Determinants of Biomass Fuel Use among Women in Rural Communities of Ekiti, Kwara and Edo States, Nigeria

Alade Fisayo Oluwatoyin[1]*, Sawyerr, Henry Olawale[2], Opasola Afolabi Olaniyi[3]

[1,2,3]Department of Environmental Health Science, Kwara State University, Malete, Nigeria

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ABSTRACT

Biomass fuel remains the principal source of household cooking energy in rural Nigeria despite increasing awareness of its adverse health and environmental consequences. This study investigated the determinants of biomass fuel use and examined the influence of socioeconomic status on the extent of biomass fuel utilization among women in rural communities of Ekiti, Kwara, and Edo States, Nigeria. A cross-sectional survey design was adopted, and data were collected from 371 women selected through a multistage stratified sampling technique using a structured questionnaire. Descriptive statistics, chi-square tests, binary logistic regression, and multinomial logistic regression were employed for data analysis. The findings revealed that firewood was the predominant biomass fuel, with 49.87% of respondents reporting extensive use, followed by charcoal (18.87%) and sawdust (7.01%).

Economic factors, particularly cost of living (70.4%), fuel subsidy removal (59.8%), and inflation (55.5%), emerged as the most influential determinants of biomass fuel choice, whereas cultural beliefs (8.1%) and perceived health benefits (1.6%) exerted relatively little influence. Chi-square analysis demonstrated significant associations between state of residence, educational attainment, annual income, and the extent of firewood use ($p < 0.001$). Binary logistic regression further indicated that women with NCE/ND qualifications were significantly less likely to rely extensively on firewood than women without formal education (OR = 0.01, $p < 0.001$), whereas those earning ₦500,001–₦1,000,000 annually exhibited significantly higher odds of extensive firewood use (OR = 6.30, $p = 0.009$). Multinomial logistic regression showed that higher income and tertiary education significantly increased the likelihood of using charcoal rather than firewood as the primary cooking fuel. The study concludes that household biomass fuel choice is driven predominantly by economic realities rather than cultural or health considerations. Policies aimed at reducing dependence on traditional biomass should therefore prioritize improving the affordability, accessibility, and availability of clean cooking technologies while promoting educational and income-enhancing interventions to facilitate a sustainable transition to cleaner household energy.

Keywords: Biomass fuel; household energy; socioeconomic status; fuel choice; rural women; Nigeria.

INTRODUCTION

Access to clean, safe, and affordable household energy remains a major public health, environmental, and sustainable development challenge across many low- and middle-income countries (Raman et al., 2025; Woolley et al., 2021). Although modern cooking fuels such as liquefied petroleum gas (LPG), electricity, and biogas are increasingly promoted because of their environmental and health benefits, biomass fuels continue to dominate household cooking in many rural communities. Biomass fuels such as including firewood, charcoal, crop residues, sawdust, and animal dung, still remain the principal source of domestic energy for millions of households due to their affordability, accessibility, and widespread availability (Awan et al., 2024; Habtamu, et al. 2023; Roche et al., 2024).

Nigeria ranks among the countries with the highest dependence on biomass for household cooking (Adekanye, 2025; Sani et al., 2026; Slater et al., 2025). According to Olanrewaju (2019), and Sani et al. (2026), solid biomass, such as firewood and charcoal, accounts for more than 80% of household energy

consumption in the country, a figure that places Nigeria among the most biomass-dependent nations in the region. Despite various government initiatives aimed at promoting cleaner energy sources, rural households continue to rely heavily on traditional biomass fuels. Previous studies have attributed this persistent dependence to widespread poverty, inadequate energy infrastructure, limited access to modern cooking technologies, and rising prices of cleaner fuels (Adebayo et al., 2025; Derebe et al., 2025; Gill-Wiehl et al., 2026; Jiang et al., 2025). For instance, Kadafa et al. (2017) identified poverty and income as the dominant factors shaping domestic energy choice across African households more broadly. Recent economic developments, particularly fuel subsidy removal, persistent inflation, and the increasing cost of living in Nigeria, have further constrained household purchasing power and may have reinforced more dependence on traditional biomass fuels.

