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# Investigating the determinants of household energy consumption in Nigeria: insights and implications

Ismaila Rimi Abubakar[1], Andrew Adewale Alola[2,4*], Festus Victor Bekun[3,4] and Stephen Taiwo Onifade[5]

## Abstract

**Background** The present study draws motivation from the United Nations Sustainable Development Goals and explores the nexus between access to modern cooking energy sources, responsible energy consumption, climate change mitigation, and economic growth. Using 2018 demographic and health survey data, the study examines the influence of key socioeconomic and demographic factors on household choice of cooking energy in Nigeria.

**Results** The empirical results show that traditional energy sources are dominant among Nigerian households (74.24%) compared to modern energy sources (25.76%). Regarding energy demographics, male-headed households show more usage of modern energy sources (19.86%) compared to female-headed households (5.90%). Regional analysis reveals that the northwest region predominantly uses traditional energy sources (18.60% of the share of total traditional energy sources), while the southwest region shows the greatest usage of modern energy sources (10.52% of the share of total modern energy sources). Binary logistic regression analysis reveals the positive and statistically significant influence of wealth index, education, and geopolitical region on the likelihood of utilizing modern energy sources. Conversely, household size and place of residence indicate an inverse relationship with the likelihood of adopting modern energy sources.

**Conclusions** These findings have important policy implications for energy efficiency, environmental sustainability, and improving the quality of life in Nigeria, which is currently plagued with significant energy poverty, especially in rural communities.

## Highlights

- Examination of household energy utilization in Nigeria.
- We found that traditional energy utilization is accounted for by 74.24% of households.
- Clean energy source is accounted for by 25.76% of the household.
- 19.86% and 60.86% of male-headed households utilize clean and traditional energy, respectively.
- 5.90% and 13.38% of female-headed households utilize clean and traditional energy, respectively.
- 18.60% and 7.14% of Northwestern region and Southwest region has the highest traditional and cleaner energy sources, respectively.

*Correspondence:
Andrew Adewale Alola
andrew.alola@hotmail.com
Full list of author information is available at the end of the article

**Keywords** SDGs, Cooking fuel, Demographic and health survey, Stratified sampling technique, Logistic regression analysis, Household energy, Nigeria

## Background

In the twenty-first century, energy consumption has become increasingly more critical than ever before due to growing concerns about climate change, environmental sustainability, and energy intensity resulting from human activities [1]. The residential, transportation, industrial, and commercial sectors are the major end-use sectors for energy consumption, according to documentation from the United States Energy Information Administration [2]. Residential energy usage, including cooking, air conditioning, and powering electric appliances, significantly contributes to energy consumption and greenhouse gas emissions. Therefore, understanding household energy consumption is vital for assessing energy intensity and its impacts on people, the economy, and the environment.

Geographical location and climate increasingly shape the dimensions of household energy demand. In developed countries, energy consumption in the residential and transportation sectors accounts for at least 40% of total country-level energy use [3]. For instance, in the United States, household energy use for space heating and air conditioning accounted for more than 51% of total annual household energy consumption in 2015 [4]. In the European Union (EU), household energy uses accounted for 26% of total energy consumption in 2019, with space heating (63.3%), lighting and appliances (14.1%), water heating (14.8%), cooking (6.1%), and space cooling (0.4%) being the primary end uses [5]. To encourage more sustainable consumption patterns and reduce environmental pollution, there is an increasing focus on promoting energy efficiency in developed countries [6, 7].

In contrast, household energy needs in regions like sub-Saharan Africa, including Nigeria, are significantly determined by factors such as the physical home characteristics, the nature of energy devices, place of residence, and household size [8, 9]. Culture and living standards also play a significant role in household energy usage across developing economies [10]. Other studies have highlighted the influence of access and type of energy sources [11, 12], education [13], and income or wealth status [14, 15] on household energy consumption. The complexity of promoting widespread access to sustainable energy services in developing countries is evident from the various factors that shape household energy consumption.

The United Nations Sustainable Development Goals (SDG) energy goal (SDG-7) 7.1 emphasizes ensuring "universal access to affordable, reliable, and modern energy services" by 2030. However, attaining this goal requires addressing inequalities among regions and populations rather than focusing solely on the proportions of populations or households with access to modern energy sources at the national level. This generalized representation of achievement can overemphasize success levels while concealing the key challenges to further improvements. To effectively track progress toward achieving SDG-7.1, there is a need for a sharper focus on disparities among various populations and regions, particularly in developing countries. Therefore, the present study aims to achieve two interrelated objectives: (a) to understand the disparity in the proportions of households using traditional versus modern energy sources according to sociodemographics and geography, and (b) identify the socioeconomic determinants of household energy consumption in Nigeria. Assessing disparities in household energy choices according to gender, wealth, education, rural/urban living, and geopolitical region is necessary for comparing regions and populations, monitoring progress towards achieving SDG-7.1, and targeting interventions towards marginalized regions and populations to ensure more equitable access to modern energy sources for all.

While several studies have investigated the determinants of energy consumption across sectors and energy sources [16–18], the current study is novel for several reasons. First, while the subject matter has been studied within the Nigerian energy literature, many of these studies did not use nationwide data [12, 13, 19–21]. Hence, unlike many previous studies, the current study re-assesses the subject matter using the latest national dataset, which provides a better and more up-to-date representation of the situation. Although Nwaka et al. [19] used a nationwide dataset, it is an older version of the survey data. Second, the present study further broadens the literature on the context of energy consumption determinants of Africa's most populous nation while uniquely categorizing the dataset into traditional cooking fuels (such as biomass, wood, and charcoal/coal/lignite) versus modern energy sources (electricity, liquefied petroleum gas (LPG), natural gas, biogas, and kerosene), providing useful insights for SDG tracking. Third, by considering household-level energy consumption, this study offers relevant information and dimensions of energy consumption and sources according to geographical distribution of households (regional and rural–urban divides).

