Vol. 1,No. 1, June 2025 ISSN (Print): 3088-5426 | ISSN (Online): 2953-2728

Eastern Africa Journal of Official Statistics

Journal Homepage: https://journal.eastc.ac.tz/index.php/eajos/index

DOI: https://doi.org/10.63933/eajos.1.1.2025.2

Decomposing Rural-Urban Disparities in Clean Energy Use for Cooking in Tanzania: Evidence from the 2022 Tanzania Demographic and Health Survey

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KEYWORDS

Clean Cooking Energy, Fairlie Decomposition Technique and Rural-Urban

ABSTRACT

The potential positive impact of clean energy on sustainable development is widely recognised in economic development discussions. This study analysed rural-urban variation in clean cooking energy usage in Tanzania, using data from the 2022 Tanzania Demographic and Health Survey (TDHS). The findings highlighted key determinants of household cooking fuel choices, with education level, household wealth, and household size identified as significant predictors. A Fairlie decomposition technique revealed that, on average, rural households have a lower probability of using clean energy for cooking compared to urban households. The decomposition analysis showed that the rural-urban gap in clean energy adoption is primarily explained by differences in household wealth (80.5%), household size (7.5%), and the education level of the household head (4.4%). Based on these findings, the study recommends that the government introduce targeted financial support and subsidies for low-income households, particularly in rural areas. In addition, both government and non-governmental organisations should invest in large-scale education and awareness campaigns to promote the benefits of clean cooking energy. Policies should also encourage the development and distribution of energy-efficient and affordable cooking technologies, such as improved biomass stoves that are fuel-efficient and less harmful to health. These interventions will help bridge the rural-urban divide in terms of clean energy access and support sustainable development in Tanzania.

1. Introduction

The role of clean energy in sustainable development is widely acknowledged in economic discussions. According to the 2022 Tanzania Demographic and Health Survey (TDHS), clean cooking energy includes electricity, solar energy, liquefied petroleum gas (LPG), piped natural gas, and kerosene/paraffin. However, findings from the same survey reveal that only 7% of Tanzanian households use clean fuels and technologies for cooking, with stark differences between urban and rural areas. While 18% of the urban population in mainland Tanzania utilises clean fuels, only 2% of rural households have access. The predominant cooking fuel remains wood (67%), followed by charcoal (25%). Similarly, the 2022 Tanzania Population and Housing Census (TPHC) classifies clean energy as electricity, gas, biogas, solar, generator/private sources, and wind-generated electricity. The census indicates that the use of clean energy for cooking has risen from 2.7% in 2012 to 16% in 2022. Bridging the gap between rural and urban households in clean energy consumption is crucial for enhancing rural productivity and reducing poverty.

Reliable and sufficient energy is fundamental to economic growth and human development. Energy access is a key component of modern life, influencing health, education, and livelihoods. Expanding access to affordable clean energy is particularly critical in developing regions. The global importance of clean cooking is reflected in Sustainable Development Goal (SDG) 7, which aims to ensure universal access to affordable, reliable, sustainable, and modern energy by 2030 (UNDP, 2020). The reliance on biomass fuels for cooking presents significant health and environmental risks. Biomass combustion releases pollutants that contribute to respiratory diseases, particularly among women and children. In addition, deforestation and fossil fuel burning increase greenhouse gas concentrations, exacerbating global warming (Benti *et al.*, 2021).

Globally, 2.4 billion people lacked access to clean cooking energy in 2021, with 40% residing in sub-Saharan Africa and 55% in developing Asia (IEA,2022). Approximately 3 billion people in low- and middle-income countries rely on biomass energy, including firewood, charcoal, and other solid fuels. This dependence results in preventable deaths due to household air pollution, with short-lived climate forcers and greenhouse gas emissions further accelerating climate change (Floess *et al.*, 2023). According to the World Health Organization (WHO), about half of acute respiratory infection (ARI) mortality among children under five is linked to particulate matter from biomass-based household air pollution (WHO, 2016). Moreover, the widespread reliance on biomass fuels contributes to environmental degradation and climate change (Haines et al., 2017; Bailis *et al.*, 2015).