Beyond their economic importance, biomass fuels present significant public health and environmental concerns. Prolonged exposure to smoke generated from biomass combustion has been associated with respiratory infections, chronic obstructive pulmonary disease, cardiovascular illnesses, adverse pregnancy outcomes, and premature mortality (Olasehinde et al., 2026). The continued harvesting of fuel-wood also contributes to deforestation, biodiversity loss, and climate change through greenhouse gas emissions (Okoye, 2026). Consequently, reducing household dependence on biomass has become an important policy objective for achieving several Sustainable Development Goals (SDGs), including good health and well-being (SDG 3), affordable and clean energy (SDG 7), climate action (SDG 13), and life on land (SDG 15).

Household energy choice has been widely explained using the Energy Ladder Theory, which suggests that households progressively transition from traditional biomass fuels to cleaner and more efficient energy sources as income and socioeconomic conditions improve (Kumar, 2026; Salami et al., 2026).

More recent evidence, however, supports the Energy Stacking Model, which argues that households often use multiple fuels simultaneously rather than completely abandoning traditional fuels (Ntiyakunze & Stage, 2025; Yadav et al., 2026). In many developing countries, economic realities, fuel availability, cultural practices, household size, and reliability of energy supply combine to influence cooking fuel decisions. Understanding these interacting factors is therefore essential for designing effective interventions aimed at promoting clean cooking.

Previous studies conducted in Nigeria and other sub-Saharan African countries have identified income, education, occupation, household size, and fuel accessibility as important determinants of cooking fuel choice (Adebayo et al., 2025; Okoye, 2026; Olasehinde et al., 2026).

Nevertheless, much of the existing literature has focused on the adoption of clean cooking fuels or the transition from biomass to modern energy sources. Comparatively fewer studies have examined the factors influencing differences in the use of specific biomass fuels, such as firewood, charcoal, and sawdust, among rural women. Furthermore, limited empirical evidence exists regarding how socioeconomic characteristics influence not only the choice of biomass fuel but also the extent to which different biomass fuels are utilized across diverse geographical settings within Nigeria.

This study addresses these gaps by examining the determinants of biomass fuel use among women in selected rural communities of Ekiti, Kwara, and Edo States, Nigeria. Specifically, it identifies the economic, environmental, accessibility, and sociocultural factors influencing biomass fuel choice and investigates the effects of socioeconomic characteristics such as including state of residence, educational attainment, and annual income, on the extent and pattern of biomass fuel utilization.

Unlike previous studies that primarily examined transitions from biomass to clean fuels, and region-specific socioeconomic influence, this study explores variations within biomass fuel use itself by distinguishing between firewood, charcoal, and sawdust through both binary and multinomial logistic regression analyses. The findings provide evidence that can guide policymakers in designing targeted interventions aimed at improving access to affordable clean cooking energy while considering the socioeconomic realities of rural households.

LITERATURE REVIEW

Biomass Fuel

Biomass fuel refers to organic materials derived from plants and animals that are used as sources of energy for cooking, heating, and other domestic activities (Derebe et al., 2025; Kalak, 2023; Kumar et al., 2023). Common biomass fuels include firewood, charcoal, sawdust, crop residues, animal dung, and agricultural wastes. In many developing countries, biomass remains the dominant household energy source because it is inexpensive, readily available, and often locally accessible (Derebe et al., 2025; Mulatu et al., 2025). Despite these advantages, the combustion of biomass fuels using traditional cooking technologies produces substantial household air pollution, exposing users to harmful pollutants such as particulate matter, carbon monoxide, and other toxic compounds. These emissions have been associated with respiratory diseases, cardiovascular disorders, eye irritation, adverse pregnancy outcomes, and premature mortality, particularly among women and children who spend considerable time near cooking areas (Kravchenko & Minkina, 2025; Olasehinde et al., 2026; Zahra et al., 2025).

Household Energy Choice

Household energy choice can be described as the method through which households select one or more energy sources to meet their domestic cooking and heating purposes (Mondal et al., 2025). This decision is influenced by a complex interaction of environmental, economic, cultural, social, demographic, and infrastructural factors. Household income, educational attainment, fuel prices, accessibility, availability, household size, occupation, and government energy policies have consistently been identified as important determinants of cooking fuel selection (Adebayo et al., 2025; Mulatu et al., 2025). In many rural communities today, households often rely on multiple energy sources simultaneously, depending on affordability, convenience, and seasonal availability. Thus, several factors are responsible for the type of biomass choice used among women rural settlements. As such, this study made an attempt to identify those factors.

THEORETICAL FRAMEWORK

Energy Ladder Theory (ELT)

The EL theory basically proposes that households gradually transit from traditional biomass fuels to transitional fuels and ultimately to modern, cleaner energy sources as their socioeconomic conditions improve (Wali et al., 2025). According to this theory and as established by Adamu et al. (2020), increasing income enables households to substitute firewood and other traditional fuels with cleaner alternatives such as liquefied petroleum gas (LPG), electricity, or biogas.