Moreover, this study provides valuable insights for policymakers and scholars regarding household energy consumption from sociodemographic perspectives, including gender, wealth distribution (richest, richer, middle, poorer, and poorest), and educational attainment of Nigerian households. In particular, energy challenges have become more complicated as the country experiences rapid urbanization amidst population expansion, raising concerns about energy poverty and other related environmental and equity problems. Nigeria had an estimated population of 214 million people in 2022, about 40% of whom lived below the poverty line of $1.25 per day [22]. This West African country faces other socioeconomic challenges, including unemployment, infrastructure deficits, and increasing threats of environmental degradation [23–26]. Importantly, most regions of the country are contending with poor electricity access, as indicated in Appendix A, and electricity connection was reportedly limited to 55.4% of the total population in 2020 [27]. The combination of these factors could have far-reaching consequences for the overall socioeconomic wellness of the nation.

One notable channel through which these challenges can exacerbate difficulties is through energy deprivation and poverty vis-à-vis household access to modern energy sources, which are more efficient and cleaner than traditional sources. According to the International Energy Agency (IEA), more than 1.3 billion people of the global population do not have access to basic energy supplies, while over 2.5 billion people lack access to clean energy sources for basic chores like cooking [28]. Unfortunately, a significant proportion of these people live in sub-Saharan Africa. Hence, this study focuses on Nigeria as Africa's most populous country with one of the lowest energy consumption rates per capita in the world and a reported high prevalence of energy poverty nationwide [27, 29, 30]. As such, the outcome of this investigation is expected to further provide guidelines for improving the working framework of related clean energy policies in the country, such as the National Renewable Energy and Energy Efficiency Policy, and the Nigeria Energy Transition Plan.

This paper is divided into six sections to enhance readability. The next section provides a literature review of related studies. While Section three, "Methods," describes the datasets and methods of data analysis used in this study, Sections four and five, "Results" and "Discussion," present the results and discusses them, respectively. The final section concludes the paper and adds some policy implications.

## Literature review

Household energy is consumed in a residential setting for various purposes, including cooking, lighting, space heating/cooling, and powering appliances and electronic devices. Studies on the access to and use of household cooking energy have increased recently in the energy-related literature. However, most of these studies have focused on high-income nations of the global north [14, 31–34], with less attention paid to middle- to low-income countries of the global south. Moreover, related studies for developing countries mostly concentrate on the Asian and Latin American regions [e.g. [8, 9, 35]. In contrast, the literature has been relatively silent about many low-income African countries, where challenges related to energy use are even more pronounced.

Existing studies on household energy use have identified various socioeconomic and demographic factors that contribute to cooking fuel choices, with diverse outcomes due to variations in study areas. Notable factors in include income distribution, which may encompass the effects of expenditure patterns and the socioeconomic status of households on their energy consumption levels [6, 16]. Gender differences are also linked to variations in energy consumption patterns [33, 36]. Other factors, including cultural values and social norms [34, 37], family size and people's lifestyles [38], educational attainment [39–41], and information penetration also influence household attitudes and cooking technology use [42, 43]. Finally, geographical factors, ranging from regional economic development to the rural–urban divide, rate of urbanization, vegetation type, and climatic experiences like temperature and rainfall, can influence household energy choices [44–48].

Numerous studies have shown that determinants of energy use are interwoven, as the impact of one factor, such as income, can extend to other issues that influence household energy consumption patterns. Therefore, the scope of studies on income distribution is often broad. Substantial research has been carried out on different economies concerning energy poverty issues. The term is often used to explore the nexus between access to energy and major energy use determinants, such as income distribution, where the latter is insufficient to meet a household's energy requirements [7, 32, 49–51]. A study by Kolokotsa and Santamouris [32] revealed that energy poverty is a growing issue in the EU because environmental burdens have varying degrees of impact on low-income households, especially in urban areas. Phimister et al. [49] explored the energy poverty challenge in Spain by using longitudinal data to compare energy poverty with income levels in the country. Their findings showed that the rate of transition out of expenditure-based energy poverty is relatively higher than that

of income poverty, suggesting that changing expenditure behaviour can dampen energy poverty levels. In a study on how income inequality affects household energy consumption and carbon emission levels in the United Kingdom (UK), Ghosh [7] emphasized the urgent need to address inequality in income distribution as a key strategy for enhancing equity in energy use among households. Moreover, Karpinska and Śmiech [51] revealed that 23.57% of the populations in Central and Eastern EU countries are vulnerable to hidden energy poverty.

Gender gap can also influence household energy choices. For example, Räty and Carlsson-Kanyama [33] examined the impacts of gender on household energy use in four EU countries: Greece, Germany, Norway, and Sweden. Their study provides significant evidence supporting gender roles in energy use only in the case of understudied single households in Sweden and Greece. Galvin and Sunikka-Blank [6] also identified gender-based income inequality as one of the factors affecting household choices as far as energy consumption among high-income societies is concerned. Sánchez et al. [36] also pointed out the gender-based energy poverty challenges in which households headed by women accounted for about 50% of the estimated 23% of households exposed to energy poverty in the city of Madrid. These studies highlight the significance of gender distribution when studying household energy use patterns.

Regarding the role of socio-cultural values and geographical variations in household energy choices, Sahakian et al. [34] applied a living lab approach with 306 households across eight EU countries to analyse the impacts of social norms on household energy use. Their results suggest that taking into consideration the complexities of normal daily human activities, such as doing laundry and keeping warm, is critical for minimizing household energy use. Borozan [48] explored the determinants of household energy use in 64 EU regions and found that household energy consumption levels correlate with economic development levels across regions, despite some common factors that influence energy use among households. The study recommended region-specific policies to boost energy efficiency in the EU. In a separate study, Navamuel et al. [44] analysed micro-data using ordinary least squares and quantile regression techniques and found that urban agglomerations reduce the levels of electricity consumption, while residence in detached houses had a contrary effect on energy consumption, in the case of Spain. This underlines the importance of considering social norms and spatial variations as determinants of household energy use.