Several studies have examined household cooking fuel choices across Africa. Murshed (2022) argues that structural barriers drive persistent use of unclean cooking fuels in sub-Saharan Africa, and that only after surpassing key efficiency thresholds alongside improvements in income and access does clean fuel adoption significantly increase. The study highlights the importance of addressing both technological and socioeconomic factors to support effective energy transitions. Similarly, Omojolaibi and Alasinrin (2025) analysed data from the General Household Survey in Nigeria, using a multinomial logistic regression model. Their findings revealed that urbanisation and rising incomes significantly drive the transition to clean cooking fuels. In contrast, large household sizes, lack of clean energy sources, and low education levels hinder the shift.

In Ghana, Dongzagla and Adams (2022) explored the socioeconomic and demographic determinants of urban household cooking fuel choices using data from the 2014 Ghana Demographic and Health Survey. Their binary logistic regression results indicated that factors such as the household head's gender, age, marital status, household size, educational level, and wealth were significant in determining clean energy adoption. However, wealth emerged as the strongest predictor of clean fuel use. Similarly, Ozughalu (2023) examined the patterns of household energy choices in Nigeria, finding that education levels, ownership of electric appliances, and improved housing conditions increase the likelihood of clean energy use. The study confirmed the energy ladder hypothesis, where higher-income households transition from biomass fuels to cleaner alternatives.

Other studies have provided further insights into cooking energy transitions. Ang'u *et al.* (2023) assessed household cooking and lighting energy choices in Kenya using a probit model. Their findings suggested that income, credit access, male-headed households, higher education levels, and larger household sizes positively influenced the decision to adopt clean cooking fuels. Sani et al. (2024) examined regional disparities in clean cooking energy use among Nigerian women, revealing that wealth, education, and urban residence were significant determinants. The study also highlighted stark regional variations, with the southwest region showing the highest adoption rates. Twumasi *et al.* (2021) employed a multivariate probit model in Ghana, finding that education, internet access, off-farm work, and access to credit significantly influenced cooking energy choices. Their endogenous switching regression analysis suggested that clean cooking energy use could enhance household health outcomes, particularly for women.

In Tanzania, studies have also investigated energy access disparities. Ntegwa and Olan'g (2024) used the Tanzania National Panel Survey data to analyse economic and rural-urban inequalities in clean cooking fuel use. Their findings indicated that education, financial status, and electricity access contributed significantly to disparities. Despite economic growth and increased electrification, clean cooking fuel access remains low, particularly among rural households. Grimsby *et al.* (2024) examined multiple fuel use in peri-urban Dar es Salaam, using a mixed-methods approach. Their study found that many households stack different fuels, such as charcoal and LPG, based on economic constraints, cultural preferences, and cooking needs.

Yongolo *et al.* (2023) assessed determinants of cooking energy choices in Morogoro, Tanzania, finding that charcoal remains the dominant fuel. Their binary logistic regression analysis identified education level, marital status, and economic activity as key determinants. Similarly, Alananga (2024) examined household energy behaviour in Kigamboni, revealing that energy stacking remains prevalent, with wealthier households still relying on biomass fuels. Ishengoma and Igangula (2021) explored the relationship between household energy-mix choices and socioeconomic attributes, confirming that income growth, awareness of health risks, and access to market information increase LPG adoption.

According to the 2022 Tanzania Population and Housing Census (TPHC, 2024), firewood remains the primary cooking fuel, used by 55.7% of households, followed by charcoal at 28.8%. In rural areas, 79% of households depend on firewood, compared to 20.1% in urban areas. The Tanzanian government has taken steps to expand modern energy access, aiming for universal electricity coverage by 2030 (Ministry of Energy, 2020). Efforts include the Tanzania Rural Electrification Expansion Program (TREEP), expansion of the national grid, and promotion of solar home systems and mini-grids (World Bank, 2022; Ministry of Finance & Planning, 2021; The Mini-Grids Partnership, 2020; Odarno *et al.*, 2017).