Furthermore, educational attainment has the capability to also facilitate this transition through increased awareness of the health outcomes, environmental implications, and economic benefits associated with the use of modern cooking technologies. But the reverse is the case if socioeconomic status of biomass consumers remains stagnant or declines when national or global economic condition worsens.

Although the Energy Ladder Theory has received substantial empirical support based on studies such as Adamu et al. (2020), Ahmad and De Oliveira (2015), Wali et al. (2025), recent evidence indicates that household energy transitions are rarely linear, especially in developing countries where affordability and accessibility remain significant constraints.

Thus, in the event of increasing economic hardship in Nigeria, even though World health Organization and the United Nations are working tireless to ensure safer environment and improved condition for all, the reverse side of the ELT was proposed in this study. Hence, the study hypothesized that socioeconomic factors will increase biomass use among the rural women in the selected states of Nigeria.

Energy Stacking Theory

The Energy Stacking Theory extends the ELT by suggesting that households do not necessarily abandon traditional fuels after adopting modern energy sources. Instead, they simultaneously use multiple fuels to meet different household needs. That is, a household may rely on LPG for quick cooking while continuing to use firewood or charcoal for preparing foods requiring prolonged heating or during periods of economic crises such as fuel scarcity or high energy prices. This theory provides a more realistic explanation of household cooking behaviour in rural Nigeria, where economic uncertainty, unstable energy supply, and fluctuating fuel prices encourage households to diversify or replaces energy sources completely. Therefore, ES theory provides the principal theoretical lens for this study because it helps to explain why socioeconomic improvement may reduce continued dependence on firewood without necessarily eliminating biomass fuel use altogether, or otherwise.

MATERIALS AND METHODS

Study Design

This study employed a descriptive cross-sectional survey design to investigate the determinants of biomass fuel use and examine the influence of socioeconomic status on the extent of biomass fuel utilization among women in selected rural communities in Ekiti, Kwara, and Edo States, Nigeria. The cross-sectional design was considered appropriate for this study because it enabled the collection of data on household fuel-use patterns, and associated socioeconomic characteristics at a single point in time.

Study Area

The study was conducted in three purposively selected rural Local Government Areas (LGAs) which are; Ijero LGA in Ekiti State, Asa LGA in Kwara State, and Esan West LGA in Edo State. These locations were selected because of their substantial dependence on biomass fuels for household cooking, abundant forest resources, and predominantly rural, low-income populations. The selected communities from different geopolitical regions in Nigeria also enhanced the geographical diversity and external validity of the findings.

Study Population

The target population comprised women aged 18 years and above who were primarily responsible for household cooking and had resided in the selected communities for at least one year before the commencement of data collection. The study focused on women because they are the principal household energy users and are disproportionately exposed to the health risks associated with biomass fuel combustion. However, since the population cannot be readily determined, that is unknown at the time of this study; the study adopts Cochran's (1963) formula for an unknown population.

$n_0 = Z^2pq/e^2$, where n_0 = required sample size for an unknown population; Z = Z-score corresponding to the desired confidence level (that is, 95% confidence level which is equal to 1.96); p = estimated proportion of the population with the attribute of interest; q = 1 – p; e = desired margin of error (that is 0.05).

Thus, based on the Cochran's formula, the study determined 384 as the population of the study.

Sample Size Determination

The sample size was determined using the Kothari (2004) formula for estimating sample size in large populations. A prevalence estimate of 62% obtained from the African Energy Commission (2018), a 95% confidence level, and a 5% margin of error were applied, yielding a minimum sample size of 362 respondents. To compensate for possible non-response and incomplete copies of questionnaire, the sample size was increased by 20% leading to distribution of 434 copies of the questionnaire. A total of 371 completed copies were eventually retrieved and included in the analysis.

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Sampling Technique

A multistage stratified sampling procedure was adopted. In the first stage, the three states constituted the primary strata. In the second stage, one rural Local Government Area with substantial biomass fuel utilization was purposively selected from each state. Subsequently, rural communities within each Local Government Area were identified, after which households were selected using purposive sampling. This enabled the researcher to identify and focus on the most appropriate respondents for the study. Where more than one eligible woman resided within a household, one respondent was selected to enable more coverage.