Despite the increasing trend of studies on household energy consumption and the challenges of energy poverty, it is crucial to note that these challenges are more pronounced in low-income developing economies where numerous households are multidimensionally poor. Sadly, this situation is the case for many countries in sub-Saharan Africa. While efforts to bridge the study gap between developed and developing countries have intensified in recent years, particularly concerning rapidly emerging economies like China, Brazil, and India, there is still much to explore regarding low-income African countries. De Abreu et al. [9] pointed out the gap in the literature regarding studies on developed and developing economies and noted that socioeconomic changes and income distribution significantly influence the behavioural patterns of household energy use, including preferences for cooking fuels. The study drew conclusions from the analysis of energy consumption behaviour in Brazilian households between 2002 and 2008. Similarly, Daioglou et al. [8] observed a gradual shift in the household energy consumption paradigm from traditional to modern fuel types in some developing countries, including China, India, and Brazil, among others. The authors noted that environmental policies could inhibit the pace of this shift despite their desirable impacts on cutting down pollutant emission levels. In another study, Ekholm et al. [14] noted that households in rural India largely depend on biomass as the main cooking fuel. Reliance on traditional cooking fuels has also been a major challenge facing many households in other developing economies, particularly low-income countries in sub-Saharan Africa, where access to modern cooking fuels is still abysmally low [15, 52].

In Nigeria, several studies have investigated household energy consumption preferences [9, 12, 13, 20, 21]. For example, Oyekale [12] examined the factors affecting Nigerians' access to electricity supply and their usage of modern cooking fuels, relying on the old version of the Demographic and Health Survey (DHS) conducted in 2008. The study found that access to electricity has grown significantly among urban and educated households, with a similar conclusion reached regarding access to modern cooking energy sources. Ogwumike et al. [13] examined a much older version of the data based on a 2004 survey and indicated that most Nigerian households lack access to modern energy sources. This finding differs slightly from those reported by Oyekale [12], possibly due to gains made between 2004 and 2008. Other studies have used the 2013 Nigeria DHS and found significant differences in the type of cooking fuels used by rural and urban households, with wealth and levels of education among the major determinants [20, 21]. Buba et al. [21] noted a gender gap, mainly in the case of biomass fuel type usage, which was also noted by De Abreu et al. [9].

However, some limitations of many of these previous studies are the failure to use nationwide data and the

use of older versions of DHS datasets [9, 12]. Therefore, the current study aimed to reassess the subject matter using the latest national dataset, which provides a better nationwide representation of the situation compared to most previous studies. Moreover, the study categorizes the dataset into traditional and modern energy sources, which is useful for tracking progress towards achieving SDG-7. The study analysed household cooking energy use according to fuel type in the Nigerian context, systematically accounting for the impacts of crucial factors such as the rural–urban divide, gender differences, educational achievements, regional variations, and household socioeconomic status on energy choices. Investigating these key factors influencing energy consumption can inform targeted interventions in marginalized areas, thereby addressing the fundamental challenges of access to modern energy options. The insights from this study are crucial for achieving SDG-7 targets, which has gained more relevance in contemporary studies [8, 36, 53, 54]. Therefore, this study aimed to narrow the existing gap in the literature about household energy consumption and contribute to a better understanding of the subject matter.

## Methods

The 2018 Nigeria DHS is the sixth wave of a cross-sectional, nationwide survey of a representative sample of 40,427 households selected through a two-stage stratified sampling technique. The survey report from the National Population Commission describes the sampling procedure and the questionnaire used. Some trained surveyors asked household heads or their representatives a series of questions, including "What type of fuel does your household mainly use for cooking?" Out of the total sample, 39,761 households (98.35%) reported using a variety of cooking fuels and were included in the present study. However, 666 households (1.65%) reported not cooking food in their houses and were therefore excluded from the analysis. The study categorized household energy sources according to the classification used in monitoring the SDG-7 targets for all countries. Electricity, LPG, natural gas, biogas, and kerosene are classified as modern household energy sources. Non-modern energy sources, such as wood, biomass (straw, shrubs, grass, agricultural crops), and charcoal/coal/lignite were considered traditional sources.

Table 1 displays the variables used in this study, including the dependent variable and socioeconomic and demographic variables (independent variables). The study employed descriptive statistics alongside the binary logistic regression (BLR) technique to explore the determinants of household energy consumption. The BLR is appropriate for this study because it models the relationship between a binary dependent variable and several independent variables, as utilized in similar studies [39, 55]. This study aimed to predict the likelihood of a Nigerian household using one of two energy sources (binary outcome: 1 = modern energy source and 0 = traditional source) using several predictor variables, including gender, age, education, wealth index, place of residence, and region. Additionally, Pearson's Chi-square analysis was applied to assess whether significant relationships between household cooking energy choices and their socioeconomic and demographic factors exist, which is suitable for categorical variables with two or more independent groups [20, 56]. This study conducted basic summary statistics of key variables that potentially influence access to energy in Nigeria (Table 1). The statistics indicate that traditional energy sources dominate

**Table 1** Descriptive statistics of key study variables

| Variable | Description |
|---|---|
| Household energy source (DV) | 0 = traditional (74.24%), 1 = modern (25.76%) |
| Wealth index | 1 = poorest (17.87%), 2 = poorer (19.27%), 3 = middle (22.97%), 4 = richer (21.58%), 5 = richest (19.32%) |
| Gender of household head | 1 = male (80.72%), 2 = female (19.28%) |
| Age of household head | 15–98 ($\bar{x}$ = 45.84, σ = 15.63) |
| Household size | 1–37 ($\bar{x}$ = 4.71, σ = 3.17) |
| Total number of bedrooms | 1–24 ($\bar{x}$ = 2.23, σ = 1.44) |
| Place of residency | 1 = urban (41.58%), 2 = rural (58.42%) |
| Geopolitical region | 1 = North-central (18.07%), 2 = Northeast (15.51%), 3 = Northwest (19.69%), 4 = Southeast (13.56%), 5 = South-south (15.51%), 6 = Southwest (17.66%) |
| State | 1–37 (36 states of Nigeria and the FCT) |
| Highest education level | 0 = no formal education (12.46%), 1 = primary (8.58%), 2 = secondary (12.79%), 3 = higher (6.60%) |
| Connected to electricity | 0 = No (41.3%), 1 = Yes (58.7%) |
| Ownership of agricultural land | 0 = No (40.4%), 1 = Yes (59.6%) |
| Ownership of livestock | 0 = No (55.6%), 1 = Yes (44.4%) |

the study area, accounting for over 74%, while modern energy sources—electricity, LPG, natural gas, biogas, and kerosene—account for approximately 26% of households.