Despite these initiatives, the 2022 TPHC report (2024) indicates that only 16% of Tanzanian households rely on clean energy for cooking. This study employs the Fairlie decomposition technique to analyse rural-urban variations in clean energy adoption using the 2022 TDHS. Understanding the underlying factors driving energy transition can inform policies aimed at promoting equitable access to clean cooking solutions across Tanzania.

2. Methodology

2.1 Study area

This study focuses on the United Republic of Tanzania, located in East Africa at coordinates 6.3690° S, 34.8888° E. According to the 2022 Population and Housing Census, Tanzania has a population of 61,741,120, comprising 30,053,130 males and 31,687,990 females (NBS, 2022). The census also reported a total of 14,152,803 private households, with 5,605,470 (39.6%) in urban areas and 8,547,333 (60.4%) in rural areas.

The study area was selected due to significant fluctuations in the use of clean fuel for cooking. In urban Tanzania, only 18% of the population uses clean cooking fuel, while in rural areas, the figure drops to just 2%. Wood remains the primary cooking fuel (67%), followed by charcoal (25%). This study examines the factors driving these trends, focusing specifically on the Tanzania Mainland.

2.2. Research Design

This study employed a cross-sectional research design to analyse differences in clean energy use for cooking in Tanzania. The data used in this study were derived from the 2022 Tanzania Demographic and Health Survey (TDHS), conducted by the Tanzania National Bureau of Statistics (NBS). The TDHS collects information on various social, economic, and demographic variables, among which relevant variables were selected for this study.

The target population consists of all women of reproductive age in Tanzania in 2022 within selected households. The accessible population includes women of reproductive age who participated in the 2022 TDHS. The pregnancy and postnatal recode file from the 2022 TDHS, containing data from 7,281 women, was utilised, representing households across all regions of Tanzania. The final study sample comprised 7,281 women who were either pregnant or had given birth within two years prior to the survey. However, after excluding households that did not meet the study's objective, which focuses on primary cooking fuel use, the final sample size was reduced to 6,976 households.

2.3. Study Variables

In this study, the primary household cooking energy source served as the dependent variable and was measured on a binary scale. Cooking energy sources were categorised into two groups: clean energy sources (electricity, solar, gas, and paraffin) and unclean energy sources (charcoal, firewood, farm residuals, animal dung, and others). Households using clean energy sources were assigned a value of 1, while those using unclean energy sources were coded as 0.

The independent variables included household size, place of residence, age of the household head, sex of the household head, household wealth index, and the education level of the household head. These variables were selected based on empirical evidence from similar studies and their availability in the 2022 Tanzania Demographic and Health Survey (TDHS).

2.4 Methods of Data Analysis

To decompose the rural-urban disparity in household clean energy use for cooking, this study employed the Fairlie decomposition method, which is well-suited for binary outcome variables. The technique decomposes the difference in the probability of clean energy use between two groups (urban vs. rural households) into two components: (1) a part explained by differences in observable characteristics (endowments), and (2) an unexplained part, often attributed to differences in the effects of these characteristics or unobserved factors.

The decomposition equation can be expressed as follows:

$$Y_{\bar{U}} - Y_{\bar{R}} = \sum_{I=1}^{N^U}\left[\frac{F\left(X_i^U \hat{\beta}\right)}{N^U}\right] - \sum_{j=1}^{N^R}\left[\frac{F\left(X_j^R \hat{\beta}\right)}{N^R}\right]$$

Where:

$Y_{\bar{U}}$ and $Y_{\bar{R}}$ are the average predicted probabilities of clean cooking energy use for Urban(U) and Rural(R) households, respectively.

X_i^U and X_j^R are the observed characteristics of individuals in the urban and rural samples.

$\hat{\beta}$ are the estimated coefficients from a pooled logistic regression model.

F(.) is the logistic cumulative distribution function.

The total difference $\boldsymbol{Y_{\bar{U}} - Y_{\bar{R}}}$ is then decomposed into:

Explained (Endowment) Component**:** The portion attributable to differences in observable characteristics (age, sex, education, household size, and wealth index) between rural and urban households.

