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Assessing the nexus between household dynamics and cooking energy choice: Evidence from Kaduna state, northwestern Nigeria

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ABSTRACT

Cooking is the most energy-intensive activity in the household sector. In developing countries, it accounts for about 90% of the total domestic energy use. With this, knowledge of its dynamics in terms of energy choice and use is imperative. This study explored the nexus between household dynamics and cooking energy choice in Kaduna State, Northwestern Nigeria. Data were collected from 400 households with the aid of a structured questionnaire following a multi-stage sampling approach. Descriptive statistics was used to analyze the data and a multinomial logit regression model was employed to assess the impact of household factors on the choice of primary cooking energy. The results from the descriptive analysis depict charcoal as the most used cooking energy in the surveyed area, followed by fuelwood and Liquified Petroleum Gas (LPG). These choices are influenced by cost, accessibility, and availability. Furthermore, the results from the multinomial logit regression analysis indicated that the choice of cooking energy is significantly influenced by household factors such as household size, household income, occupation of household head, marital status, age, and education of the main cook, and the household head. These findings can be crucial for policymakers and organizations working towards promoting clean and sustainable energy, climate change mitigation, and the reduction of household air pollution.

1. Introduction

Access to clean and affordable energy for all corresponding to the United Nations Sustainable Development Goal (SDG) 7 is one of the pivotal goals targeted for realization by 2030. While a lot has been invested in attaining the stated goal, about 2.4 billion people are still cooking with harmful fuels [1]. This implies that more than one-third of the world's population lives in energy poverty [2]. The continuous rise in population across the globe has significantly increased energy demand and has made it incommensurable to the available energy resources. Similarly, as energy consumption keeps increasing the emission of greenhouse gasses also increases. According to the International Energy Agency (IEA) [3], the global carbon dioxide (CO_2) emissions that emanate from the use of energy have increased by 0.9% or 321 Mt in 2022. While a substantial proportion of the said emissions are induced by anthropogenic activities, especially through the use of fossils, it is worth noting that attaining the 1.5 °C or 2 °C target surface temperature must involve a rapid decline from the use of non-renewable fuels [4]. In the phase of household cooking energy, it becomes imperative to curtail the use of solid fuels and traditional cookstoves and adopt clean cooking solutions such as the use of Liquefied petroleum gas (LPG) and electricity [5], or improved biomass cookstoves in the case of biomass users [6]. For low-income households that cannot afford or access clean cooking energy, Yunusa et al. [7] recommended the use of biomass briquettes as they are products of lignocellulosic biomass that are emission neutral. Furthermore, the use of briquettes in place of fuelwood and charcoal curtails deforestation and climate change.

The household or residential sector is one of the major energy-consuming sectors. This trend of energy consumption in the household sector is said to continue and increase even further as population and economic activities increase [8]. In Sub-Saharan Africa, cooking is the most energy-intensive activity in the household sector [9]. In developing countries cooking accounts for about 90% of domestic energy

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Nomenclature

SDG	Sustainable development goal
UN	United Nations
IEA	International energy agency
CO_2	Carbon dioxide
Mt	Megatonnes
°C	Degree celsius
LPG	Liquefied petroleum gas
CO_2	Carbon dioxide
CCA	Clean cooking alliance
NGOs	Non-governmental organizations
STIRPAT	Stochastic impacts by regression on population, affluence, and technology
ARDL	Autoregressive Distributed Lag Model
LGAs	Local government areas
n	Sample size
N	Population
e	Margin of error
V_{ij}	Indirect utility function of households i for cooking with energy j
Y_i	Vector of individual households
B_j	Vector of coefficients of explanatory variables
U_{ij}	Stochastic component of unobserved utility
IIA	Independent of irrelevant alternative
P(Z=j)	Probability of a household choosing energy j
Y	Explanatory variable
t	Dummy variable of respondent's age
λ	Province dummy variable
ε	Error term
JSCE	Junior secondary school certificate
SSCE	Senior secondary school certificate
HND	Higher national diploma
B.*Sc*.	Bachelor of science
M.*Sc*.	Master of science
Ph.D.	Doctor of philosophy
LR	Log likelihood ratio
Chi2	Chi-square
R2	R-square

consumption [10]. From an estimate released by the Clean Cooking Alliance (CCA) [11], the burning of solid fuels especially fuelwood in cooking accounts for about 1.9% - 2.3% of the global CO_2 emissions. If the stated emissions are combined with the impact of deforestation recorded through fuelwood and charcoal production, it significantly impacts climate change. Currently, there are over 2.8 billion people globally who rely solely on solid fuels (charcoal, fuelwood, coal, dung, and agro-residues) and kerosene to meet their cooking energy needs [12]. Owing to this, about half of the world's population is exposed to household air pollution [13]. In Africa over 82% of the population relies on solid fuels to meet their energy needs [14]. With this, it becomes imperative to assess the nexus between household dynamics and cooking energy choice as a measure of tracking and reducing the carbon footprint in the household sector.

Population growth is one of the major factors inducing anthropogenic greenhouse gas emissions. With over 200 million people in Nigeria [15], the country is susceptibleto an increased carbon footprint and climate change. Despite being blessed with diverse socioeconomic resources, Nigeria still battles with an unstable electricity supply as the cumulative wattage generated is below the country's requirement [16]. With this, most of the households rely heavily on solid fuels and kerosene owing to their inability to afford cleaner options [17]. This, coupled with other factors has made the country to be energy inefficient [18]. Hence, an extensive study on the factors influencing energy choice and use is essential for understanding household energy dynamics [19]. While the choice of cooking energy has been influenced by several factors, household income was found to be a major factor influencing the choice of cooking energy [19,20]. On this basis, transiting to cleaner options such as biofuels, LPG and electricity would require interventions from the government, NGOs, and other relevant stakeholders. However, in the absence of adequate intervention, several studies have developed low-cost biofuels and improved biomass cookstoves with enhanced energy efficiency and low emissions compared to conventional fuels and cookstoves. These include a double-burner biomass cookstove developed by Yunusa et al. [21], a rock bed cookstove developed by Bailis et al. [22], and a twisted tape-incorporated cookstove [23]. The use of the stated cookstoves is not only better than using traditional cookstoves and open fires but perceived to be cleaner than LPG because they are powered with biomass which are form of renewable energy, whereas LPG is a non-renewable fuel. This assertion was verified in the study of Dioha and Kumar [9] where transiting from using fuelwood to LPG was found to reduce indoor air pollution but with the potential of increasing CO_2 emissions by 2050.