## Results

This section focuses on the empirical results and discussion of the investigated themes. It begins with the basic summary statistics, which are pertinent in an empirical study as a preliminary analysis, prior to exploring the influence of socioeconomic variables on household energy choices and the results of regression analysis of the predictors of using modern or traditional energy sources. The results reveal the types of household cooking fuels in Nigeria, with wood, kerosene, and LPG the predominant options. It is worrisome from an environmental sustainability perspective that wood energy, which largely accounts for the significant level of deforestation vis-à-vis environmental degradation, ranks first (67.6%). The statistics show that traditional energy sources dominate the study area at over 74%, while modern energy sources account for approximately 26%.

Among the modern cooking options, kerosene shows strong dominance (13.5%). Kerosene consumption in Nigeria has raised controversy, with fluctuations in pump prices over the years. LPG is the second-leading modern cooking energy source, used by 10.5% of households, while biogas is the least modern energy option for used as cooking fuel. The results shown in Fig. 1 highlight the dominance of wood and biomass (straw/shrubs/grass/agricultural crops) over electricity, biogas, and natural gas.

The present study subsequently explored the influence of rural–urban dynamics on household energy consumption in Nigeria, which was found to be statistically significant, with a Chi-square value ($\chi^2$) of 5785.1, degree of freedom (*df*) of 1, and *p*-value (*p*) of 0.001 (Fig. 2). In rural areas, traditional energy sources dominate cooking options, accounting for over 51% of households. This overwhelming proportion of traditional energy users, compared to 22.7% of households in urban areas, explains the environmental issues of poor air quality and human health risks from using such cooking sources in the countryside. Nigeria's rural dwellers are largely subsistence farmers, poor, and less aware of the environmental and health benefits of using modern cooking sources. Conversely, more urban

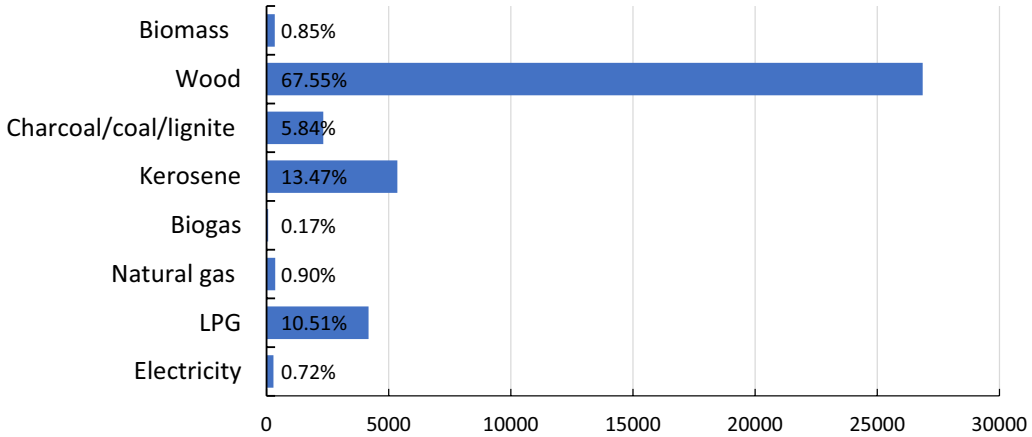


**Fig. 1** Household energy sources in Nigeria, 2018 ($n = 39{,}761$)

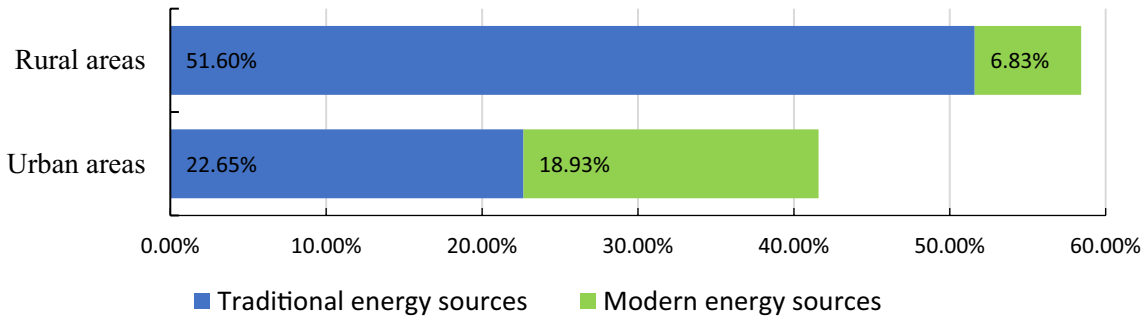


**Fig. 2** Rural–urban divide in household energy sources ($\chi^2 = 5{,}785.1$, $df = 1$, $p = 0.001$)

households (18.9%) tend to utilize modern energy sources than rural households (6.8%).

The study also investigates the influence of gender dynamics on household energy use choices. The case of Nigeria shows interesting statistics, as presented in Fig. 3. Male-headed households used traditional cooking fuel (60.9%) significantly more frequently than female-headed households (13.4%). Also, 19.9% of male-headed households used modern energy sources as compared to female-headed households (5.9%). The plausible explanation for male-headed household dominance in energy use (traditional) compared with female-headed households is demonstrated by less willingness to use modern energy sources among both genders, as outlined in Fig. 3. Interestingly, both genders use fewer modern energy sources, which is not desirable for environmental sustainability.