Unexplained Component**:** The portion attributable to differences in the effects (coefficients) of those characteristics or unobserved variables, such as preferences, access to markets, or policy environments.

The explained component helps identify which characteristics contribute most to the rural-urban gap in clean energy use. In contrast, the unexplained component may reflect structural inequalities, discrimination, or omitted factors not captured in the model.

In the Fairlie decomposition method, when the overall rural-urban disparity in household cooking energy use is negative, it indicates lower clean energy use in rural areas. A negative coefficient for a given variable implies that this factor contributes to widening the inequality. Conversely, a positive coefficient indicates that the variable helps to reduce the disparity by narrowing the rural-urban gap.

3. Results and Discussion

3.1 Results

3.1.1 Characteristics of the Respondents

Table 1 presents the profile of 6,976 households surveyed in the 2022 Tanzania Demographic and Health Survey (TDHS). Among these households, 93.3% primarily used unclean energy sources for cooking, while only 6.7% relied on clean energy sources. The results indicate that the majority of household heads (35.7%) were aged 15 to 34 years, 47.4% were between 35 and 54 years old, and 16.9% were aged 55 years or older. Moreover, most households (79.5%) were headed by males, while females headed 20.5%. Education levels among household heads were generally low, with 53.1% having completed primary education and only 1.2% attaining higher education. In terms of household size, the majority (44.8%) of households had four to six members at the time of the survey. Furthermore, 71.2% of households were located in rural areas, while 28.8% resided in urban areas. The findings also indicate an equal distribution of households across different wealth index categories.

Table 1: Socioeconomic and Demographic characteristics of respondents

Variable	N (6,976)	Percentage (%)
Type of Cooking Fuel		
Clean Energy Source	470	6.74
Traditional Source	6,506	93.26
Age of Household Head		
15-34	2,492	35.72

35-54	3,307	47.41
55 and above	1,177	16.87
Sex of Household Head		
Male	5,546	79.50
Female	1,430	20.50
Education Level of Household Head		
No education	2,031	29.11
Primary	3,701	53.05
Secondary	1,162	16.66
Higher	82	1.18
Household Size		
1-3	1,100	15.77
4-6	3,127	44.83
7-9	1,744	25.00
10 and above	1,005	14.41
Place of Residence		
Urban	2,010	28.81
Rural	4,966	71.19
Wealth Index of Household		
Poorest	1,408	20.18
Poorer	1,327	19.02
Middle	1,411	20.23
Richer	1,409	20.20
Richest	1,421	20.37

Source: Own compilation from TDHS (2022)

3.1.2 Fairlie Decomposition of the Variations in Household Main Energy for Cooking between Rural and Urban

3.1.2.1 Logistic Regression

The binary logistic regression results revealed that the education level of the household head, household wealth index, and household size were statistically significant predictors of the primary cooking fuel used in Tanzanian households. However, the sex and age of the household head did not significantly influence the choice of cooking fuel in this study.

As shown in Table 2, there is a strong positive and significant relationship between the education level of household heads and the likelihood of using clean energy sources for cooking. The positive coefficient of 0.2894 indicates that as the education level of the household head increases, the likelihood of using clean energy for cooking also increases, holding other variables constant.

In addition, the results in Table 2 show that the household wealth index is strongly and positively associated with the use of clean energy sources for cooking. The positive coefficient of 2.1525 suggests that financially stable households are more likely to use clean energy for cooking, holding other variables constant.

Conversely, household size was found to have a strong and significant negative relationship with the primary cooking fuel used. The negative coefficient of -0.5471 indicates that as household size increases, the likelihood of using clean energy for cooking decreases, holding other variables constant.

Furthermore, higher education is linked to greater awareness and income opportunities, which enhance the ability to adopt clean cooking energy. Wealthier households can better afford clean fuels, while larger households, often associated with lower education and income, face greater energy demands and cost constraints, making them more reliant on unclean fuels.