Considering the relevance of cooking energy in the household sector, several studies have employed different approaches ranging from descriptive analysis, dynamic modeling, and simulations to comprehend the dynamics influencing household energy choice, adoption, and use especially in developing countries where the use of clean and renewable energy is limited. In the study of Shari et al. [24], a system dynamics model was employed to predict how some strategies could influence the adoption of clean cooking. The simulation revealed that clean cooking adoption occurs faster in the early years among urban households compared to rural households, as factors such as awareness are required to enhance adoption in rural households which comes up in the later years. Imran et al. [25] used the STIRPAT model to examine the impact of some household factors on energy consumption. The result revealed biomass (fuelwood, dung, and crop residue) as the most consumed form of energy, and further found out that its consumption increases as the size of households increases and as the level of income decreases. Nwaka et al. [26] studied the determinants of household fuel choice among family heads by gender. The study revealed heterogeneity by gender of household heads as biomass usage was found to be more dominant among de-jure female-headed households compared to male-headed households. However, because the male-headed households were found to be more educated, the use of clean fuels such as electricity, biogas, and LPG was more prevalent in such households. Ogbeide-Osaretin [27] examined the nexus between energy consumption and poverty reduction using the Autoregressive Distributed Lag Model (ARDL). The study observed that the use of traditional fuels like fuelwood and coal significantly impacts poverty, whereas the use of clean energy has a negative correlation to poverty. Overall, some of the factors influencing the choice of cooking energy are, income and education [19,27], age [28], health status and family records [29], geographical location, access to credit, assets, and the Internet [30], access to sanitation facilities and information [31,32], as well as affordability and accessibility to the source of energy [33].

In Nigeria, several studies have examined the factors influencing household energy choices. This includes the study of Oyeniran and Isola [20], Ifegbesan et al. [34], and Ozughalu [35] where secondary data previously collected on a national scale were adopted and used in comprehending the various cooking energy choices and uses in the country. The findings in these studies revealed firewood as the primary energy used by most households in Nigeria. However, these studies are from secondary data collected between 2013 and 2019. Others include the study of Bisu et al. [36], and Danlami et al. [37] carried out in Bauchi State, Northeastern Nigeria, where fuelwood was also found to be the most used cooking energy. However, in the Southwestern part of Nigeria, kerosene was found to be the most used cooking energy based on a survey conducted in Ondo, Lagos, and Oyo State [38–40]. In the Southeastern part of the country, LPG was discovered as the most used cooking energy [41].

Though several studies have attempted to comprehend the nexus between energy choice and household factors, the nexus is still not adequately studied [42]. The bulk of the literature on cooking energy choices among households is predominantly focused on rural and peri-urban areas where the use of solid fuels has intensified. Knowledge of the various cooking options and choices in the urban parts is grossly limited. This could be because the rural parts are more vulnerable to the effects of unclean cooking and deforestation as they primarily rely on solid fuels. However, it is imperative to note that the users of charcoal and fuelwood have also increased significantly in the urban parts especially now that the cost of electricity and LPG has skyrocketed in many parts of the world. In this vein, fuelwood and charcoal are transported from the rural parts into the cities which also contributes to CO_2 emission. Therefore, knowledge of the cooking energy dynamics in both rural and urban parts is very important as it will give an insight into the real-time differences and the influencing factors. Similarly, previous studies focused more on cooking fuels with just a few reports on the types and conditions of the cookstoves used in various households. In Nigeria, recent studies on household cooking energy are grossly unavailable, as the available studies were conducted between 2009 and 2020. The few recently reported studies were carried out with secondary data obtained on a national scale. Apart from the fact that these secondary data are susceptible to errors, they may not reflect the status of cooking energy in the country as they were collected more than a decade ago (2013), with some collected about a decade ago (2015), and half a decade ago (2019). Also worthy of note is that there are no such studies conducted in the Northwestern part of Nigeria as previous studies in the country were carried out in the Southeastern, Southwestern, and Northeastern parts. Similarly, none of these studies assessed the presence and use of biofuels such as briquettes, pellets, and biogas as energy options in the surveyed households. It is pertinent to note that knowledge of this would inform the scientific community on the progress made thus far in terms of awareness, acceptance, and use of these renewable energy options in the study area. Most importantly, while only a few studies modeled household factors relating to cooking energy choice, the factors related to the main cooks were not previously considered.

It is against the foregoing background that this study deemed it necessary to explore the nexus between household dynamics and cooking energy choice in Kaduna State Nigeria while assessing the progress in the use of biofuels in the study area. Another novelty of the study is that it considers the main cooks in the households as the respondents and integrates factors related to them such as age, gender, marital status, and education level into the fuel choice modeling. This is contrary to the existing approach of using only factors related to household heads.

2. Materials and methods

The flowchart highlighting the stages followed in the study is presented in Fig. A1 (Appendix). This ranges from the design of a structured questionnaire to the analysis of collected data using descriptive analysis and a multinomial logit regression model.