The study also examines the pertinent influence of socioeconomic status (wealth index), calibrated on a 5-point Likert scale (poorest, poorer, middle income, richer, and richest) on household energy choices (Fig. 4). Wealth index or divide also plays a key role in access to energy, with 23.5% of the richest and richer households having access to modern energy, while middle-class and poor households account for only 2.3%. The strata with low purchasing power, the poorest, poor, and middle income, demonstrate a strong preference for traditional cooking energy. More logically, households with higher purchasing power (wealth status) prefer modern energy sources for cooking. Thus, Fig. 4 underscores the implication of income distribution on cooking energy use among Nigerian households.

Furthermore, this study demonstrates the role of education attainment in the household choice of cooking energy. Education has been identified as an important factor for the socioeconomic development of any society, including household decisions on energy choices. The results shown in Fig. 5 highlight the pertinent role of education level on the choice of cooking energy options. The results disclose that Nigerian household heads with less education attainment (secondary education or less) prefer traditional cooking energy sources over modern ones. This expected result suggests that education level plays a vital role in energy preference. In contrast, households with higher education levels prefer modern energy options more than households with lower education attainment. This result is instructive and resonates with

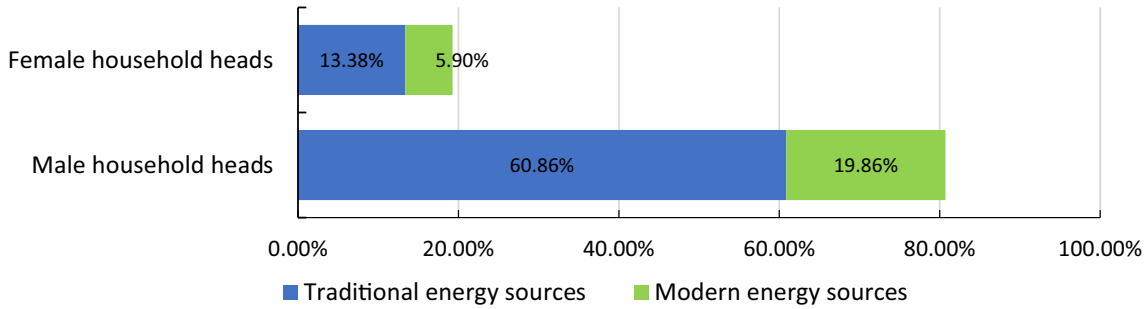


**Fig. 3** The influence of gender on household energy sources ($\chi^2 = 116.68$, $df = 1$, $p = 0.001$)

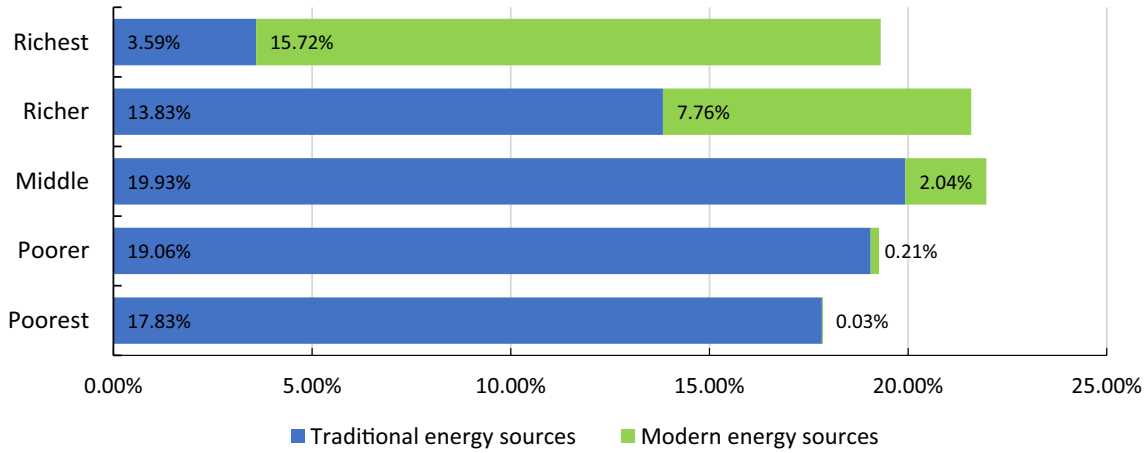


**Fig. 4** The influence of wealth index on household energy sources ($\chi^2 = 19{,}008.3$, $df = 4$, $p = 0.001$)

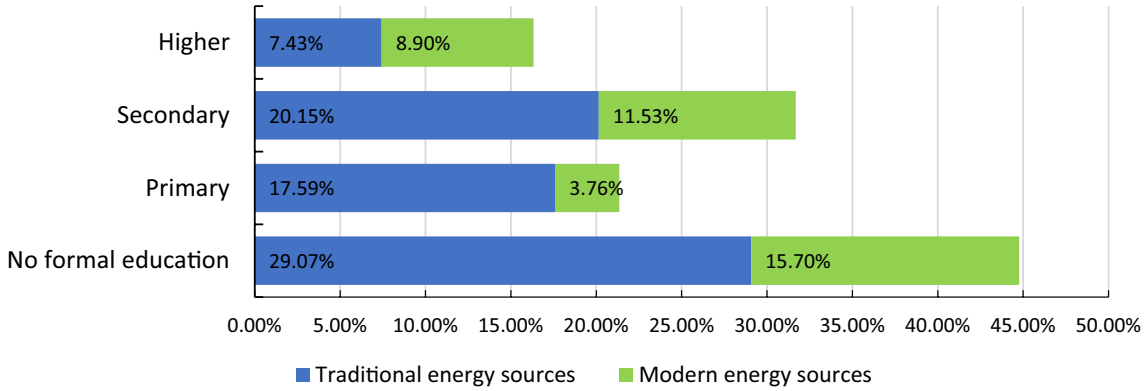


**Fig. 5** The influence of educational attainment on household energy sources ($\chi^2 = 6552.9$, $df = 3$, $p = 0.001$)

the income distribution of households and its impact on cooking energy choices. This finding implies that higher-income strata in Nigeria are coincidentally well-educated and much more aware of the need for energy efficiency and environmental sustainability via adopting modern cooking energy.