Table 2: Results for Binary Logistic Regression

Variable	Coefficient	Std. Err.	z	P>z	[95% conf. interval]	
Age	-0.2289	0.1775	-1.2900	0.1970	-0.5767	0.1189
Sex	0.3292	0.2519	1.3100	0.1910	-0.1644	0.8229
Education Level	0.2894	0.0931	3.1100	0.0020	0.1069	0.4718
Household Size	-0.5471	0.1445	-3.7900	0.0000	-0.8304	-0.2638
Wealth Index	2.1525	0.1794	12.0000	0.0000	1.8008	2.5041
Constant	-11.4816	0.8907	-12.8900	0.0000	-13.2273	-9.7359

Number of observations =4966
LR chi2(5) =508.18

Prob > chi2=0.0000

Log likelihood = -329.58066
Pseudo R2=0.4353

Source: Own compilation from TDHS (2022)

3.1.2.2 Non-linear decomposition by location

Table 3 presents the results of the Fairlie decomposition analysis, which examines rural-urban disparities in the primary household energy sources for cooking. The study identifies key factors contributing to these disparities, including household size, the education level of the household head, and household wealth index.

The estimated difference in the probability of using clean cooking energy between rural and urban households was -0.14647, indicating that rural households, on average, have a significantly lower likelihood of utilising clean cooking energy compared to their urban counterparts. This finding underscores the persistent rural-urban divide in access to clean energy solutions.

The decomposition analysis revealed that household wealth was the most significant explanatory factor for the observed gap. Specifically, differences in household wealth accounted for 80.5% of the total rural-urban disparity in cooking energy use. Although household wealth emerged as the primary driver of this disparity, other factors also contributed, including household size (7.5%) and the education level of the household head (4.4%). The finding suggests that while socioeconomic and demographic factors influence household energy choices, financial constraints remain the dominant structural barrier to energy transition in rural areas.

Table 3: Decomposition of the Variations in Household Main Energy for Cooking between Rural and Urban

Number of obs.	6,976
Number of observations in Rural	4966
Number of observations in Urban	2010
Probability-Rural	0.025171
Probability- Urban	0.171642
Difference (Rural-Urban Gap)	-0.14647

Variable	**Coefficient**	**Std. Err.**	**z**	**P>z**	**Percentage**
Age	-0.0017	0.0014	-1.2400	0.2140	1.1559
Sex	-0.0017	0.0014	-1.2600	0.2070	1.1755
Education Level	-0.0065	0.0022	-2.9400	0.0030	4.4274
Household Size	-0.0110	0.0026	-4.1600	0.0000	7.4843
Wealth Index	-0.1180	0.0105	-11.2400	0.0000	80.5490

Source: Own compilation from TDHS (2022)

3.2 Discussion

This study assessed the factors influencing household clean energy use for cooking in Tanzania, revealing that the education level of the household head, household wealth, and household size significantly impact fuel choice. These variables do not operate in isolation; rather, they interact in complex ways that shape household energy decisions and contribute to disparities in clean energy adoption, especially between rural and urban areas.

Education emerges as a critical driver of clean energy use. Educated household heads are more likely to be aware of the health risks associated with traditional cooking fuels and the benefits of clean alternatives such as electricity and liquefied petroleum gas (LPG). This awareness, coupled with better access to information, makes them more open to adopting modern cooking technologies. Moreover, education enhances access to formal employment, resulting in higher and more stable income levels. These factors are instrumental in enabling households to afford the initial and recurring costs associated with clean energy use.

Closely linked to education is household wealth, which further amplifies a household's ability to transition to cleaner fuels. Households with higher wealth indices are better positioned to afford appliances and fuel required for modern cooking methods. In contrast, poorer households face financial constraints that not only limit access to clean fuels but also perpetuate reliance on cheaper, traditional alternatives such as firewood and charcoal. Moreover, infrastructure deficits, particularly in rural and low-income settings, compound these challenges by restricting access to electricity and LPG distribution networks. These findings are consistent with prior research by Dongzagla and Adams (2022), Ang'u et al. (2023), and Omojolaibi and Alasinrin (2025), which emphasises the role of financial and structural barriers in clean energy transitions.

