

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GOD BLESS YOU ALL

Abstract

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This research examines the key factors influencing Tanzanian households in their adoption of clean cooking fuels, addressing an essential development challenge tied to public health and gender equality. By employing a mixed-methods framework, the study combines quantitative analyses, utilizing multinomial logit and probit regression models on household survey data from the Tanzania National Bureau of Statistics, with qualitative insights drawn from academic literature. The analysis identifies critical determinants of fuel choices, including financial resources, access to electricity, infrastructure development, cultural practices, and socio-demographic factors such as education level, gender, and household composition.

The findings demonstrate the importance of financial support mechanisms, such as microloans and credit schemes, in increasing accessibility to clean cooking technologies. Expanding rural electrification and implementing widespread awareness campaigns to address the health and environmental impacts of traditional cooking fuels are highlighted as key measures. Policy recommendations advocate for subsidizing clean fuel technologies, strengthening energy infrastructure, and integrating culturally appropriate education initiatives to tackle barriers like affordability, safety concerns, and deeply rooted cultural norms.

Keyword: Clean cooking fuels, Energy, Tanzania, Health, Gender, Household
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List of abbreviations

Sub - Sahara Africa

IEA - International Energy Agency

SDGs - Sustainable Development Goals

LPG - Liquefied Petroleum Gas

PM2.5 - Particulate matter that have a diameter of less than 2.5 micrometers

WHO - World Health Organization

ICS - Improved Cook Stove

MNL - Multinomial Logit

IASES - Impact of Access to Sustainable Energy Survey

WHO - World Health Organization

IEA - International Energy Agency

Chapter 1. Introduction

1.1 Background

Access to clean cooking fuels is a critical issue affecting millions of households in developing countries, including Tanzania. The heavy reliance on traditional energy sources like firewood, charcoal, and agricultural residues for cooking has significant implications for health and socio-economic development. In Tanzania, the majority of households, particularly in rural areas, continue to use these traditional cooking fuels, leading to severe indoor air pollution and associated health risks. These risks predominantly impact women and children, who often spend extended periods near cooking stoves. As a result, a dedicated Sustainable Development Goal (SDG) has been established to address this issue: SDG 7, which aims to ensure universal access to affordable, reliable, and sustainable energy by 2030, with clean cooking fuels being a key component of achieving this goal.

The International Energy Agency (IEA) (2023) highlights that access to clean cooking fuels remains critically low in sub-Saharan Africa, with fewer than 20% of the population in 29 countries having access. In 2022, the number of people without access reached nearly 990 million. The heavy dependence on traditional cooking fuels in the region has severe consequences for health and productivity, disproportionately affecting women and children.

The lack of clean cooking fuels has resulted in adverse health impacts for people living in developing countries. According to the World Health Organization (WHO, 2023), around 2.3 billion people worldwide, representing about a third of the global population, use open fires or inefficient stoves fueled by biomass, kerosene, or coal, leading to harmful household air pollution. The World Bank (2019) reports that indoor air pollution from such sources causes more than 4 million premature deaths annually, half of which are children under the age of five.

Indoor pollution caused by traditional cooking fuels deserves special attention because its effects can be both immediate and severe. Unlike outdoor pollution, which often reveals its impacts over a longer period, indoor pollutants can quickly lead to health issues such as respiratory problems and allergic reactions.

Addressing indoor pollution is crucial not only for immediate health benefits but also for improving overall quality of life.

A research conducted by Dzioubinski and Chipman (1999) highlights that nearly 90% of household energy consumption is dedicated to cooking and water heating. This emphasizes the importance of household fuel selection for both families and policymakers.

Access to clean cooking fuels in Tanzania is notably limited with just 9.2% of the entire population (World Development Indicators, 2022). In urban areas like Dar es Salaam, charcoal remains the primary cooking fuel, while rural communities largely depend on firewood. Cooking stove-related incidents are common, with approximately one in 25 households reporting serious accidents each year (IASES, 2021/22). Enhancing access to clean cooking fuels is closely tied to better health outcomes, increased educational prospects, and greater environmental sustainability.

A 2023 report titled Unlocking Clean Cooking Pathways by the World Bank Group and ESMAP identified Tanzania as one of the top 20 countries with the largest deficits in access to clean cooking fuels and technologies. In response, several policies and strategies have been introduced, including the 2024–2034 National Clean Cooking Strategy by the Tanzanian government.

1.2 Key Metrics for Access to Clean Cooking Fuels in Tanzania

Figure 1 illustrates the distribution of households across regions in Mainland Tanzania by their primary type of cooking stove. The data reveal that a significant portion of households still depends on traditional cooking methods. Additionally, Figure 2 presents trends in access to clean cooking fuels and technologies in Tanzania from 2000 to 2022, which have remained relatively low nationwide.

Fig 1: Percentage of Households by Region and Main Cooking Stove by Type of Fuel and Improved Efficiency, Mainland Tanzania, IASES 2021/22