This study also examines the regional variation in household energy use as outlined in Fig. 6. The results indicate a statistically significant ($p = 0.001$) divide in energy use across the six geopolitical regions of Nigeria. Northwest, northeast, and north-central Nigeria demonstrate high levels of preference for traditional cooking energy. The result of northern Nigeria showing a high affinity for traditional cooking energy is further explained by the region's high poverty rates and low levels of education attainment. Conversely, Nigeria's southern regions show less affinity for traditional cooking energy and high levels of preference for modern energy sources. The plausible reason is tied to the fact that the southern part of Nigeria holds the nation's economic nerve centre of oil energy, including its exploration, production, and marketing. However, the southern region of Nigeria has suffered spill-over effects from oil energy exploration by multinational corporations in the region.

Finally, this study explored the likelihood of applying modern or traditional energy sources among Nigerian households using a BLR analysis, as illustrated in Table 2. The regression analysis explores several predictors of modern energy source usage. The results reveal a positive and statistically significant relationship between geopolitical zone and utilization of modern energy sources in Nigeria, indicating that regional variances have a key influence on household preference for cooking energy in the country. This result aligns with the outcomes shown in Fig. 6 and the study from [62]. Also, high wealth index, highest education levels, ethnicity, and state of residence of household head all exhibited a positive and significant statistical relationship with the likelihood of adopting modern energy sources for cooking. Conversely, households with a female head, in rural areas, with ownership

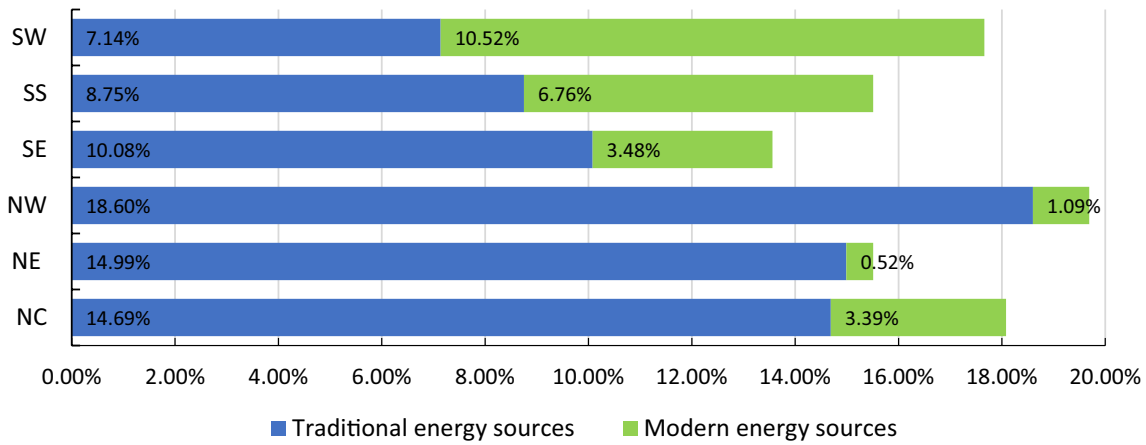


**Fig. 6** The influence of geopolitical region on household energy sources ($\chi^2 = 8{,}708.2$, $df = 5$, $p = 0.001$)

**Table 2** Binary logistic regression analysis of the likelihood of using modern energy sources among Nigerian households

| Variable | Coef. | Std. error | *z* | *P*>\|*z*\| | [95% Conf. interval] | |
|---|---|---|---|---|---|---|
| Household size | − 0.1946 | 0.0096 | − 20.33 | 0.001 | − 0.2134 | − 0.1759 |
| Geopolitical zone | 0.2651 | 0.0153 | 17.38 | 0.001 | 0.2352 | 0.2950 |
| Place of residence | − 0.5314 | 0.0440 | − 12.09 | 0.001 | − 0.6175 | − 0.4452 |
| Gender of household head | − 0.1587 | 0.0491 | − 3.23 | 0.001 | − 0.2550 | − 0.0624 |
| Age of household head | − 0.0101 | 0.0015 | − 6.77 | 0.001 | − 0.0130 | − 0.0072 |
| Ownership of agricultural land | − 0.9200 | 0.0444 | − 20.72 | 0.001 | − 1.0070 | − 0.8329 |
| Ethnicity of household head | 0.1386 | 0.0249 | 5.57 | 0.001 | 0.0898 | 0.1873 |
| Ownership of livestock | − 0.4838 | 0.0496 | − 9.76 | 0.001 | − 0.5810 | − 0.0387 |
| Wealth index | 2.0439 | 0.0480 | 42.60 | 0.001 | 1.9499 | 2.1380 |
| Highest education level | 0.2686 | 0.0262 | 10.26 | 0.001 | 0.2173 | 0.3200 |
| State of residence | 0.0044 | 0.0003 | 13.21 | 0.072 | 0.0038 | 0.0051 |
| Connected to electricity | − 0.1000 | 0.0556 | − 1.80 | 0.001 | − 0.2088 | 0.0090 |
| _constant | − 6.4617 | 0.3642 | − 17.74 | 0.001 | − 7.1754 | − 5.7479 |

$n = 39{,}761$, log likelihood = − 8681.0708, pseudo-$R^2 = 0.6173$; Chi-square ($df = 32$) = 28,006.75; $p = 0.001$

of land and livestock, and with lack of access to electricity have a lower likelihood of using modern energy sources for cooking. Similarly, household size and the age and gender of the household head, highlighted in the model, have an inverse relationship with the likelihood of using modern energy sources.