Research Instrument

Data were collected using a structured close-ended questionnaire developed from previous empirical studies on household energy utilization. The questionnaire consisted of three sections. Section A obtained respondents' demographic and socioeconomic characteristics, including age, marital status, educational attainment, occupation, employment status, annual income, and state of residence. Section B assessed the extent of utilization of seven biomass fuel types using a four-point Likert scale ranging from 1 (Not at all) to 4 (Large extent). Section C examined the perceived influence of ten factors affecting biomass fuel choice using a three-point scale of Low extent, Moderate extent, and Large extent.

Validity and Reliability of the Instrument

The questionnaire was subjected to expert review by specialists in environmental health, public health, and research methodology to establish face and content validity. Prior to the main survey, the instrument was pre-tested among women residing in a rural community with characteristics similar to those of the study population but outside the selected study areas, specifically in this case, Gboyin Local Government of Ekiti State. Feedback from the pilot study was used to improve clarity, wording, and sequencing of the questionnaire items. Internal consistency reliability was assessed using Cronbach's alpha coefficient, with values of 0.70 or higher, which is considered acceptable for research purposes.

Data Collection Procedure

Data collection was undertaken personally and with the help of self-trained research assistants who were proficient in both English and the relevant local languages spoken within the study communities. Direct data collection was adopted through one-on-one reading of the questionnaire items to the respondents in their respective local dialects. The essence was to minimise non-response and accommodate respondents with limited literacy. Completed copies of the questionnaire were reviewed daily to ensure completeness and consistency before data entry. However, incomplete copies were excluded during analysis.

Data Analysis

Data were entered, cleaned, and analysed using Python statistical packages, including pandas, SciPy, and statsmodels. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise respondents' characteristics and patterns of biomass fuel utilization. Pearson's chi-square test of independence was employed to examine associations between socioeconomic characteristics and biomass fuel utilization. Binary logistic regression analysis was conducted to identify predictors of extensive firewood use, while multinomial logistic regression was used to determine factors influencing the choice of primary biomass fuel, with firewood serving as the reference category. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported to quantify the strength of associations. Statistical significance was established at $p < 0.05$.

Ethical Considerations

Ethical approval was obtained from the appropriate institutional ethics committee before commencement of the study. Permission was also obtained from community leaders within the selected communities. Participation was entirely voluntary, and informed consent was obtained from all respondents prior to data

collection. In addition, confidentiality and anonymity were maintained throughout the study. Also, respondents were informed of their right to withdraw from the study at any stage without penalty.

RESULTS

Demographic and Socioeconomic Characteristics of the Respondents

Out of the 371 women surveyed, 128 (34.50%) resided in Kwara State, 125 (33.69%) in Ekiti State and 118 (31.81%) in Edo State. The largest age group falls between 31 and 40 years (29.11%), and the respondents were predominantly married (79.25%) and of Yoruba ethnicity (61.46%). Educational attainment skewed low, with 28.30% of respondents having no formal education and 35.85% holding only the West African School Certificate or its equivalent, described in this study as O/Level. Most respondents were self-employed (58.49%), working principally as traders (46.63%), and most of the respondents (64.96%) earned 360,000 naira or less annually. The results are presented in Table 1.

Table 1 Demographic/Socioeconomic Characteristics of Respondents (N = 371)

Variable	**Category**	**n**	**%**
State	Kwara	128	34.50
	Ekiti	125	33.69
	Edo	118	31.81
Age group (years)	31 to 40	108	29.11
	41 to 50	97	26.15
	51 to 60	65	17.52
	21 to 30	45	12.13
	20 or below	38	10.24
	61 or above	18	4.85
Marital status	Married	294	79.25
	Single	65	17.52
	Divorced	12	3.23
Education	O Level	133	35.85
	Not educated	105	28.30
	Leaving certificate	82	22.10
	NCE or ND	40	10.78
	HND or B.Sc	11	2.96
Annual income	Not more than N360,000	241	64.96
	N360,001 to N500,000	91	24.53

	N500,001 to N1,000,000	29	7.82
	Above N1,000,000	10	2.70

Source: Researchers' computation (2026)

Extent of Biomass Fuel Use

As presented in Table 2, firewood was the most heavily used fuel, reported at a large extent by 49.87% of respondents and a moderate extent by a further 28.84%, leaving only 17.52% who did not use it at all. Charcoal followed at a considerable distance, used to a large extent by 18.87%, while sawdust was used to a large extent by only 7.01%. Animal dung, crop residue, peat dung and coal were used only marginally, with non-use exceeding 88% for each.