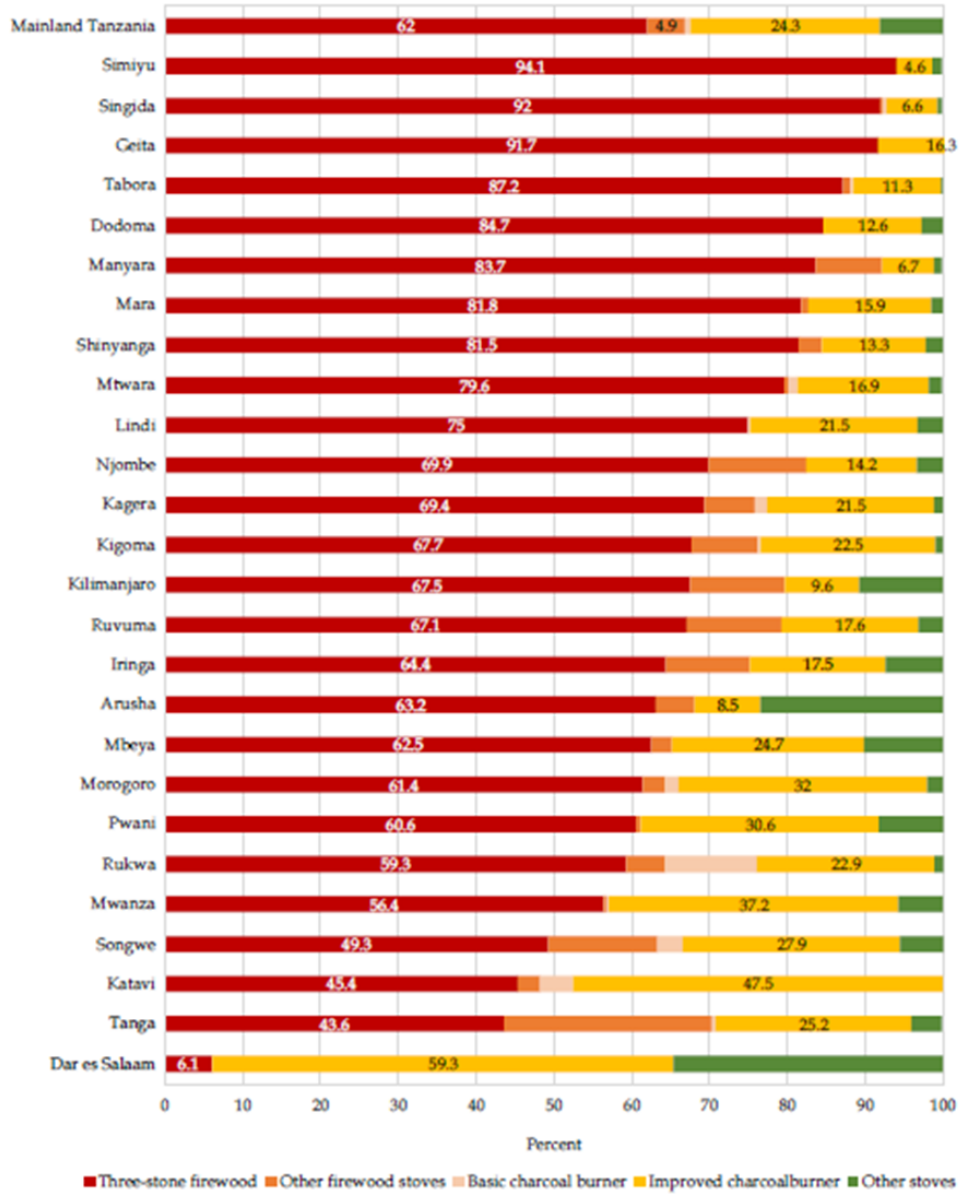
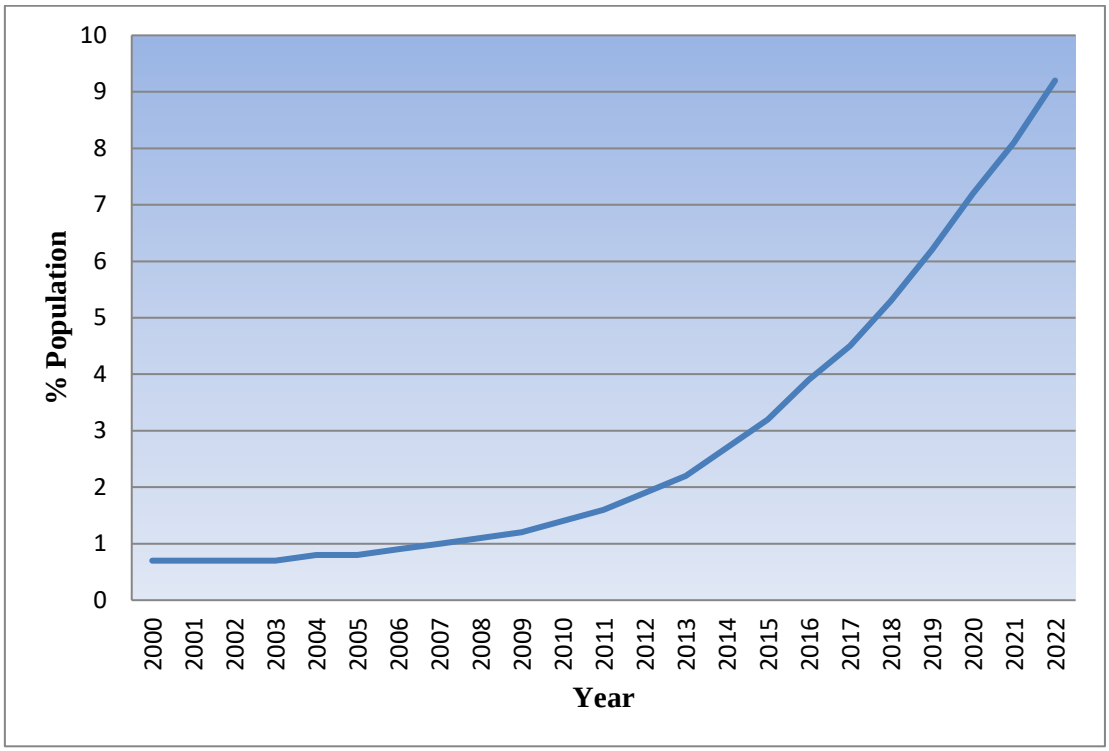


Fig 2: Trends in access to clean cooking fuels in Tanzania from 2000 – 2022



Source: Drawn by the author from data provided by the World Development Indicators.

1.3 Purpose of the Research

The aim of this study is to examine the key factors influencing household decisions regarding their choice of cooking fuels and to understand the trends shaping these preferences.

1.4 Research question

What are the primary socio-economic, cultural, and environmental factors that shape households' choices in selecting specific cooking fuels as their primary energy source?

1.5 Structure of the thesis

The rest of the paper is as follows: Chapter 2 reviews previous research, while Chapter 3 outlines the methodology used for data analysis. Chapter 4 presents the findings of the study, followed by a detailed discussion in Chapter 5. Chapter 6 offers the conclusion, and Chapter 7 provides policy recommendations. Finally, Chapter 8 contains the bibliography.

Chapter 2. Literature review

Many studies have investigated access to clean energy technologies, particularly concerning cooking fuels and electricity. Nevertheless, there is a significant lack of research specifically addressing clean cooking fuels within the Tanzanian context. The United Republic of Tanzania's National Clean Cooking Strategy highlights this issue, emphasizing that inadequate research on clean cooking solutions poses a significant challenge. This results in a lack of data, a limited understanding of current trends in clean cooking solutions usage, and an inability to develop effective strategies to promote their adoption in the country.

2.1 The concept of Clean Cooking

"The International Energy Agency (IEA) in 2023 defines clean cooking access as 'a household that has reliable access to and uses, as their primary cooking means, fuels and equipment that significantly limit or avoid the release of pollutants harmful to human health,' as stated in its special report titled A Vision for Clean Cooking Access for All.

The World Health Organization (WHO) Guidelines of 2021 assess clean fuels and technologies based on their levels of fine particulate matter (PM2.5) and carbon monoxide (CO) emissions. Fuels and technologies are considered clean if they comply with specific air quality standards, which include limits on the concentration of these pollutants in the air. In this context, this study defines clean cooking solutions as those that minimize harm to human health and the environment. These include options such as electricity, biogas, liquefied petroleum gas (LPG), ethanol stoves, and solar ovens."