Moreover, larger households are significantly less likely to use clean energy for cooking. The higher daily energy needs associated with large households often lead to a preference for bulk, low-cost fuel sources, especially where financial resources are limited. Furthermore, decision-making in large households may be influenced by older members who favour traditional cooking practices or resist change. This interplay between household size and affordability reinforces the barriers to clean energy adoption already posed by low income and limited education. Similar observations were made by Omojolaibi and Alasinrin (2025), who found that large household sizes inhibit the uptake of modern cooking fuels.

The Fairlie decomposition analysis reinforces these findings by highlighting significant rural-urban disparities in clean cooking energy use. Rural households are markedly less likely than their urban counterparts to adopt clean energy sources, primarily due to lower income levels and limited access to energy infrastructure. Household wealth was identified as the largest contributor to this disparity, underscoring the role of economic capacity in determining energy choices. These disparities point to the need for rural-specific policy interventions that address both affordability and infrastructure deficits.

Furthermore, the study underscores the interconnected nature of education, income, household structure, and location in determining household energy behaviour. Financial limitations remain a core barrier, but they are intricately linked to structural issues such as inadequate energy access and demographic factors like household size. Addressing these barriers requires an integrated policy approach that simultaneously promotes educational opportunities, expands rural energy infrastructure, and supports low-income households with targeted subsidies or financing schemes. As Ntegwa and Olan'g (2024) note, closing the rural-urban gap in clean cooking energy use will depend on addressing both socioeconomic and infrastructural inequalities.

4. Conclusion and Recommendations

4.1 Conclusion

The findings of this study highlight the key determinants of household cooking fuel choices in Tanzania, with education level, household wealth, and household size emerging as significant predictors. Higher education levels among household heads were associated with increased use of clean cooking energy, emphasising the role of awareness and knowledge in energy transition. Similarly, household wealth was a strong positive determinant, reinforcing the impact of financial stability on clean energy adoption. In contrast, larger household sizes were negatively associated with clean cooking fuel use, suggesting that economic constraints and higher fuel demands in bigger households drive reliance on traditional biomass fuels. Furthermore, the Fairlie decomposition analysis revealed substantial rural-urban disparities in clean energy use, with rural households significantly less likely to adopt modern cooking fuels. Household wealth was identified as the primary driver of this disparity, accounting for 80.5% of the observed gap, followed by household size (7.5%) and the education level of the household head (4.4%). These findings indicate that while education and household size play a role, financial constraints remain the dominant structural barrier preventing rural households from transitioning to clean energy solutions.

4.2 Recommendations

Based on the findings of this study, several key policy recommendations can be made to enhance the adoption of clean cooking energy in Tanzania, particularly in rural areas. These recommendations aim to address the socioeconomic, infrastructural, and educational barriers identified in the study.

1. The government should introduce targeted financial support and subsidies for low-income households, especially those in rural areas. These economic incentives can help reduce the initial cost of clean cooking technologies

2. Policymakers should prioritise the expansion of clean energy infrastructure, such as electricity grids, solar power, and LPG supply networks, to rural and peri-urban areas.

3. Government and non-governmental organisations should invest in large-scale education and awareness campaigns about the benefits of clean cooking energy. These campaigns should target both urban and rural populations, emphasising the health, economic, and environmental benefits of using clean cooking fuels.

4. Policies should promote energy-efficient and affordable cooking technologies, including the development and distribution of improved biomass stoves that are both fuel-efficient and less harmful to health.

5. Expanding access to credit for households to purchase clean cooking technologies could also help overcome the financial barriers identified in the study. Financial institutions should be encouraged

to offer low-interest loans or microfinance options specifically for the purchase of clean cooking solutions.

6. Policymakers should invest in further research and data collection to monitor trends in energy use across different regions, household sizes, and socioeconomic groups. This data can guide the design and implementation of more effective, evidence-based policies that are tailored to specific population needs.

Acknowledgment

The successful completion of this work is attributed to the cooperation and support of several individuals and institutions. The authors sincerely thank everyone who contributed, particularly the Eastern Africa Statistical Training Centre (EASTC) for providing funding to support the writing of this paper, the Tanzania National Bureau of Statistics (NBS) for providing the data set and the referees for their valuable insights and refinements.

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