Table 2 Extent of Use of Biomass Fuel Types (N = 371)

Fuel type	Large extent %	Moderate extent %	Low extent %	Not at all %
Firewood	49.87	28.84	3.77	17.52
Charcoal	18.87	23.72	8.63	48.79
Sawdust	7.01	2.96	32.35	57.68
Coal	0.00	1.35	2.43	96.23
Crop residue	0.81	1.89	8.36	88.95
Animal dung	0.00	1.35	1.62	97.04
Peat dung	0.00	0.00	1.62	98.38

Source: Researchers' computation (2026)

Factors Influencing the Choice of Biomass Fuel

Cost of living was rated as exerting large extent influence on fuel choice by 70.4% of respondents, ahead of subsidy removal (59.8%) and inflation (55.5%). Local environment (57.4%) and easy accessibility (52.3%) also ranked highly. Health benefit (69.8%) and culture (63.6%) were, in contrast, most often rated as having only low extent influence, suggesting that economic pressure outweighs both health consciousness and tradition in shaping what these women burn to cook. The results are presented in Table 3.

Table 3 Perceived Extent of Influence of Selected Factors on Biomass Fuel Choice (N = 371)

Factor	Large extent %	Moderate extent %	Low extent %
Cost of living	70.4	21.3	8.4
Subsidy removal	59.8	29.9	10.2
Local environment	57.4	29.6	12.9

Inflation	55.5	14.0	27.8
Easy accessibility	52.3	36.7	11.1
Poor income level	50.1	40.7	9.2
Cost implication	35.6	48.2	16.2
High cost of cleaner fuels	31.8	30.2	38.0
Culture	8.1	28.3	63.6
Health benefit	1.6	28.6	69.8

Source: Researchers' computation (2026)

4.4 Effect of Socioeconomic Status on Extent of Biomass Fuel Use

Chi-square (χ^2) analysis as presented in Table 4 shows that the extent of use of firewood, sawdust, and charcoal varied significantly by state of residence, educational attainment, and annual income. Firewood use differed significantly across states ($\chi^2(6) = 96.43$, $p < 0.001$), educational levels ($\chi^2(12) = 76.54$, $p < 0.001$), and annual income categories ($\chi^2(9) = 51.39$, $p < 0.001$). Similar patterns were observed for sawdust and charcoal, both of which exhibited significant associations with state of residence, educational attainment, and annual income ($p < 0.05$ for all). In contrast, the use of animal dung and peat dung showed no significant association with either state of residence or educational attainment ($p > 0.05$), reflecting their consistently low utilization across the study population irrespective of respondents' demographic and socioeconomic characteristics.

Table 4 Association between Socioeconomic Variables and Extent of Use of Biomass Fuels

Biomass fuel	**Socioeconomic variable**	**χ^2**	**df**	**p-value**
Firewood	State of residence	96.43	6	<0.001
	Educational attainment	76.54	12	<0.001
	Annual income	51.39	9	<0.001
Sawdust	State of residence	350.35	6	<0.001
	Educational attainment	105.43	12	<0.001
	Annual income	42.53	9	<0.001
Charcoal	State of residence	205.33	6	<0.001
	Educational attainment	72.44	12	<0.001
	Annual income	42.38	9	<0.001
Coal	State of residence	14.54	4	0.006
	Educational attainment	22.17	8	0.005

	Annual income	71.12	6	<0.001
Crop residue	State of residence	66.78	6	<0.001
	Educational attainment	29.85	12	0.003
	Annual income	26.81	9	0.002
Animal dung	State of residence	6.18	4	0.186
	Educational attainment	64.77	8	<0.001
	Annual income	35.40	6	<0.001
Peat dung	State of residence	3.11	2	0.211
	Educational attainment	6.19	4	0.186
	Annual income	19.62	3	<0.001

Source: Researchers' computation (2026)

Note. χ^2 = Pearson chi-square statistic; df = degrees of freedom; p values less than 0.05 indicate statistically significant associations. Significant associations were observed for most biomass fuels with socioeconomic characteristics, except for the associations between peat dung use and state of residence or educational attainment, and between animal dung use and state of residence.