2.2 Overview of Previous Studies on Access to Clean Energy Technologies

2.2.1 Socio-demographic and economic determinants of cooking fuel choice

A study by Odame and Amoah (2023) found that household wealth, size, educational level, and the age of household heads are key socio-demographic and economic determinants of clean cooking fuel usage across 33 countries in Sub-Saharan Africa. Mangula et al. (2019) in rural Tanzania found that household size and the age of household heads significantly influenced the choice between charcoal, firewood, and LPG. Older heads of households preferred charcoal and firewood, while younger heads leaned towards LPG. Wei and Lin (2024) found that greater socio-economic development

encourages the adoption of clean cooking fuels, particularly gas, highlighting the role of economic empowerment. Similarly, Rahut et al. (2016), using multinomial logit models, showed that female-headed households, those with higher education and wealthier urban households are more likely to choose modern energy sources like LPG and electricity over solid fuels.

2.2.2 Gender and cultural influences on clean cooking fuel adoption

The study by Yan et al. (2024) showed that internet access can facilitate the adoption of clean energy, particularly for female-headed households, by improving access to information and empowering women to make informed energy choices. Mperejekumana et al. (2024) also highlighted that women, despite their significant role in energy access, are often marginalized in decision-making, particularly in rural areas. This affects their ability to influence the transition to cleaner energy sources. Ishengoma and Igangula (2021) identified safety concerns around LPG as a barrier to its adoption in Tanzania, particularly among households more culturally inclined to use firewood or charcoal. Cultural factors, such as the need for large cooking pots or specific temperatures for traditional foods like injera or ugali, often discourage the adoption of modern stoves, as noted by Mperejekumana et al. (2024). Additionally, some communities reject alcohol-based energy sources due to religious beliefs.

2.2.3 Barriers to Clean Cooking Fuel Adoption

Mangula et al. (2019) identified high installation and operating costs, along with a lack of training on modern cooking stoves, as key barriers to the adoption of LPG and electricity in rural areas. A study by Mhache (2021) revealed that the low cost and high availability of charcoal in Dar es Salaam made it the predominant cooking fuel, with 75.9% of households relying on it despite the availability of alternative cleaner fuels. Ishengoma and Igangula (2021) emphasized that safety concerns about LPG are a major barrier to its adoption. Increased public awareness about the safety and benefits of LPG use is needed to overcome this issue. Aemro et al. (2021) suggested that affordability remains a key constraint for rural households, as energy-efficient electric stoves are more expensive than improved cook stoves (ICS), making ICS a more accessible option for many households. Makonese et al. (2018) argued that access to electricity does not always lead to the abandonment of traditional cooking fuels, suggesting that practical factors, such as cost and availability, still play a major role in household energy decisions. Mperejekumana et al. (2024) found that while ICSs are more efficient than traditional

stoves, their adoption faces challenges in terms of cost and the potential health and environmental benefits they offer compared to cleaner alternatives like LPG.

2.2.4 Empirical review

Rahut et al. (2016) used the multinomial logit model and the Probit model to show that urban, wealthier, and female-headed households are more likely to adopt clean energy sources like LPG and electricity. Similarly, Kulindwa et al. (2018) used a multinomial logit model in rural Tanzania and found that offering multiple types of ICS led to higher adoption rates, while Akter et al. (2023) employed an instrumental variable approach in India and found that improvements in electricity reliability were positively associated with the transition to cleaner cooking fuels. These findings highlight the models' capability to identify preferences in cooking fuels for different household types.

This study will employ multinomial logit regression and probit regression to analyze the factors influencing household choices of cooking energy in Tanzania, incorporating variables from previous research alongside less commonly studied factors. The study aims to investigate households' willingness to transition to alternative energy sources and to identify barriers to this shift.

2.2.5 Specific Gaps in Existing Research

Despite the growing body of literature on clean cooking fuel adoption, significant gaps remain, particularly in the Tanzanian context. Much of the existing research, such as Rahut et al. (2016) and Mangula et al. (2019), focuses on socio-economic factors like income, education, and urbanization as primary determinants of energy transitions. While these studies provide valuable information, they often overlook the cultural and behavioral dimensions influencing household energy decisions. For instance, beliefs in the insect-repelling properties of smoke from traditional stoves or cultural preferences for cooking methods tied to staple foods like ugali remain underexplored. These norms can act as significant barriers to adopting clean cooking fuels, even among households with the financial and infrastructural means to transition.

Additionally, while the energy ladder theory provides a foundational framework for understanding energy transitions, it often assumes a linear progression from traditional to modern fuels as household income increases. This assumption fails to account for the

persistence of traditional fuel use among middle and high-income households due to reliability issues with electricity or safety concerns around LPG. Furthermore, limited research examines how access to services, such as financial institutions, interacts with cultural and economic barriers to influence energy transitions. By addressing these gaps, this thesis offers a clearer understanding of the determinants of clean cooking fuel adoption, providing insights that extend beyond the conventional focus on income and education.

This study seeks to address gaps in current research by analyzing household data to examine behavioral shifts, identify progress, and uncover persistent challenges. It aims to provide a deeper understanding of the obstacles to adopting cleaner cooking fuel alternatives in Tanzania. Ultimately, the findings aim to support the development of strategies that enhance household well-being and improve public health.

Table 1: A comparative review of this study and previous literature

Author/s	**Study area and time**	**Methodology**	**Key finding**
Odame and Amoah (2023)	Sub-Saharan Africa, 2010 - 2020	Ordered Probit Regression	Approximately 67% of households cook indoors, and 86% rely on fuels that produce smoke, exposing them to significant health risks.
Mangula et al. (2019)	Tanzania,	Multinomial logit model	The study concludes that, alongside household income, education, age, occupation, and family size are key factors influencing cooking fuel choices in rural Tanzania.
Wei and Lin (2024)	Global, 2000 - 2020	Probit Model	Economic growth, infrastructure improvements, education, and global collaboration are crucial for reducing disparities in household cooking energy use.
Yan et al. (2024)	China, 2018	Probit model	Internet access broadens information access, supports off-farm employment, fosters social connections, and promotes clean energy adoption, especially in rural women-led households.

Mperejekumana et al. (2024)	Sub-Sahara Africa	An analysis of key articles, reports, research papers, and various online sources.	The widespread adoption of improved cook stoves is obstructed by multiple factors, such as cultural beliefs, financial limitations, lack of awareness, technical and logistical barriers, and insufficient policy support.
Rahut et al. (2016)	Ethiopia, Malawi and Tanzania , 2012 - 2013	Multinomial logit model	Households with greater financial resources are less dependent on traditional cooking fuels
Kulindwa et al. (2018)	Tanzania,	Multinomial logit model	Households offered multiple types of improved cook stoves (ICS) had higher adoption rates (48%) compared to those provided with only one type (30%), with charcoal and firewood-compatible stoves being the most popular (80%), promoting ICS should focus on offering choices, extending credit, and aligning sales with agricultural income cycles.
Aemro et al. (2021)	Sub-Saharan Africa	An analysis of key articles, reports, research papers, and various online sources.	Electric cook stoves, compared to traditional wood fuel stoves, can significantly reduce energy use, eliminate CO2 emissions when powered by renewable energy, lower life cycle costs, and prevent harmful PM2.5 emissions in households annually.
Aemro et al. (2021)	Ethiopia	Laboratory experiments	Pressure cookers are more efficient and cost-effective than locally manufactured cook stoves
Makonese et al. (2018)	Sub-Saharan Africa, 2006 - 2012	Multiple Regressions	Socio-demographic factors, including access to electricity, household size, education level, and wealth, positively influence households' selection of cooking fuel.