2.1. Study area

The study was conducted in six Local Government Areas (LGAs) of

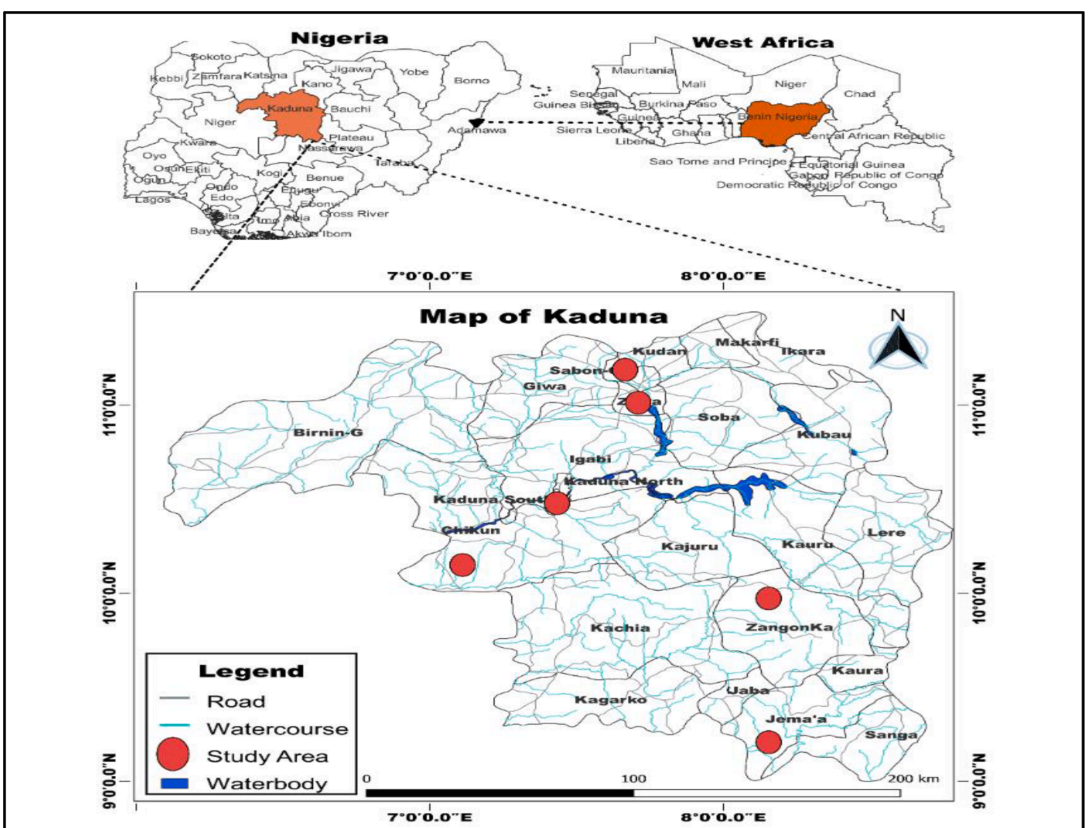

Fig. 2. Map of the study area.

Kaduna State, Northwestern Nigeria. The state lies on latitude 10° 34′ 5″ North and longitude 7° 27′ 7″ East (Fig. 2). Kaduna State has a land mass of 46,053 km^2 and is characterized by a unimodal rainfall pattern with an annual average of 1323 mm [32,33]. The state lies within the northern Guinea Savanna ecological zone comprising typically of woodland and deciduous vegetation type with grasses and shrubs of the *androgenae* family occurring in tussocks [43].

2.2. Household sampling and data collection

The sample size (n = 400) was computed based on a 5% margin of error (e) using Eq. 1 as brought by [44].

$$n = \frac{N}{1 + Ne^2} \tag{1}$$

The population (N = 1155,029) which is the number of households in the study area was obtained from the Kaduna State Bureau of Statistics. In distributing the sample size (400 households), a multi-stage sampling technique was employed. The study area was first stratified into the three (3) existing districts, namely: Kaduna North, Kaduna Central, and Kaduna South. In the first sampling stage, two Local Government Areas (LGAs) were randomly selected from each of the state's three (3) districts (making six LGAs). Consequently, Sabon Gari and Zaria LGAs were selected from Kaduna North, while Chikun and Kaduna South were selected from Kaduna Central, and Jema'a and Zangon Kataf were selected from Kaduna South. In the second sampling stage, five (5) Wards were randomly selected from each of the six LGAs (making a total of 30 Wards), and in the third stage, 10 – 15 households were randomly selected from each of the 30 Wards to obtain the 400 households.

The criterion followed in selecting the respondents in this study was based on the person who is most familiar with the household cooking energy use, defined as the main cook. To ensure a hitch-free session, respondents were made to consent to take part in the survey by signing a consent form. Due to the volatile nature of the surveyed area in terms of security, questions on household income were kept in confidence and analyzed based on the type and level of energy use, as well as the type of building. Thus, the households were classified as either low-income or middle to high-income households.

The data obtained were classified into three main categories, viz: data on respondents and households (age, gender, marital status, education level, occupation, household size, and income), data on cooking energy use (cooking energy, primary cooking energy, energy purchase frequency, the reason for selection, quantity of energy used per day, and daily cooking hours), and data on cookstove usage (daily usage of cookstove and cookstove type). Before commencing the survey, the questionnaire was validated through a pre-testing survey. Based on the observation made during the pre-testing phase, some questions and methods were modified. The variables used in the survey are described in Table 1.

Table 1
Description of the variables used in the analysis.