Furthermore, binary logistic regression was performed to examine the association between socioeconomic characteristics and the likelihood of extensive firewood use, the predominant biomass fuel use pattern observed in the study population. The overall model was statistically significant (likelihood ratio χ^2, $p < 0.001$), with a Nagelkerke pseudo-R^2 of 0.147. Compared with women who had no formal education, those with a National Certificate in Education (NCE) or National Diploma (ND) had significantly lower odds of extensive firewood use (OR = 0.01, $p < 0.001$), as did women with a Higher National Diploma (HND) or Bachelor's degree (B.Sc.) (OR = 0.18, p = 0.032).

In contrast, respondents with First School Leaving Certificate (FSLC) or O-Level qualifications did not differ significantly from those with no formal education. Annual income exhibited a less consistent pattern, with women earning ₦500,001–₦1,000,000 per year having significantly higher odds of extensive firewood use than those in the lowest income category (OR = 6.30, p = 0.009). After adjustment for educational attainment and annual income, state of residence was not a significant predictor of extensive firewood use, suggesting that the state-level differences observed in the χ^2 analysis were largely explained by differences in the socioeconomic composition of the populations across states. The results are presented in Table 5.

Table 5 Binary Logistic Regression Analysis Predicting Extensive Firewood Use (N = 371)

Predictor	**Reference category**	**OR**	**95% CI**	**p-value**
State of residence:				
Ekiti	Edo	1.51	0.80–2.83	0.204
Kwara	Edo	1.51	0.83–2.73	0.178

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Educational attainment:				
First School Leaving Certificate (FSLC)	No formal education	0.80	0.41–1.57	0.517
O-Level	No formal education	0.88	0.48–1.61	0.669
NCE/ND	No formal education	0.01	0.00–0.05	<0.001
HND/B.Sc.	No formal education	0.18	0.04–0.86	0.032
Annual income:				
₦360,001–₦500,000	≤ ₦360,000	0.95	0.57–1.59	0.847
₦500,001–₦1,000,000	≤ ₦360,000	6.30	1.57–25.30	0.009
> ₦1,000,000	≤ ₦360,000	14.37	0.80–254.62	0.069

Source: Researchers' computation (2026)

Note: OR = odds ratio; CI = confidence interval. Reference categories were Edo State, no formal education, and annual income ≤ ₦360,000. Nagelkerke pseudo-R^2 = 0.147. The overall model was statistically significant (likelihood ratio test, $p < 0.001$).

To further examine household fuel preferences, a primary biomass fuel was assigned to each respondent based on the biomass fuel reported as being used to the greatest extent. Firewood was the primary fuel for 75.7% of respondents, followed by charcoal (19.1%) and sawdust (5.1%). A multinomial logistic regression model was fitted using firewood as the reference category and educational attainment and annual income as predictors. Compared with women with no formal education, those with tertiary education (NCE/ND/HND/B.Sc.) had significantly higher odds of using charcoal rather than firewood as their primary cooking fuel (OR = 2.66, p = 0.015).

Conversely, women with O-Level qualifications had significantly lower odds of using sawdust rather than firewood as their primary fuel (OR = 0.17, p = 0.008). Annual income exceeding ₦360,000 was associated with significantly higher odds of using charcoal (OR = 2.53, p = 0.001) and sawdust (OR = 3.90, p = 0.006) instead of firewood as the primary cooking fuel. No respondent with tertiary education reported sawdust as the primary fuel, resulting in sparse data for this category and preventing reliable estimation of the corresponding regression coefficient. This finding is therefore presented as an observed empirical pattern rather than a stable model estimate. The results are presented in Table 6.

Table 6 Analysis Predicting Primary Biomass Fuel Choice Relative to Firewood (N = 371)

Predictor	**Reference category**	**Charcoal vs. Firewood OR**	**p-value**	**Sawdust vs. Firewood OR**	**p-value**
Educational attainment:					
First School Leaving Certificate (FSLC)	No formal education	0.58	0.231	0.37	0.100
O-Level	No formal	0.96	0.920	0.17	0.008

	education				
Tertiary (NCE/ND/HND/B.Sc.)	No formal education	2.66	0.015	0.00†	>0.99
Annual income					
> ₦360,000	≤ ₦360,000	2.53	0.001	3.90	0.006

Source: Researchers' computation (2026)

Note. Firewood was the reference outcome category. OR = odds ratio. Nagelkerke pseudo-R^2 = 0.095. The estimated OR of 0.00 resulted from complete separation because no respondent with tertiary education reported sawdust as the primary biomass fuel. Consequently, this coefficient is unstable and should not be interpreted as a reliable estimate.