Mhache (2021)	Tanzania, 2013	An analysis of key articles, reports, research papers, and various online sources.	The main factors preventing people from transitioning away from charcoal to alternative energy sources are its availability, reliability, and affordability.
Ishengoma and Igangula (2021),	Tanzania, 2017	Logit and Multinomial Regression Models	Increasing perceptions of LPG as unsafe decreases its usage, so policies aimed at boosting household incomes, enhancing market awareness of LPG safety, and highlighting the environmental and health risks of fuel wood are essential for promoting LPG adoption.
Gitau et al. (2019)	Kenya, 2016 - 2017	An analysis of key articles, reports, research papers, and various online sources.	Households preferred gas stoves but faced challenges, with 42%, 77%, and 19% of users reporting difficulties in fuel preparation, reloading, and lighting, respectively, among those experiencing issues.
Akter et al. (2023)	India, 2015 - 2018	Instrumental variable	These findings demonstrate that improving electricity quality and reliability facilitates the shift to clean energy sources.
Bofah et al. (2022)	Ghana, 2016 - 2017	Multinomial Logistic Regression	Education, household size, employment, and income are key factors influencing household energy choices where higher education, formal employment, and higher income promote cleaner energy use.
Hsu et al. (2021)	Kenya, 2019	Multiple Regressions	Encouraging the adoption of LPG by offering microloans for equipment is both financially sustainable and beneficial for health by decreasing the dependence on polluting biomass fuels.

(Masera, Saatkamp, & Kammen, 2000).	Mexico, 1992 - 1996	Large scale survey and Descriptive analysis	Households with greater education and income levels are more inclined to transition to cleaner cooking fuels as their socio-economic conditions improve.
Shittu et al. (2024)	Global, 2005 - 2022	Multiple Regressions	Financial incentives are essential for encouraging households to adopt cleaner cooking fuels is essential for improving both environmental and health outcomes.
Ahmad et al. (2023)	Bangladesh, 2017 - 2018	An analysis of key articles, reports, research papers, and various online sources.	The energy ladder hypothesis suggests that as household income increases, people tend to switch to cleaner energy sources for cooking.
Gj (2022)	Malawi, 2010 - 2019	Multinomial Logistic Regression	The adoption of alternative cooking fuels remains low due to misconceptions, household economics, low awareness, and a mismatch between supply and demand,

Chapter 3. Methodology

3.1 Data source

This study is based on data obtained from the Tanzania National Bureau of Statistics (NBS) survey database. In partnership with Statistics Norway, the NBS carried out a survey in 2021/22 to investigate the impact of sustainable energy access in Mainland Tanzania. The survey was jointly funded by the Government of Tanzania and the Norwegian Agency for Development Cooperation (Norad) with the assistance of Statistics Norway. It was designed to be nationally representative, gathering data from

both urban and rural regions, and focusing on various household and community characteristics.

The primary objective of the 2021/22 Impact of Access to Sustainable Energy Survey (IASES) was to assess the level of access to sustainable energy, examine the patterns of its use, and understand its effects across different regions of Mainland Tanzania.

As the study relies on publicly accessible datasets, ethical clearance was not necessary. This approach is in line with the fact that all surveys conducted under this program are approved by the relevant institutional and ethical review boards at the national level, in consultation with the organizations involved in data collection.

The dataset is nationally representative and initially includes data from 5,931 households, drawn from a wide range of regions, demographic groups, and socio-economic backgrounds. However, due to missing data and the need to generate specific variables, the final study population comprises 2,252 households. The dataset contains information on various household-level and individual-level characteristics, including cooking fuel, age, gender, education level, employment status, household size, type of residence, electricity connection, access to financial services, distance to utility centers, blackout durations, and cultural factors. A summary of the key variables used in this analysis is presented in Table 2.

This study adopts a mixed-methods approach, combining quantitative and qualitative data to provide a thorough and well-rounded analysis of the topic. By integrating these two types of data, the study aims to offer a well-rounded perspective on sustainable energy access, thereby enhancing the reliability and depth of the findings.

3.2 Variables selection

The variables for this study were selected based on their theoretical relevance and a detailed review of previous studies in the field. This selection process ensures that the variables included are not only relevant but also grounded in existing research. By carefully selecting the variables, the study captures all relevant factors, thereby strengthening the analysis. This approach allows the study to draw meaningful insights into how sustainable energy access affects different demographic groups and facilitates the identification of key areas where policy interventions could be most effective.

Table 2: Summary of definitions of variables

Variables	Definitions
Cooking fuel	This is the dependent variable: A categorical (outcome) variable for household's main cooking fuel. 0 = Clean source, 1 = Charcoal, 2 = Firewood/Wood/Residuals
Age	This is a continuous variable for household head's age in years
Employment status	This is a categorical variable: Employment status household member. 1=Yes , 0 = No
Household size	This is a categorical variable for employment status household size. 0 = 1 - 2 members, 1 = 3 - 4 members, 2 = 5+ members
Education	This is a categorical variable: Household head's education. 0 = Primary Education, 1 = Secondary_Highschool, 2= University Education
Gender	This is a categorical variable: Gender of household head. 0 =Male , 1 = Female
Residence	This is a categorical variable: Household residence. 0 =Rural , 1 = Urban
Electricity connection	This is a categorical variable: Household access to electricity. 1= Yes , 0= No
Distance to utility center	This is a categorical variable: Distance of household to the nearest utility office (TANESCO). 0 =< 2 km , 1= 2-9 km , 2 = 10–19 km , 3 = 20–49 km , 4 = 50+ km
Blackout duration	This is a categorical variable: Total number of hours a household experienced blackout. 0 =< 2 hours , 1= 2-4 hours , 2 = 5–9 hours , 3 = 10–19 hours , 4 = 20+ hours
Financial access	This is a categorical variable: Household has access to financial services 1= Yes , 0= No
Cultural influences	This is a categorical variable being examined for the first time through this study, focusing on households that believe smoke from stoves is effective in repelling insects. 1 = Agree , 0 = Disagree

3.3 Analytical Framework

This study utilizes both the Multinomial Logit Model (MNL) and the Probit Model to examine the factors influencing households' selection of cooking fuels. The models aim to estimate the likelihood of choosing one option from multiple unordered categories. Specifically, the research investigates how variations in socio-economic factors impact households' decisions to use different types of cooking fuels, including firewood, charcoal, and clean energy sources such as LPG, biogas, or electricity.