Variable	Description
Cooking Energy	This is a multiple response variable that considers the whole cooking energy options
Primary Cooking Energy	1 = Firewood, 2 = Charcoal, 3 = Kerosene, 4 = LPG, 5 = Electricity
Age	This is a continuous variable of respondents' age in years
Gender	The gender of the respondent, 1 if Male, 2 if female
Household Income	1 if low-income households, 2 if middle to high-income
Marital Status	Current marital status of the respondent
Size of Household	Number of individuals in the household
Occupation of head	This is a categorical variable of the primary source of income of the head
Education of head	This is a categorical variable of the highest educational qualification of the head
Education of Respondent	This is a categorical variable of the highest educational qualification of the respondent
Daily usage of cookstove	The number of hours cookstoves are used in a household
Daily usage of fuel	The quantity in kg of fuel used by households in a day
Fuel purchase frequency	The rate at which fuel is purchased in the household
Knowledge of health impact	If the respondents are aware of the health implications of their energy choices
Reason for selection	Major reasons why a household selects the cooking energy types being used
Cookstove types	The type of cookstoves present in a household

2.3. Theoretical framework and model

Like the study of Bofah et al. [45], this study theoretically follows the 'utility-theory' approach. The utility theory assumes that users of energy have preferences, thus their choice of cooking energy also depends on those preferences. While this study is not oblivious of the fact that in some instances, household energy choices follow the energy-ladder and energy stacking hypothesis, an econometric theory was deemed more fit as it aligns better with the study objective. Nonetheless, the outcome of this study was compared with the energy-ladder hypotheses. The energy-ladder hypothesis assumed that advancing to cleaner energy options such as LPG and electricity depends on the households' income. Thus, according to the model, household income and wealth are the key factors [46]. Whereas the energy stacking hypothesis suggests that a household switch to a different cooking energy option occasionally, or accumulate and continue to use multiple energy options [47]. This implies that users of traditional energy may occasionally switch to modern energy options based on peculiar needs or based on household income and vice versa.

Thus, following the utility theory, if a variable Y represents a set of options, a consumer-choice model can be considered in the form $Y \subset Rn$, which implies that there are n different cooking energy choices (firewood, charcoal, LPG, electricity, etc.,). In addition, it can be assumed that $y \subset Y$ so that y = (y1, ..., yn), where y = clean energy and other energy types (i.e., wood and charcoal). Thus, the utility function for the household cooking energy options can be explained by Eq. 2 [45].

$$V_{ij} = B_j Y_i + U_{ij} \tag{2}$$

Where *Vij* is the indirect utility function of household *i* for cooking with energy *j; Yi* stands for the vector of individual households and other factors that influence a household's choice of cooking energy; *Bj*, on the other hand, is a vector of coefficients of explanatory variables which quantifies the average likelihood that a household chooses a particular cooking energy type; and *Uij* is the stochastic component that captures the unobserved utility.

2.3.1. Multinomial logit model

Multinomial logistic regression is a powerful statistical tool used in analyzing the relationship between multiple categorical independent variables and a categorical dependent variable with more than two levels. The multinomial logit model works on the hypothesis known as the independent of irrelevant alternative (IIA) [20]. This implies that the link between probabilities of being part of an energy category (e.g., fuelwood) is independent of the other categories (e.g., LPG and electricity) [20]. The multinomial logit regression model is expressed in Eq. 3 [29].

$$ln\left[\frac{P(Z=j)}{P(Z=i)}\right] = \alpha + \beta Y + t + \lambda + \varepsilon \tag{3}$$

Where $P\ (Z= j)$ is the probability of a household choosing energy *j* as its primary cooking energy. *Y* is the independent variable (explanatory) that may influence cooking energy choice by the various households, *t* is a dummy variable of respondents' age in years, λ is the province dummy variable, and ε is the error term. Thus, the regression coefficients can be expressed as the effect of the explanatory variables on the log of the probability ratio between energy type *j* and energy type *i*, where energy type i is the baseline group, and $i \neq j$.

2.4. Statistical analysis

Descriptive statistics in the form of proportions and frequencies using a linearized method of variance estimation were used in the analysis. Because the outcome variable is nominal with more than two mutually exclusive unordered categories, a multinomial-logit regression model was employed in estimating the impact of the various household dynamics on the choice of primary cooking energy. The data were analyzed using Stata SE version 17.0 software.

3. Results

3.1. Descriptive analysis of variables

3.1.1. Household characteristics

The result of the various household factors is presented in Table 2. The result shows that 63% of the respondents are between the age of 21 and 40 years. The result further revealed 87.5% of the respondents to be females based on which 78% are married. The findings also showed that most of the households (62.7%) have large family sizes (five or more members) and are predominantly (68.2%) low-income households. Similarly, the heads of the households are mainly (55.3%) self-employed who are engaged in farming and small-scale businesses. In terms of the educational qualification of the household heads and respondents, the result depicts a higher proportion (29.3%) of the household heads to be senior secondary school certificate (SSCE) and bachelor's degree (B.Sc.) holders (23.4%). However, these were more common among urban households, as heads of rural households are either without education or are holders of primary or junior secondary certificates (JSCE). In the case of the respondents, most of them are SSCE holders (39.2%).

Table 2
Descriptive statistics of household variables.