DISCUSSION

This study examined factors that determine biomass fuel use and its association with household cooking fuel choices among women across selected communities in Kwara, Ekiti, and Edo States, Nigeria. Firewood remained the dominant biomass fuel, serving as the primary fuel for approximately three-quarters of the respondents, while charcoal and sawdust accounted for smaller proportions. This persistence of solid biomass dependence is consistent with evidence from Nigeria and other low- and middle-income settings, where household energy transitions have been slow because clean cooking alternatives remain constrained by affordability, availability, and reliability rather than preference alone (Derebe et al., 2025; Habtamu et al., 2023; Oyedeji et al., 2026; WHO, 2021). Although cleaner fuels such as liquefied petroleum gas (LPG) and electricity are increasingly promoted in Nigeria, many households continue to rely on biomass because it represents an accessible and relatively inexpensive energy source, particularly where household economic resources are limited (Gill-Wiehl et al., 2026; Muhammed et al., 2026).

The predominance of firewood observed in this study agrees with previous research from rural Nigeria demonstrating that fuel-wood remains the most common cooking energy source despite government efforts to promote modern energy alternatives. Arowolo et al. (2018), using multinomial regression analysis among rural Nigerian households, similarly reported that fuel-wood and charcoal remained dominant cooking fuels, with household socioeconomic characteristics significantly influencing transitions toward cleaner energy sources. Comparable findings have been reported across sub-Saharan Africa, where biomass fuels continue to account for a substantial share of household energy consumption because they are locally available and require limited financial investment compared with modern fuels (Derebe et al., 2025; Karimu et al., 2016; Rahut et al., 2017).

A major finding of this study was that economic pressures were perceived as the strongest influences on biomass fuel selection. Cost of living, subsidy removal, inflation, and poor income levels were ranked considerably higher than cultural factors or perceived health benefits. This finding supports the broader evidence that household energy decisions in low-income settings are primarily shaped by economic feasibility rather than by knowledge of environmental or health consequences alone (Gill-Wiehl et al., 2026; Tereka et al., 2025). In Nigeria, increases in the cost of modern cooking fuels, particularly LPG, may further limit adoption among economically vulnerable households. The findings of Arowolo et al. (2018) similarly demonstrated that household income was a significant determinant of cooking energy transition, with higher-income households having greater likelihood of adopting cleaner fuels such as gas. Thus, the strong influence of cost-related factors reported by respondents in this study reflects the practical economic considerations involved in household energy decisions.

Interestingly, perceived health benefit was ranked among the least influential factors affecting fuel choice. This does not necessarily indicate that respondents lack awareness of the health consequences of biomass combustion; rather, it suggests that health considerations may be outweighed by immediate economic constraints. Previous studies have shown that households may recognize the potential risks associated with biomass smoke but continue using these fuels because cleaner alternatives are perceived as unaffordable, inaccessible, or unreliable (Ayodele-Olajire et al., 2025; Cyriac, 2026; Pienaah et al., 2026). Consequently, interventions focused solely on health education may have limited impact unless accompanied by strategies that improve affordability and accessibility of cleaner fuels.

Educational attainment showed an important association with biomass fuel patterns in this study. Women with tertiary-level education had substantially lower odds of extensive firewood use compared with women without formal education. Similarly, tertiary education increased the likelihood of charcoal being selected over firewood as the primary biomass fuel. These findings are consistent with evidence that education contributes to household energy transitions by improving access to information, employment opportunities, income-generating capacity, and awareness of alternative energy technologies (Sani et al., 2026; Zoungrana & Sawadogo, 2025). Arowolo et al. (2018) similarly found that education of household heads significantly increased the likelihood of adopting cleaner cooking fuels, particularly gas, while reducing dependence on fuel-wood.

However, the present findings also highlight that education alone may not be sufficient to produce complete transitions away from biomass. Despite higher educational attainment being associated with reduced firewood dependence, charcoal remained an important alternative fuel. This suggests that households may undergo partial energy transitions, replacing one biomass fuel with another rather than immediately adopting non-biomass options. Similar observations have been reported in household energy studies, where transitions often occur gradually and involve combinations of traditional and modern fuels depending on affordability, availability, and household circumstances (Bawakyillenuo et al., 2025; Gill-Wiehl et al., 2026; Olasehinde et al., 2026). Therefore, movement away from firewood should not automatically be interpreted as a transition toward clean energy unless substitution with LPG, electricity, or other low-emission technologies is specifically achieved.