Similar to the approach taken by Mangula et al. (2019), who used MNL to examine the factors affecting cooking fuel choices in rural Tanzania, this study also applies the MNL

method. This methodology is endorsed by Hosmer and Lemeshow (2000), who argued that MNL is effective for analyzing multinomial dependent variables while also considering continuous independent variables.

The following equation represents the multinomial logit model used for analysis.

$$\Pr(Y_i = c) = \frac{e^{\beta_c \cdot x_i}}{\sum_{j=1}^{K} e^{\beta_j \cdot x_i}}$$

Where e is exponential function; and
Yi represents the observed energy (fuel) used by households. For each subscript,
i denotes observation of household;
j denotes the fuel chosen by the household;
β is the vector of coefficients for
Xi a vector of household characteristics, the following characteristics are included in Xi to find which ones are statistically significant: the
age of household head;
employment status of household members;
household size;
education level of household head;
gender of the household head;
whether the household lives in urban or rural areas;
electricity connection status;
access to financial services;
cultural influence;
duration of blackout; and the
distance to utility center.

In this study, the dependent variable, cooking fuel choice, is nominal with three categories: clean sources (electricity, biogas, LPG, solar cookers, and private generators), charcoal, and firewood/wood/residuals. Clean sources are used as the reference category. The independent variables include age, gender, education, employment, household size, residence, electricity connection, financial access, cultural influences, blackout duration, and distance to the utility center.

Similar to the approach of Rahut et al. (2016), this study will also employ a probit model to reassess the choice of clean energy sources by using clean sources as the sole dependent variable while keeping the independent variables unchanged. A probit model is a binary choice model that determines the probability of an event occurring, predicting

whether a choice will be made or not. This analytical approach allows for a detailed examination of how socio-economic factors influence households' decisions regarding the adoption of clean cooking fuels, thereby informing targeted policy interventions aimed at promoting sustainable energy practices.

3.4 Research strategy

The statistical software STATA was utilized for all computations and analyses, including regression analysis. Descriptive statistics such as means, percentages, and frequencies were used to evaluate households' energy sources and usage patterns, as well as to examine various socio-economic characteristics. The findings are presented through tables, figures, and narratives.

3.5 Theoretical framework

The signs of the estimates indicate the direction of relationships between independent variables and outcome categories, while the significance levels indicate the statistical reliability of these relationships. Evaluating both signs and significance helps researchers identify variables that significantly influence the likelihood of different outcomes. This interpretive framework is important for understanding the impact of various predictors within the model.

Table 3: Expected relationships between control variables and the outcome variable

Variable	**Expected direction**	**Author/s**
Household head gender, education, residence and income	Positive	Rahut et al. (2016)
Electricity access	Negative	Aemro et al. (2021)
Internet access	Positive	Yan et al. (2024)
Education, Employment	Positive	Wei and Lin (2024)
Household size	Negative	Gitau et al. (2019) and Mangula et al. (2019)
Quality and reliability of electricity	Positive	Akter et al., 2023
Gender	Positive	Bofah et al. (2022)
Financial access	Positive	Hsu et al. (2021), Shittu et al. (2024)
Education, Size, Income, Age	Positive,	Odame and Amoah (2023)
Age, Household size, Employment, education	Positive	Mangula et al. (2019)
Cultural influences	Negative	Mperejekumana et al. (2024)
Income	Positive	Ishengoma and Igangula (2021),
Education and wealth.	Positive	Makonese et al. (2018)
Age	Negative	Kulindwa et al. (2018)

Chapter 4. Results

4.1 Descriptive statistics

Table 4 presents a detailed summary of the key variables. Around 43.8% of households relied on charcoal, 44.4% used firewood or residuals, and approximately 11.8% used clean energy sources such as Liquefied Petroleum Gas (LPG), biogas, or electricity. The average age of household heads was 44 years, with 25.4% being female and 74.6% male. Education levels showed that 73.1% of households had at least primary education, while 21.2% had completed secondary school, and 5.7% had attained university-level education. Employment was recorded for 24.9% of household heads, with the remaining 75.1% unemployed.

Household size data indicated that 93.6% of households had 1 to 2 members, 5% had 3 to 4 members, and 1.4% had more than 5 members. The sample was split between 44.3% rural and 55.7% urban households. With regard to electricity access, only 47.6% of households were connected, leaving 52.4% without access. Regarding beliefs about stove smoke, 21.7% agreed it helps repel insects, while 78.3% disagreed. Financial service access was reported by 32.3% of households, with 67.7% lacking such services.

In terms of proximity to utility centers, 11.1% of households were less than 2 km away, 45.4% were between 2 and 9 km, 14.6% were 10 to 19 km away, 16.3% were between 29 and 49 km, and 12.6% were more than 50 km away. Regarding blackouts, 17.8% of households experienced outages lasting less than 2 hours, 22.2% faced blackouts of 2 to 4 hours, 21.1% endured 5 to 9 hours, 22.2% experienced 10 to 19 hours, and 16.7% faced blackouts exceeding 20 hours.

Table 4: Descriptive statistics of the variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Cooking fuel	.	.	.	.	.
Clean Source	2252	.117	.322	0	1
Charcoal	2252	.438	.496	0	1
Firewood/Wood/Residuals	2252	.444	.497	0	1
Age	2252	43.718	13.8	18	92
Employment status	.	.	.	.	.
No	2252	.751	.432	0	1
Yes	2252	.249	.432	0	1
Household size	.	.	.	.	.
1-2	2252	.936	.245	0	1
3-4	2252	.05	.218	0	1
5+	2252	.014	.117	0	1
Education	.	.	.	.	.
Primary Education	2252	.731	.444	0	1
Secondary Education	2252	.212	.409	0	1
University Education	2252	.057	.232	0	1
Gender	.	.	.	.	.
Male	2252	.746	.436	0	1
Female	2252	.254	.436	0	1
Residence	.	.	.	.	.
Rural	2252	.443	.497	0	1
Urban	2252	.557	.497	0	1
Electricity connection	.	.	.	.	.
No	2252	.524	.5	0	1
Yes	2252	.476	.5	0	1
Distance to utility center	.	.	.	.	.
< 2 km	2252	.112	.315	0	1
2 - 9 km	2252	.454	.498	0	1
10 - 19 km	2252	.146	.353	0	1
20 - 49 km	2252	.163	.369	0	1
50+ km	2252	.126	.332	0	1
Blackout duration	.	.	.	.	.
< 2 hours	2252	.178	.382	0	1
2 - 4 hours	2252	.222	.415	0	1
5 - 9 hours	2252	.211	.408	0	1
10 - 19 hours	2252	.222	.416	0	1
20+ hours	2252	.167	.373	0	1
Financial access	.	.	.	.	.
No	2252	.677	.468	0	1
Yes	2252	.323	.468	0	1
Cultural influences	.	.	.	.	.
Disagree	2252	.783	.412	0	1
Agree	2252	.217	.412	0	1

4.2 Correlation Measures and Multicollinearity

Table 5 displays correlation measures indicating the strength and direction of relationships between variables. This study investigates the determinants of household use of clean cooking fuels by initially testing for multicollinearity within the sample. The results indicated that the maximum correlation value was 0.5, suggesting no significant multicollinearity issues in this dataset.