Variable	Options	Proportion	Std. Err.	[95%_Conf. Interval]	
Age of respondent	< 20	0.043	0.017	0.018	0.098
	21–30	0.353	0.048	0.256	0.463
	31–40	0.282	0.032	0.217	0.358
	41–50	0.166	0.030	0.110	0.244
	>50	0.156	0.037	0.091	0.255
Gender	Male	0.125	0.081	0.028	0.415
	Female	0.875	0.081	0.585	0.972
Marital Status	Married	0.78	0.042	0.676	0.857
	Divorced	0.028	0.012	0.011	0.068
	Single	0.117	0.046	0.048	0.258
	Widow(er)	0.075	0.024	0.037	0.148
Size of household	Single	0.033	0.026	0.006	0.167
	2	0.087	0.022	0.050	0.149
	3	0.095	0.020	0.060	0.148
	4	0.158	0.015	0.127	0.194
	5 or more	0.627	0.059	0.494	0.744
Occupation of head	Farming	0.090	0.013	0.065	0.124
	Civil Servant	0.320	0.033	0.251	0.397
	Self-employed	0.553	0.049	0.443	0.658
	Part-time Job	0.037	0.016	0.014	0.096
Household Income	Low	0.682	0.050	0.564	0.780
	Middle to High	0.318	0.050	0.220	0.436
Education of Head	None	0.075	0.031	0.029	0.182
	Primary	0.097	0.030	0.047	0.187
	JSCE	0.053	0.011	0.034	0.082
	SSCE	0.293	0.025	0.241	0.351
	Diploma	0.131	0.016	0.100	0.169
	HND	0.065	0.017	0.036	0.117
	B.*Sc.*	0.234	0.041	0.155	0.336
	M.*Sc.*	0.044	0.008	0.030	0.064
	Ph.D.	0.009	0.007	0.002	0.045
Education of Resp.	None	0.122	0.049	0.048	0.277
	Primary	0.144	0.027	0.094	0.215
	JSCE	0.107	0.017	0.073	0.152
	SSCE	0.392	0.037	0.313	0.476
	Diploma	0.147	0.030	0.092	0.228
	HND	0.019	0.008	0.008	0.045
	B.*Sc.*	0.066	0.010	0.047	0.092
	M.*Sc.*	0.003	0.003	0.000	0.028

3.1.2. Energy use

The results of energy use were analyzed based on the usage of cookstoves and cooking fuel/energy in the various households. The findings in this category are presented in Table 3. The result revealed that more than half (57.5%) of households use their cookstoves within a range of 5–7 hours per day. This includes the time spent while using the cookstoves for other applications different from cooking such as water heating. This further corroborates the findings of Kabir et al. [48] where an average weekly cooking time of 25.48 hours was noted among households in the northern part of Nigeria. In Fig. 3, the various cooking energy types used in the households are presented. From the result, charcoal is the most used cooking energy option with 31.02% of the households followed by LPG with 19.52% of the households, and fuelwood with 17.96% of the households. However, in Fig. 4 only the primary cooking energy used in the households was considered. Here, the results revealed charcoal and fuelwood as the most used cooking energy with 41.60% and 27.07% of the households, respectively. The reasons the respondents gave for selection are presented in Fig. 5. These were based on availability (35.22%), especially for the users of agro waste and firewood, cost (33.60%), mainly for the users of charcoal and firewood, and efficiency (30.53%), majorly selected by households using LPG and electricity. The quantity of fuel used per day among the surveyed households is between 1 to 5 kg. However, it was observed that about 69.75% of the households that use less than a kilogram of fuel per day are LPG users, whereas 31.1% are households that use charcoal and fuelwood. Similarly, 67.5% of households that use between 1- 5 kg of fuel per day are charcoal users while 32.1% are firewood users.

In terms of energy purchase frequency, households that use charcoal and fuelwood were noted as the households that purchase fuel daily with about 39.6% of households recorded. On the other hand, the households

Table 3
Descriptive statistics of stove and fuel variables.

Variable	Options	Proportion	Std. Err.	[95%_Conf. Interval]	
Daily Stove Use (h)	< 2	0.003	0.003	0.000	0.023
	2–4	0.122	0.042	0.056	0.248
	5–7	0.575	0.046	0.473	0.671
	8–10	0.198	0.050	0.111	0.327
	11–13	0.095	0.022	0.056	0.156
	>13	0.007	0.005	0.002	0.031
Daily Fuel Use (kg)	<1	0.310	0.024	0.266	0.358
	1–5	0.633	0.025	0.583	0.680
	6–10	0.036	0.010	0.022	0.061
	11–15	0.013	0.006	0.005	0.031
	16–20	0.003	0.003	0.000	0.018
	21–25	0.003	0.003	0.000	0.018
	26–30	0.003	0.003	0.000	0.018
Fuel Purchase Freq.	Daily	0.396	0.054	0.286	0.518
	Weekly	0.085	0.023	0.047	0.150
	Monthly	0.518	0.046	0.419	0.616
Knowledge of health impact	Yes	0.922	0.042	0.767	0.977
	No	0.077	0.042	0.023	0.233

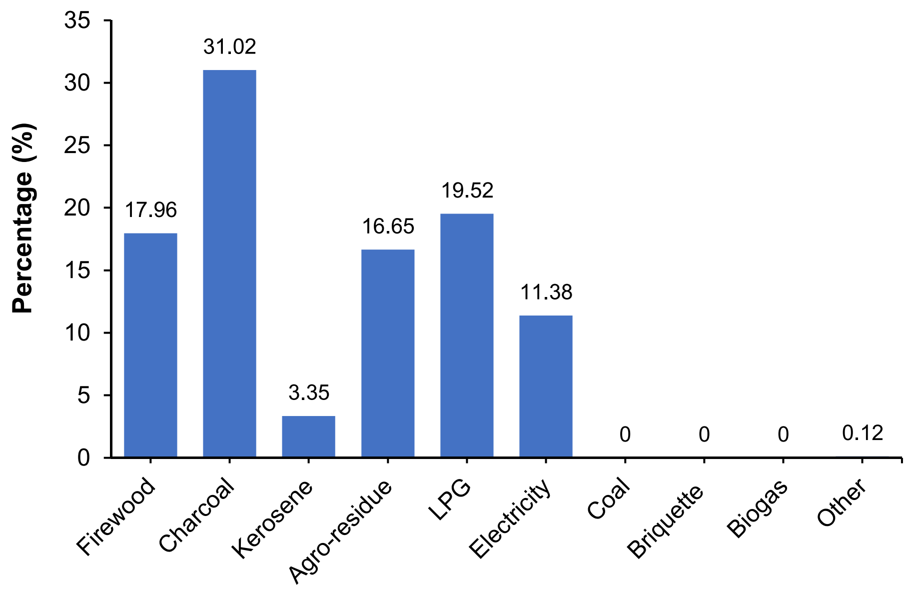

Fig. 3. Cooking energy.