## Discussion

The results indicate a significant reliance on traditional energy sources (74%) compared to modern energy sources (26%) in Nigeria. This imbalance suggests that a larger proportion of Nigeria's energy mix consists of conventional and non-renewable sources, which are major contributors to $CO_2$ emissions [31]. To promote human health and environmental sustainability, there is a need for a shift towards modern energy sources [57, 58]. Wood is the dominant traditional energy source (67.6%), primarily due to the prevalence of low income levels and rural living conditions in the Nigerian population. This reliance on wood has contributed to increasing deforestation rates in Nigeria, with implications for desertification and climate change. Between 1990 and 2012, Nigeria's forest coverage decreased by almost half, from 18.9 to 9.8% of the total land-mass [55].

The findings also reveal that urban households are more likely (18%) to use modern cooking fuels than their rural counterparts (6.8%). This disparity can be attributed to higher income and education levels among urban dwellers, enabling them to afford and access modern cooking energy sources. However, modern cooking fuels still represent a smaller share of the overall energy mix for both rural and urban areas despite their cleaner and more environmentally friendly nature. The cost implications associated with modern energy options in Nigeria likely contribute to this situation.

Moreover, male-headed households demonstrate a preference for traditional cooking energy sources, using them more than three times as often as modern sources. Similarly, female-headed households also rely on traditional fuels, although to a lesser extent. These findings support the established notion that traditional cooking energy dominates in Nigeria, particularly among male-headed households.

Regarding the influence of wealth status on cooking fuel consumption, the results indicate that the use of a modern cooking fuel increases with a higher wealth index, moving from the poorest to the richest households. Conversely, the use of traditional cooking fuels decreases as the wealth index increases. This income stratification highlights the need for policy interventions to address income inequality in Nigeria, particularly between the richest and poorest households. Bridging this gap would facilitate the adoption of modern energy sources for cooking [59–61]. It is crucial to implement income redistribution measures, improve the economic structure, and promote job creation and small and medium enterprises in the Nigerian economy.

Education attainment also plays a significant role in cooking energy use, although not in a linear manner. The usage of traditional cooking fuel generally decreases with higher education levels, except for household heads with a secondary education, who use it more than those with only a primary education. This finding aligns with the SD Goal 4 (SDG-4) objective of promoting inclusive and equitable education across genders in all nations. Investing in education contributes to national development by

accumulating human capital, leading to long-term productivity and economic growth.

Different geopolitical regions in Nigeria exhibit varying preferences for cooking fuel, influenced by their distinct geography, climate, and culture. The southwest and south–south regions report substantial usage of modern cooking fuels, while the northeast and northwest regions rely more on traditional cooking fuels. These regional disparities emphasize the need for stakeholders in the energy sector to consider the energy mix across geopolitical divisions in Nigeria and address the variations, taking into account their impacts on climate change.

Overall, this empirical investigation highlights the significant factors influencing the likelihood of Nigerian households using modern or traditional energy sources. These predictors have important implications for the nexus of energy, poverty, and sustainability in Nigeria. First, promoting equity in education across all geopolitical regions and genders can have profound effects on sustainable development in line with SDG-4. Education plays a crucial role in creating awareness about the green economy, but it comes at a cost. Thus, public–private partnerships should be pursued to improve the education sector. Second, wealth distribution is another key factor in access to and preference for modern energy sources. However, there is a significant disparity in wealth distribution in Nigeria. Therefore, the federal and state governments should implement programmes that reduce income inequality [58]. Reducing income disparities among regions and between male and female household heads will undoubtedly increase the likelihood of adopting modern energy sources in Nigeria and promote environmental sustainability. The next section will conclude with policy recommendations.

## Conclusions

This study provides valuable insights into the factors determining household energy consumption in Nigeria, considering the relevance of SDG-7 (access to modern cooking energy), SDG Goal 12 (responsible energy consumption), SDG Goal 13 (climate change mitigation), and SDG Goal 8 (economic growth). The study applied a combination of descriptive analysis, Chi-square, and BLR techniques to examine the relationships of traditional or modern energy sources with geographical distribution and sociodemographic factors among Nigerian households. Specifically, the study explores the nexus between traditional energy sources (including biomass, wood, charcoal/coal/lignite) or modern cooking fuels (e.g. electricity, LPG, natural gas, biogas, and kerosene) and geographical distribution (regional and rural–urban divides) and household sociodemographics, including gender, education attainment, and wealth distribution (richest, richer, middle, poorer, and poorest). The findings indicate that these geographical and sociodemographic factors are significantly associated with household energy usage, which creates important implications for policy and practice, particularly in reducing gender, education, wealth, and regional inequalities, to improve access to modern energy sources. It underscores the key results and their implications for energy policy directions.

The demographics of cooking energy consumption in Nigeria reveals? that traditional sources (74.24%) are more commonly used in households than are modern sources (25.76%) nationwide. The findings also show that while 19.86% of male-headed households have access to modern energy sources, 60.96% of them use traditional energy sources. In contrast, only 5.90% of female-headed households have access to modern energy sources, and they rely more on traditional energy sources (13.38%). Traditional energy sources are predominantly used in the northern region (14.7–18.6%), while modern energy source usage was the least (0.5–3.4%). In contrast, the use of modern energy sources is the highest among southerners (10.5%). Moreover, logistic regression analysis identified significant factors influencing the likelihood of using modern energy sources in Nigeria, including household size; geopolitical zone; place of residence; connection to electricity; gender, age, and ethnicity of household head; ownership of livestock and agricultural land; wealth index; and education level. However, state of residence was found to be non-significant in determining access to modern energy sources in the country. These findings provide useful policy recommendations that include the following:

- Addressing gender, wealth, and regional disparities in access to household energy can help improve access to modern energy sources. While poverty alleviation programmes (e.g. skills training, education, microfinance, and agricultural development) can narrow the gender gap and empower households to adopt modern energy sources. Public awareness can discourage the usage of traditional energy sources, and awareness campaigns through government, community-based organizations, and private participation can educate households about the benefits of modern energy sources, including their positive impact on health, the environment, and economic development. This policy recommendation is crucial because the increased use of wood and charcoal, as agents of climate change disasters, leads to deforestation.
- Instead of the age-long policy of providing huge fossil-fuel subsidies, the government should invest more and provide subsidies and incentives targeted at developing modern and renewable energy services.