Table 5: Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Cooking fuel	1.000											
(2) Age	0.199	1.000										
(3) Employment status	-0.282	-0.073	1.000									
(4) Household size	0.027	0.121	0.008	1.000								
(5) Education	-0.419	-0.159	0.318	0.017	1.000							
(6) Gender	-0.090	0.035	-0.032	-0.086	-0.051	1.000						
(7) Residence	-0.577	-0.054	0.211	-0.032	0.227	0.135	1.000					
(8) Electricity connection	-0.534	-0.020	0.216	-0.029	0.312	0.084	0.515	1.000				
(9) Distance to utility center	0.452	0.027	-0.155	0.033	-0.179	-0.086	-0.516	-0.402	1.000			
(10) Blackout duration	0.071	0.016	-0.009	0.003	-0.022	-0.016	-0.033	0.016	-0.021	1.000		
(11) Financial access	-0.362	0.078	0.275	0.023	0.369	-0.011	0.253	0.351	-0.210	-0.075	1.000	
(12) Cultural influences	0.141	0.107	0.007	-0.020	-0.064	0.014	-0.082	-0.027	0.019	0.049	-0.024	1.000

4.3 Regression Analysis Results

This section presents the empirical results that form the foundation of this paper.

4.3.1 Multinomial Logit Model (MNL)

Table 6 provides the estimates derived from the Multinomial Logit Model (MNL), illustrating the factors that influence households' decisions regarding their primary cooking fuel sources. In the MNL model, clean sources were used as the reference category. The results reveal an acceptable pseudo R^2 value of 0.38, indicating a reasonable fit of the model.

Likelihood Ratio Chi-Square Test

In this study, the overall relationship between the independent and dependent variables was evaluated through model fitting. The chi-square statistic from the final model was applied to assess whether there is a significant relationship between the dependent and independent variables. The results showed a chi-square value of 1669.17 with a p-value of 0.000, which is well below the significance level of 0.05. This suggests that the model is statistically significant; indicating that at least one of the regression coefficients in the population is significantly different from zero. A non-zero slope confirms that the model fits the data well, which validates the analysis.

Table 6: Results from the MNL model

	(1)	(2)	(Base outcome)
Variables	**Charcoal**	**Firewood/Wood/Residuals**	**Clean source**
Age	0.0161**	0.0619***	-
	(0.00627)	(0.00766)	-
Employment status	-0.0965	-0.653***	-
	(0.163)	(0.219)	-
Household size	-0.162	-0.149	-
	(0.252)	(0.308)	-
Education	-0.805***	-1.494***	-
	(0.117)	(0.178)	-
Gender	-0.552***	-0.602***	-
	(0.166)	(0.210)	-
Residence	-0.533*	-2.460***	-
	(0.280)	(0.296)	-
Electricity connection	-1.362***	-2.486***	-
	(0.264)	(0.284)	-
Distance to utility center	0.152	0.652***	-
	(0.0971)	(0.108)	-
Blackout duration	0.151***	0.230***	-
	(0.0570)	(0.0705)	-
Financial access	-0.681***	-1.312***	-
	(0.174)	(0.220)	-
Cultural influences	-0.188	0.963***	-
	(0.201)	(0.239)	-
Constant	3.724***	2.974***	-
	(0.479)	(0.562)	-
Observations	2,252	2,252	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Pseudo R2 = 0.3808

Cultural Influences

Cultural factors significantly influence the cooking fuel choices of households in Tanzania, as shown by this study, which highlights their statistical significance as key determinants. Households that believe stove smoke repels insects exhibit a strong positive correlation with the use of firewood or other traditional fuels, with statistical significance at the 1% level. This suggests that deeply ingrained cultural beliefs drive the preference for traditional fuels despite the availability of cleaner alternatives.

Additionally, norms surrounding food preparation, such as the use of large pots for traditional dishes like ugali, further discourage the adoption of modern stoves. However, these cultural influences show a weaker, statistically insignificant relationship with charcoal use, suggesting variability in their impact across fuel types.

Ishengoma and Igangula (2021) identified a negative relationship between cultural beliefs and the adoption of clean cooking fuels, suggesting that some cultural practices hinder the shift toward cleaner alternatives. Bansiya (2023) argued that raising awareness could significantly boost the adoption of clean cooking fuels. Overcoming these barriers will require culturally tailored awareness campaigns that challenge misconceptions and educate communities on the health, economic, and environmental benefits of clean cooking technologies.

Financial Capability

Financial resources have a significant impact on the type of cooking energy used in households. This study's findings reveal that families with access to financial services are considerably less dependent on traditional fuels like charcoal and firewood. The data demonstrates a strong, statistically significant correlation at the 1% level, showing that households with greater financial access are more likely to adopt clean cooking fuels, such as LPG (liquefied petroleum gas) and electricity. In a similar vein, Hsu et al. (2021) found that improved financial capacity is positively associated with the use of clean cooking fuels.

This trend is especially important for rural, low-income households, where limited financial resources force many families to stick with biomass fuels. These fuels may appear cheaper initially, but their long-term health and environmental costs are substantial. By contrast, access to banking, microloans, and credit facilities makes cleaner, healthier cooking options more affordable and attainable.

Electricity Infrastructure and Utilities

Access to reliable electricity infrastructure is a key factor driving the adoption of clean cooking fuels in Tanzania. This study reveals a statistically significant negative relationship (at the 1% level) between access to electricity and the use of traditional cooking fuels like charcoal and firewood. Households with electricity connections are significantly more likely to adopt cleaner cooking alternatives, such as electric stoves or LPG, than those without access. These findings align with Ahmad et al. (2023), who also found a positive link between electricity access and the use of clean cooking fuels.

However, the study also finds that frequent blackouts deter clean fuel adoption, with a positive correlation between blackout duration and reliance on traditional cooking fuels. The relationship between blackout frequency and reliance on traditional cooking fuels is statistically significant at the 1% level, emphasizing the importance of reliable electricity supply in promoting clean cooking. Akter et al. (2023) similarly observed that households experiencing frequent blackouts are more likely to use traditional cooking fuels, such as charcoal and firewood/wood residuals.

Moreover, households located further from utility centers are less likely to adopt clean cooking technologies, primarily due to limited access to essential services such as electricity connections and maintenance. These findings highlight the need for increased investment in rural electrification, improved grid reliability, and the expansion of utility services to underserved regions. Strengthening electricity infrastructure will help reduce reliance on harmful biomass fuels, boost energy security, and contribute to Tanzania's sustainable development goals.

The Role of Education

Household heads with higher levels of education demonstrate a strong preference for cleaner cooking sources over charcoal and firewood/wood residuals, with statistically significant results at the 1% level.