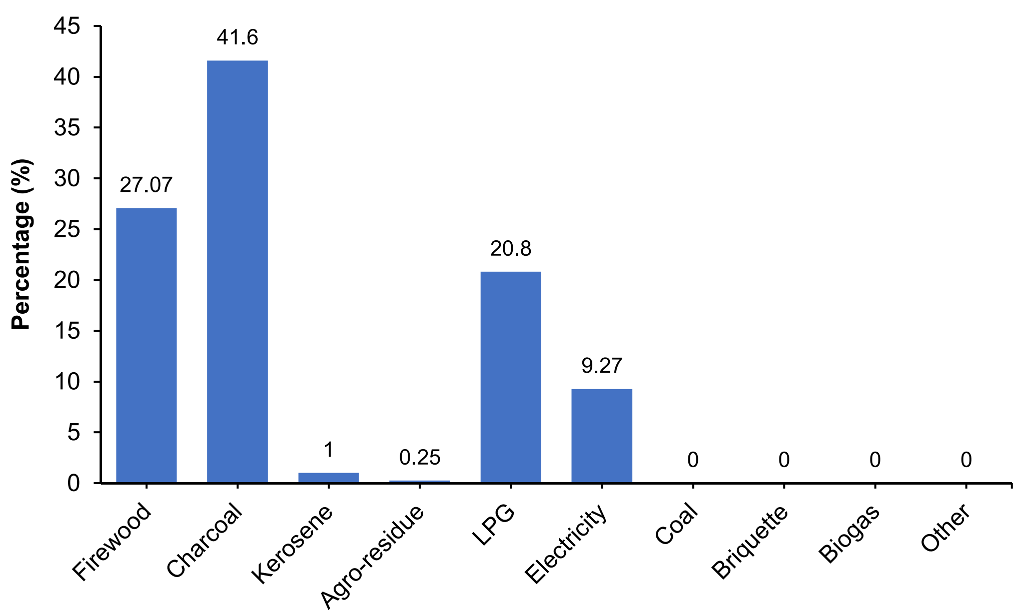

Fig. 4. Primary cooking energy.

that purchase fuel monthly, are households that use LGP and electricity as cooking energy with few other households using charcoal. However, weekly energy purchase was not reported by most households as only 8.5% of the respondents indicated such. In terms of knowledge of the environmental and health impact of the energy types, almost all the households (92.2%) affirmed being aware of the impact of unsustainable and poor use of cooking energy and cookstoves on their health and the environment. The results of cookstove types are presented in Fig. 6. As shown, most of the households use traditional charcoal cookstoves (32.70%). This conforms with the findings of Aziz et al. [33], and further confirms the assertion of Oyeniran and Isola [20] which noted that a considerable proportion of the population in Nigeria are users of traditional fuels and cookstoves.

3.2. Multinomial logit regression model results

Multinomial logistic regression analysis was conducted to understand the factors influencing household cooking energy choice. The dependent variable in this analysis represents the primary cooking energy used by households. Because only a few categorical variables can be considered in multinomial regression, only the five main primary cooking energy options were considered viz: Firewood, Charcoal, Kerosene, LPG (Liquified Petroleum Gas), and electricity as the reference category. The independent variables are household size, marital status of the respondent, education of the head of the household, education of the respondent, gender of respondent, occupation of the head, household income, and age of the respondent.

3.2.1. Model fit statistics

Table 4 presents the model fit statistics of the multinomial regression. The values obtained for the model fit parameters are 0.4269 for Pseudo R2, -206.47723 for log-likelihood ratio, 355.89 for LR (chi2), and 0.0000 for probability (Prob > chi2).

An LR chi2 value of 355.89 indicates a significant relationship

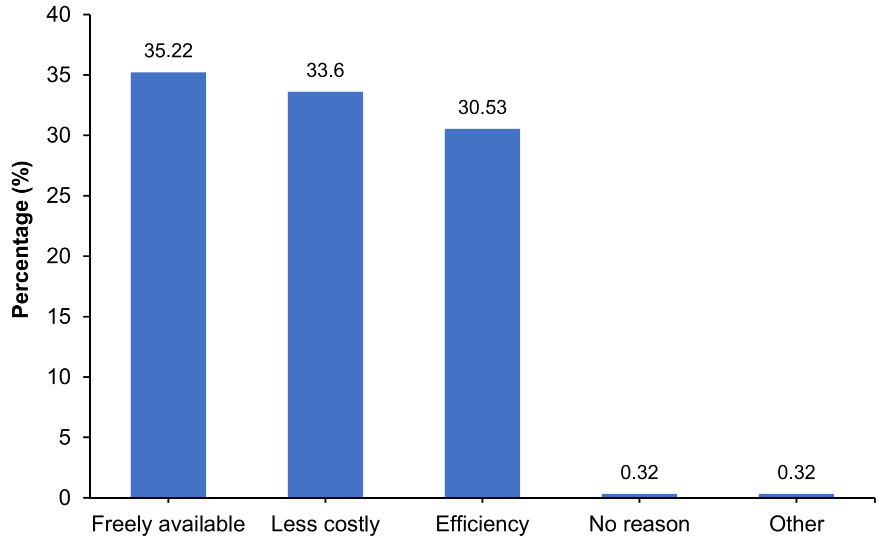

Fig. 5. Reasons for energy selection.