Similarly, energy tax policies, subsidies for clean energy technologies, and the development of energy-saving devices are useful approaches to encourage energy diversification and discourage traditional energy dependency.

- In addition to these policy recommendations, the Nigerian government, in collaboration with the private sector, could pursue building or housing energy-efficient specifications like the European Union's Energy Performance of Buildings Directive 2010/31/EU (EPBD) and the Energy Efficiency Directive 2012/27/EU. Therefore, policymakers and stakeholders should prioritize public–private partnerships for investment in the energy sector. However, caution is needed in transitioning from traditional energy sources to modern energy sources, which are cleaner and more efficient than traditional sources.

The present study makes an important contribution by assessing the determinants of household energy utilization in Nigeria. It highlights the need to promote modern energy sources because traditional energy sources, such as firewood, biomass, and charcoal, which are dominant among Nigerian households, have adverse health and environmental consequences, including deforestation and poor indoor air quality. One limitation of the study is its reliance on cross-sectional data which could not be used to identify trends over time. Future research is needed to investigate the efficacy and challenges of existing government policies and initiatives in promoting the use of modern energy sources. Furthermore, this study mainly looked at the influencing role of several socioeconomic factors on household energy use in Nigeria rather than any associations among the socioeconomic factors, such as the relationship between wealth and gender of the household head or between wealth and education. Therefore, future studies can also explore this direction, as well looking at the effects of socioeconomic factors on the use of each of the clean energy sources.

## Appendix A

*See Fig. 7.*

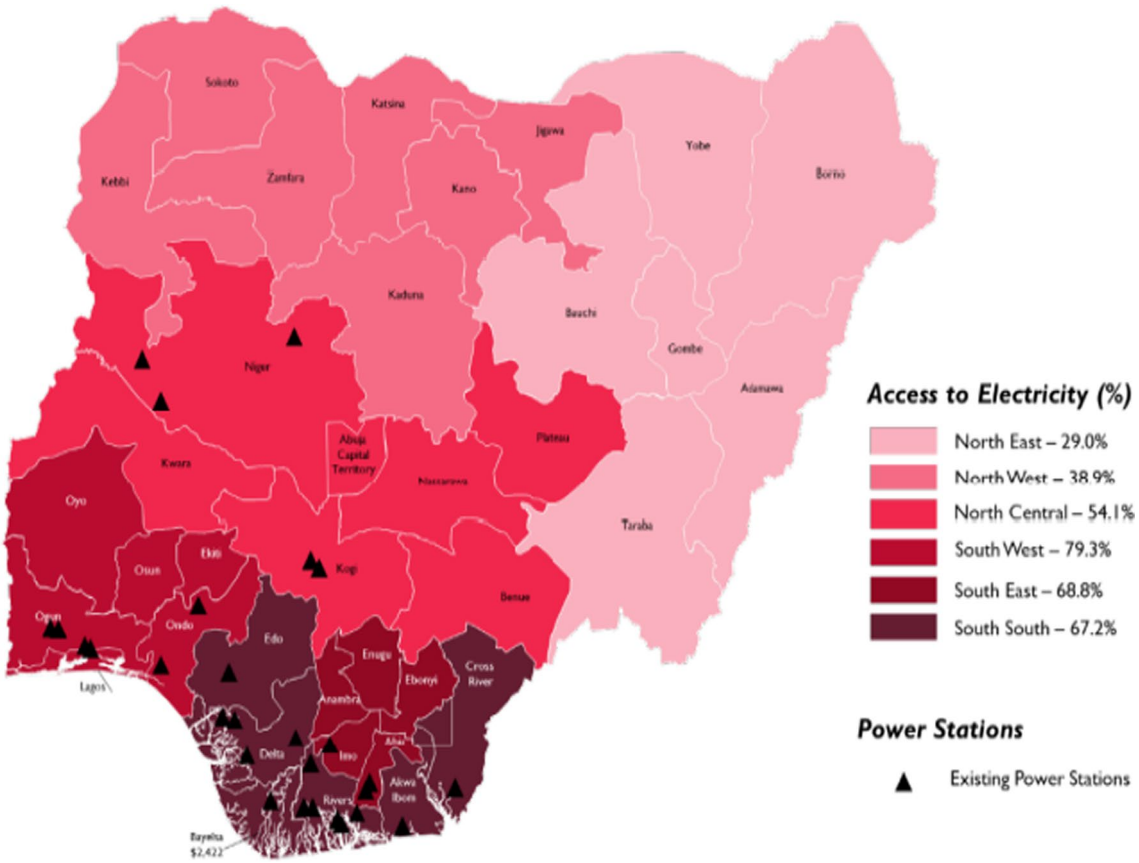


**Fig. 7** Access to electricity and distribution of power stations across Nigeria

**Abbreviations**

| | |
|---|---|
| BLR | Binary logistic regression |
| DHS | Demographic and health survey |
| DV | Dependent variable |
| EU | European Union |
| EED | Energy efficiency directive |
| EPBD | European Union's Energy Performance of Buildings Directive |
| FCT | Federal Capital Territory |
| IEA | International Energy Agency |
| LPG | Liquefied petroleum gas |
| SDGs | Sustainable development goals |
| PPP | Prioritize public–private partnerships |
| UK | United Kingdom |

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Not applicable.

**Competing interests**
Authors do not have any conflict of interest.

**Author details**
[1]College of Architecture and Planning, Imam Abdulrahman Bin Faisal University (Formerly, University of Dammam), PO Box 1982, 31441 Dammam, Saudi Arabia. [2]CREDS-Centre for Research on Digitalization and Sustainability, Inland Norway University of Applied Sciences, 2418 Elverum, Norway. [3]Faculty of Economics Administrative and Social Sciences, Istanbul Gelisim University, Istanbul, Turkey. [4]Adnan Kassar School of Business, Department of Economics, Lebanese American University, Beirut, Lebanon. [5]Department of Economics, School of Accounting and Finance, University of Vaasa, 65200 Vaasa, FI, Finland.

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