Higher education often correlates with improved financial capability and better employment prospects, further facilitating access to clean cooking options. These findings align with the work of Mangula et al. (2019) and Hsu et al. (2021), who observed that increases in socioeconomic status, such as education and income, are associated with a greater likelihood of adopting clean cooking fuels.

Promoting education, particularly in rural and low-income areas, is crucial for encouraging the widespread adoption of clean cooking technologies. This effort will contribute to advancements in public health, environmental sustainability, and socio-economic development.

4.3.2 Probit Regression as a Complementary Analysis

In addition to the Multinomial Logistic (MNL) model, this study applied a probit model as an additional analysis to evaluate the robustness of the findings. The probit model treated only clean sources as the dependent variable while keeping the independent variables constant. As a binary choice model, the probit approach revealed a similar pattern in the significance of key predictors, though some differences in the magnitude of coefficients were observed, particularly for the cultural influence variable. This suggests that the choice of model can affect the strength of certain predictors.

When comparing model fit, the MNL model demonstrated a higher pseudo-R^2 value (0.38) compared to the probit model (0.03), indicating a better fit. Nevertheless, both models provide a deep understanding into the determinants of clean energy adoption.

Table 7: Results from the Probit model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Electricity connection	1.092***	1.080***	0.921***	0.812***	0.810***	0.810***	0.808***
	(9.84)	(9.65)	(7.82)	(6.68)	(6.61)	(6.61)	(6.58)
Financial access	0.593***	0.669***	0.655***	0.434***	0.457***	0.454***	0.437***
	(7.22)	(7.89)	(7.65)	(4.70)	(4.90)	(4.87)	(4.63)
Cultural influences	-0.0784	-0.0399	-0.0134	0.0209	0.00621	0.00861	0.00229
	(-0.78)	(-0.39)	(-0.13)	(0.20)	(0.06)	(0.08)	(0.02)
Distance to utility center	-0.218***	-0.207***	-0.143**	-0.136**	-0.135**	-0.136**	-0.136**
	(-4.79)	(-4.53)	(-2.92)	(-2.71)	(-2.67)	(-2.69)	(-2.68)
Blackout duration	-0.0965**	-0.0900**	-0.0812**	-0.0895**	-0.0877**	-0.0879**	-0.0873**
	(-3.21)	(-2.96)	(-2.66)	(-2.87)	(-2.80)	(-2.80)	(-2.78)
Age		-0.0157***	-0.0153***	-0.0116***	-0.0119***	-0.0122***	-0.0120***
		(-5.00)	(-4.83)	(-3.52)	(-3.60)	(-3.66)	(-3.58)
Residence			0.539***	0.554***	0.539***	0.538***	0.533***
			(4.23)	(4.20)	(4.04)	(4.03)	(3.98)
Education				0.504***	0.525***	0.523***	0.505***
				(7.91)	(8.15)	(8.11)	(7.62)
Gender					0.322***	0.329***	0.332***
					(3.53)	(3.58)	(3.60)
Household size						0.0967	0.0934
						(0.69)	(0.66)
Employment status							0.111
							(1.21)
_cons	-1.720***	-1.118***	-1.538***	-2.296***	-2.417***	-2.407***	-2.415***
	(-12.50)	(-6.16)	(-7.30)	(-9.60)	(-9.91)	(-9.86)	(-9.86)
N	2252	2252	2252	2252	2252	2252	2252
t statistics in parentheses							
*** p<0.01, ** p<0.05, * p<0.1							

This chapter serves as the focal point of the study, providing insights that form the basis for conclusions and recommendations derived from the data. The regression results presented in Table 6 and Table 7 highlight the significance of various variables in explaining the choice of cooking fuels within the study area. Therefore, these findings highlight the determinants influencing households' preferences for cooking fuels.

Chapter 5. Discussion

The findings of this study contribute significantly to understanding the factors influencing clean cooking fuel adoption in Tanzanian households, highlighting the relationship between socio-economic, cultural, and infrastructural determinants. One of the most striking findings is the critical role of financial access in facilitating the transition to cleaner cooking fuels. Households with access to financial services, whether through microloans or credit schemes are more likely to adopt alternatives such as liquefied petroleum gas (LPG) or electricity. This aligns with research by Aemro et al. (2021), which emphasizes that financial barriers are a primary constraint in many developing countries. In Tanzania, where poverty remains widespread, the initial cost of cleaner cooking technologies is often unaffordable. Therefore, expanding access to financial resources such as microfinance programs could significantly enhance the adoption of clean fuels.

However, while financial access plays an important role, cultural influences also emerge as key barriers to clean cooking fuel adoption. The belief that smoke from traditional stoves has insect-repelling properties or the preference for cooking methods tied to cultural practices, such as preparing ugali, continue to limit the shift toward cleaner alternatives. These cultural norms have received limited attention in previous studies on cooking fuel transitions. This study fills this gap by demonstrating how cultural practices can delay the adoption of cleaner technologies, even when financial and infrastructural conditions are favorable.

This study illustrates the applicability of the energy ladder theory, demonstrating that households with higher levels of education and income tend to transition to cleaner cooking fuels as their socio-economic status improves. According to the theory, this shift towards modern energy sources occurs primarily as household income levels increase. Education plays a significant role in shaping household energy choices, as educated individuals are better equipped to assess available fuel options and associated technologies (Masera, Saatkamp, & Kammen, 2000).

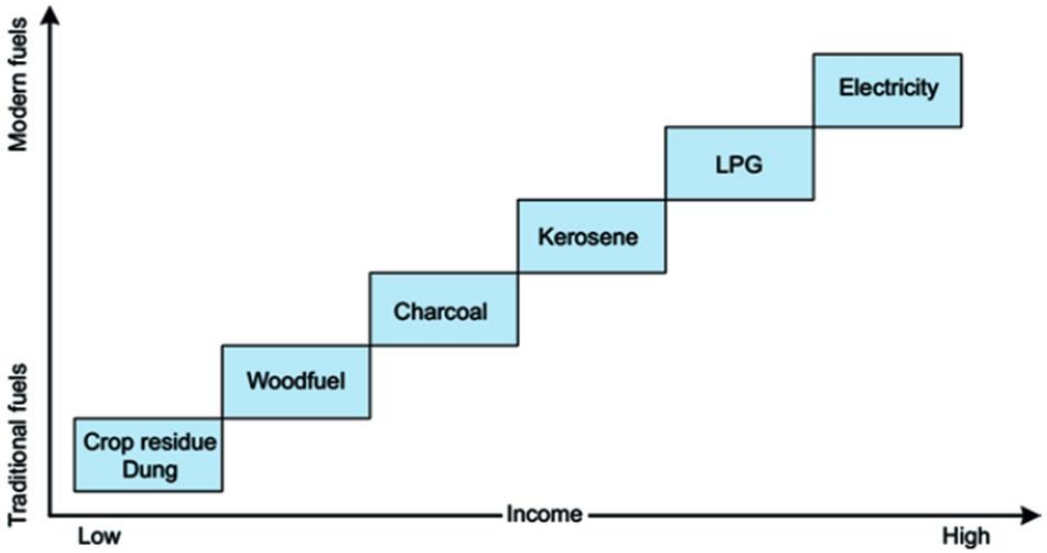


Fig 3: Energy ladder model (Kowsari and Zerriffi 2011)