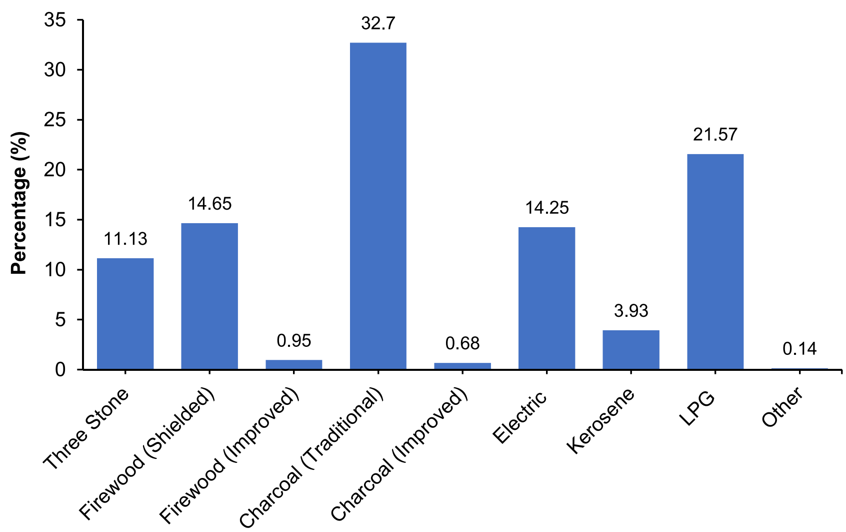

Fig. 6. Cookstove types.

Table 4
Model fit statistics.

Pseudo R^2	Log-likelihood	LR (chi2)	Prob > chi2
0.4269	-206.47723	355.89	0.0000

between the independent variables and the outcome categories. On the other hand, the Prob > chi2 is 0.0000, which is less than the conventional significance level of 0.05. This suggests strong evidence against the null hypothesis (there is no relationship between the independent variables and the outcome categories). Similarly, the log-likelihood of -206.47723 typically depicts a better fit. While it is essential to compare this value to other models or variations of the current model, it suggests that the model provides a reasonable fit to the data. With a pseudo R2 of 0.4629, it shows that the model accounts for approximately 46.29% of the variance in the outcome categories. Therefore, we can conclude that the multinomial logistic regression model is statistically significant in explaining the variation in the choice of primary cooking energy in the study area.

3.2.2. Multinomial results of variables influencing cooking energy choice

Table 5 shows the results of the multinomial logit regression analysis. In the analysis, electricity was used as the reference energy option based on which the estimated coefficients were compared. This was because, among the cooking energy options evaluated, electricity is perceived as the cleanest option. The intercepts for each energy type represent the baseline probabilities of using that specific energy when all other independent variables are zero. Based on this, the intercept for Firewood is 21.8152, indicating that in the absence of other factors, the probability of a household using firewood as its primary cooking energy is approximately 21.82%. Similarly, the intercepts for Charcoal, Kerosene, and LPG are 41.50282, -30.29589, and 9.2882, respectively. This proves that charcoal has the highest probability (41.50%) of acceptance in the absence of other factors.

In the case of household size, the computed coefficients suggest that households with large family sizes are more likely to use firewood and charcoal compared to the reference category (single households), which is consistent with the findings in Oyeniran and Isola [20]. However, the use of LPG was found to impact households with larger sizes negatively as observed by Zhu et al. [29]. This shows that households with single members are more likely to opt for LPG.

Table 5
Multinomial logit regression results.

Regressor	Firewood Coefficient	Charcoal Coefficient	Kerosene Coefficient	LPG Coefficient
Intercept	21.8152	41.50282	-30.29589	9.2882
	(0.46)	(0.990)	(0.000) ***	(0.000) ***
Household Size				
Single	(Baseline)	-	-	-
3	.7435	.6842	-	.0628
	(0.639)	(0.639)		(0.964)
4	.1319	.0001	-	.7844
	(0.933)	(1.000)		(0.447)
5 or more	1.0723	.7207	-	-0.4863
	(0.435)	(0.479)		(0.609)
Marital status				
Married	(Baseline)	-	-	-
Divorced	-0.23676	-1.7242	-77.005	-1.8684
	(0.918)	(0.292)	(0.000) ***	(0.397)
Single	1.3807	-0.2863	-66.585	-0.330
	(0.186)	(0.763)	(0.000) ***	(0.969)
Widow (er)	-0.9358	-1.5877	-55.323	-0.6261
	(1.000)	(1.000)	(0.000) ***	(1.000)
Education of head				
None	(Baseline)	-	-	-
Primary	-13.552	-13.570	-	-93.003
	(0.996)	(0.996)		(0.996)
JSCE	-14.535	-13.786	-	-94.312
	(0.996)	(0.996)		(0.996)
SSCE	-14.117	-12.895	-	-12.792
	(0.996)	(0.996)	-	(0.996)
Diploma	-	-14.306		-13.592
		(0.996)		(0.996)
HND	-	-13.477	-5.9786	-12.740
		(0.996)	(1.000)	(0.996)
B.*Sc*.	-14.4778	-13.127	-	-11.552
	(0.996)	(0.996)		(0.997)
M.*Sc*.	-	-94.960	-	-10.911
		(0.000) ***		(0.997)
Ph. D	-	-9.866	-	-11.407
		(0.999)		(0.999)
Education of respondent				
None	(Baseline)	-	-	-
Primary	-13.3164	-13.966	-72.9442	-11.245
	(0.983)	(0.982)	(1.000)	(0.986)
JSCE	2.9905	2.6328	-45.8954	3.5295
	(0.999)	(0.999)	(0.000) ***	(0.998)
SSCE	-13.0612	-13.853	3.9598	-12.1893
	(0.983)	(0.982)	(0.000) ***	(0.985)
Diploma	-	-14.650	-71.5688	-11.7833
		(0.981)	(0.985)	(0.985)
HND	-	-	-65.3264	-13.1724
			(0.986)	(0.983)
B.*Sc*.	-	-11.748	-53.9553	-11.684
		(0.985)	(0.987)	(0.985)
M.*Sc*.	-	20.835	-44.9255	-72.8052
		(0.000) ***	(0.988)	(0.000) ***
Gender				
Male	(Baseline)	-	-	-
Female	3.9671	-13.371	-20.6073	15.1223
	(0.999)	(0.995)	(0.999)	(0.997)
Occupation of head				
Farming	(Baseline)	-	-	-
Civil servant	.88024	.8246	-63.0178	.2095
	(0.559)	(0.518)	-	(0.898)
Self-employed	.9998	1.8446	2.7431	-0.5059
	(0.378)	(0.087)	(1.000)	(0.744)
Part-time job	14.2035	13.514	97.8641	14.8710
	(0.991)	(0.991)	(1.000)	(0.01) ***
Household Income				
Low	(Baseline)	-	-	-
Middle to High	-2.8128	-2.4484	-75.3792	.2608
	(0.004) ***	(<0.001) ***	(0.000) ***	(0.711)
Age				
< 20	(Baseline)	-	-	-
21–30	.38235	-1.0581	-22.7707	.7565
	(0.810)	(0.368)	(1.000)	(0.553)
31–40	1.0988	-0.6139	-	.7050
	(0.510)	(0.633)		(0.613)
41–50	16.369	14.437	-	15.508
	(0.983)	(0.985)		(0.02) ***
>50	18.715	16.662	-	16.760
	(0.994)	(0.995)		(0.01) ***