The relationship between income and fuel choice was more complex than expected. While higher income was generally associated with greater likelihood of selecting charcoal or sawdust rather than firewood as the primary fuel, respondents in the ₦500,001–₦1,000,000 annual income category showed higher odds of extensive firewood use compared with the lowest-income group. Although this appears inconsistent with conventional energy ladder theory, it may reflect the heterogeneous role of biomass fuels within households. For example, some households may continue using firewood despite improved economic status because of cooking preferences, household size, commercial food preparation activities, or availability of free or low-cost biomass resources. Previous studies have similarly argued that household energy transitions are not always linear, with households frequently combining multiple fuels according to cost, convenience, and reliability rather than moving directly from traditional biomass to modern fuels (Adamu et al., 2020; Ahmad & De Oliveira, 2015; Wali et al., 2025).

The multinomial regression findings further suggest that increasing economic resources may facilitate movement between biomass categories before complete transition to cleaner fuels occurs. Women with income above ₦360,000 had greater odds of using charcoal and sawdust compared with firewood. While these fuels may represent alternatives to traditional fuelwood, they remain biomass fuels and can still contribute to household air pollution. This finding reinforces the importance of distinguishing between reduced reliance on firewood and genuine adoption of clean cooking technologies. According to the World Health Organization (2021), only transitions to fuels and technologies that meet emission standards can substantially reduce household air pollution exposure.

The observed associations between state of residence and biomass use in the bivariate analysis were attenuated after adjustment for education and income, suggesting that socioeconomic composition may explain much of the apparent geographical variation. Similar findings have been reported in Nigerian and African household energy studies, where regional differences in cooking fuel use often reflect variations in

wealth, infrastructure, urbanization, and access to energy markets rather than location alone (Malah-Kuete, 2025; Wasswa et al., 2025). This finding suggests that policies aimed at reducing biomass dependence should consider household-level socioeconomic characteristics rather than relying exclusively on geographical targeting.

The results have important implications for household energy policy in Nigeria. Because respondents identified economic constraints as the dominant determinant of fuel choice, expanding access to affordable clean cooking technologies may be more effective than relying exclusively on awareness campaigns. Financial mechanisms such as targeted LPG subsidies, improved distribution networks, microfinance support for clean cooking technologies, and policies addressing energy price instability may improve adoption among vulnerable households. At the same time, education remains relevant because it appears to influence fuel preferences and may improve acceptance of cleaner technologies when they become economically accessible.

Several limitations should be considered when interpreting these findings. First, the cross-sectional design prevents determination of causal relationships between socioeconomic characteristics and fuel choice. Second, fuel use was based on self-reported measures, which may introduce recall or reporting biases. Third, some biomass categories, including animal dung, peat dung, and coal, had very low prevalence, limiting statistical power for subgroup comparisons. Additionally, because respondents were selected from specific local government areas within three states, the findings may not represent all households in Nigeria. Nevertheless, the study provides useful evidence regarding the socioeconomic mechanisms underlying biomass fuel dependence among women in southwestern and north-central Nigerian communities.

CONCLUSION

This study examined the factors that shape biomass fuel choice and the effect of socioeconomic status on the extent of biomass fuel use among rural women in Ekiti, Kwara and Edo States. Cost of living, subsidy removal and inflation were confirmed as the dominant drivers of fuel choice, well ahead of culture or health consideration. Firewood was confirmed as the dominant fuel overall, and its heaviest use was concentrated among women with no formal education, while education, particularly at the NCE, ND, HND or B.Sc level, was associated with markedly lower odds of large extent firewood use and a shift toward charcoal as the primary fuel.

Furthermore, state of residence shaped raw usage patterns but this effect was largely accounted for in a situation where both education and income were considered together, indicating that the socioeconomic composition of a state, rather than the state itself, drives the observed regional disparity. Together these findings confirm that biomass fuel choice in these communities is an economic decision first, shaped at the margins by the education and income a household can draw on, and that any intervention aimed at shifting this choice must engage both dimensions at once.

Based on the findings, the study recommends issuance of policies aimed at reducing dependence on traditional biomass by prioritize improving the affordability, accessibility, and availability of clean cooking technologies. This should also include promoting educational and income-enhancing interventions that can facilitate a sustainable transition to cleaner household energy. Future research should consider similar households or other regions over time to establish whether rising income or expanding education produces a measurable and lasting shift away from firewood, and should recruit larger samples of tertiary-educated and higher-income women to allow the rarer fuel categories to be modelled with greater precision.

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