The role of electricity access in clean cooking fuel adoption requires further exploration. Although some policymakers in Tanzania still believe that electricity does not play a significant role in the transition to clean cooking fuels, particularly due to its limited adaptability among households, the findings of this study demonstrate how critical electricity is in the process. While urban households are more likely to use clean fuels such as LPG or electricity, frequent blackouts and unreliable infrastructure often drive these households back to traditional fuels, particularly charcoal and firewood. This presents an inconsistency, as access to electricity is traditionally viewed as a facilitator of clean fuel adoption. However, the inconsistent supply of electricity in many areas complicates this assumption. A similar issue was noted by Rahut et al. (2016), who found that even in urban areas with electricity access, households often resort to traditional fuels due to reliability concerns. This demonstrates the importance of not only increasing access to electricity but also ensuring its reliability to effectively encourage the use of clean cooking technologies.

The findings not only highlight the urgent need for targeted interventions to promote clean cooking fuels but also illustrate the interconnectedness of energy access, financial inclusion, and cultural shifts in driving sustainable energy transitions. By tackling the challenges identified in this study, such as unreliable electricity and limited financial access, policymakers can accelerate the adoption of clean energy technologies, reduce carbon emissions, and enhance public health. Tanzania's experience offers valuable lessons that can guide global strategies, especially in other low-income regions, helping to create a more equitable and sustainable energy transition worldwide.

Chapter 6. Conclusion

This study identified several constraints similar to those highlighted in other research, highlighting the need for significant policy interventions in Tanzania. It contributes to the existing literature by addressing these gaps and demonstrating the applicability of the energy ladder theory in the Tanzanian context. By doing so, it provides insights that can inform targeted interventions and policy measures. These interventions might include offering microloans for purchasing clean cooking equipment, providing subsidies for clean fuels, and running awareness campaigns to educate communities on the benefits of adopting clean cooking technologies.

A key strength of this study lies in its use of a substantial, nationally representative dataset consisting of 2,252 households collected from recent, reliable demographic surveys in Tanzania. By incorporating variables such as financial access, cultural influences, and electricity availability, the research provides an understanding of the determinants of household cooking fuel choices. This understanding is crucial for informing effective policy strategies.

However, the study faces several limitations. For instance, the dataset lacks specific information on internet usage, which could have provided valuable information about its potential impact on the adoption of clean cooking fuels. Yan et al. (2024) demonstrate that internet access plays a positive role in the adoption of clean cooking fuels, particularly in female-headed households. Additionally, employment status was used as a proxy for household income or wealth, which may oversimplify the broader economic conditions of the household.

There is also a lack of empirical studies and data on technologies such as Improved Cooking Stoves (ICS) and eco-friendly charcoal, which are cost-effective and have minimal environmental and health impacts. These findings highlight the need for further research into these technologies to encourage the adoption of clean cooking fuels in Tanzania. Future studies should focus on evaluating the effectiveness of ICS and eco-friendly charcoal across various socio-economic contexts within the country.

By acknowledging these limitations, it becomes clear that further research is essential for gaining a deeper understanding of the factors that drive the adoption of clean cooking fuels in Tanzania, as well as in other countries facing similar challenges in achieving sustainable development goals.

Overall, this study serves as a model for interventions in other developing countries confronting similar challenges. It contributes to global efforts to improve public health, promote environmental sustainability, and foster socio-economic development through the widespread adoption of clean cooking fuels.

Chapter 7. Policy recommendation

Enhancing financial access for households through initiatives like banking, loans, and credit could offer a viable solution for marginalized communities in Tanzania seeking to adopt cleaner cooking fuels. By making clean cooking technologies more affordable, this approach would facilitate their wider adoption in underserved areas, helping to bridge the gap in access to sustainable energy.

Increasing access to electricity could accelerate the adoption of clean cooking fuels, as many affordable technologies require electricity. Investing in rural electrification projects, providing subsidies for household connections, and partnering with energy providers and development agencies can extend the electricity grid and promote off-grid solutions like solar power. This will enhance the adoption of electric cooking technologies and reduce reliance on biomass fuels.

Policymakers should prioritize ensuring that utility companies provide a more reliable electricity supply to households, as frequent outages often discourage the adoption of clean cooking fuels due to their perceived unreliability. Consequently, households may continue to rely on traditional cooking fuels. Additionally, it is crucial for policymakers to minimize the distance between households and electricity service centers to facilitate access to essential services, such as electricity applications, connections, maintenance, and the supply of LPG. This would support a smoother transition to cleaner cooking fuels.

Furthermore, there appears to be limited awareness in the community regarding the negative effects of traditional cooking fuels. Launching nationwide awareness campaigns about the health and environmental impacts of these fuels, utilizing media, community workshops, and school programs, is essential. This will improve community knowledge and encourage a shift toward clean cooking practices.

By implementing these policy recommendations, the government and stakeholders can significantly increase the adoption of clean cooking fuels in Tanzania, leading to better health outcomes, environmental sustainability, and socio-economic development.

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Abstract (Korean)

이 연구는 탄자니아 가정의 청정 조리 연료 채택에 영향을 미치는 주요 요인을 조사하고 공중 보건 및 성 평등과 관련된 필수 개발 문제를 다룹니다. 혼합 방법 프레임워크를 사용하여 이 연구는 탄자니아 통계청의 가계 조사 데이터에 대한 다항 로짓 및 프로빗 회귀 모델을 활용한 정량적 분석과 학술 문헌의 질적 통찰력을 결합합니다. 분석에서는 재정 자원, 전기 접근성, 인프라 개발, 문화적 관행, 교육 수준, 성별, 가구 구성 등 사회 인구학적 요인을 포함하여 연료 선택의 중요한 결정 요인을 식별합니다.

연구 결과는 청정 조리 기술에 대한 접근성을 높이는 데 있어 소액 대출 및 신용 제도와 같은 재정적 지원 메커니즘의 중요성을 강조합니다. 주요 조치에는 농촌 전기화 확대와 전통적인 요리 연료의 건강 및 환경 영향을 다루기 위한 광범위한 인식 캠페인 실시가 포함됩니다. 정책 권장 사항은 청정 연료 기술 보조금, 에너지 인프라 강화, 문화적으로 적절한 교육 이니셔티브 통합을 옹호하여 경제성, 안전 문제 및 깊이 뿌리박힌 문화적 규범과 같은 장벽을 해결합니다.