Notes: p-values are in parentheses, *** = P-value is significant at 0.05, Electricity is the referenced energy

Marital status is another factor that significantly influences household energy choice. The coefficients for marital status categories (Divorced, Single, Widow(er)) compared to the reference category (Married) provide insights into how marital status affects energy choice. The results suggest that a divorced household has a significant negative association (coefficient: -77.005) with the use of kerosene. Thus, divorced households are less likely to use Kerosene compared to married households. On the other hand, a single household is more likely to use Firewood (coefficient: 1.3807) and less likely to use Charcoal (coefficient: -0.2863) compared with a married household. The findings depict that married households are more likely to use charcoal, kerosene, and LPG as their cooking energy.

In terms of the education level of the head of household and the respondent, the coefficients revealed that households whose heads are educated are less likely to use traditional fuels such as firewood, charcoal, and fossils such as kerosene and LPG compared to households whose heads are not educated. This implies that such households are more likely to go for clean energy options like electricity, depicting their interest in curtailing the use of polluting fuels. This aligns with the findings of Bofah et al. [45]. However, in the case of the education level of respondents, a different outcome was observed, as households with as high as M.Sc. are more likely to use charcoal and less likely to use LPG compared to the reference category and even to the holders of JSCE whose coefficient shows a positive association (coefficient: 3.5295) to the use of LPG. This implies that the level of education of the heads of household influences the choice of cleaner cooking energy better than the education level of the respondents who are the main cooks in the various households. The gender coefficient indicates that females are 3.9671 times more likely to use Firewood and 15.1223 times more likely to use LPG compared to males. However, they are less likely to use Charcoal (coefficient: -13.371) and kerosene (coefficient: -20.6073) than males.

The occupation of the head of the household also plays a significant role in the choice of cooking energy. The findings revealed that households whose heads are civil servants are more likely to use fuelwood, charcoal, and LPG, but less likely to use kerosene (coefficient: -63.0178), while households whose heads are self-employed are more likely to use Kerosene (coefficient: 2.7431) and less likely to use LPG (coefficient: -0.5059). On the other hand, middle to high-income earning households are less likely to use Firewood (coefficient: -2.8128), Charcoal (coefficient: -2.4484), and Kerosene (coefficient: -75.3792) compared to low-income earning households. The age coefficients reveal how different age groups influence fuel choice. Households with aged cooks (i.e., 41–50 years and 50 years above) are more likely to use Firewood and Charcoal than households whose cooks are young (i.e., less than 20 years and 21 -30 years).

4. Discussion

Between 2016 and 2019, firewood and kerosene have been the most used forms of cooking energy in Nigeria, as charcoal was among the least used [20]. However, due to the increased cost of kerosene, coupled with the fact that most of the households are low-income earners, most households now rely on charcoal and firewood to meet their cooking energy needs. Further observation from the survey revealed that because most of the households have large family sizes, they find it easier and more affordable to use charcoal and fuelwood for cooking. Thus, options such as LPG and electricity are not just unaffordable, but designs that accommodate large pot sizes are still not widely available in the local markets.

Predictions from the multinomial logit model also indicate that households with large family sizes are more likely to use firewood and charcoal. This corroborates the findings of Oyeniran and Isola [20]. With sufficient evidence from the model fitness parameters, the stated prediction has high certainty of occurrence. Hence, considering the population growth of Nigeria, which is persistently rising, it depicts a potential of having more users of unclean and solid fuels in the future. Thus, if measures are not taken to address this potential problem, there is a likelihood of experiencing an increase in the rate of deforestation in the coming years making the country more vulnerable to climate change. Therefore, for a swift transition to the use of clean energy, governments, Non-Governmental Organizations (NGOs), and/or private organizations must provide interventions that will improve the accessibility and affordability of clean energy especially to low-income households. Overall, the findings from this study confirmed that the energy use pattern in the study area conforms better with the fuel stacking theory than the energy ladder theory as traditional energy is often used alongside modern energy. This is consistent with the findings of Baiyegunhi and Hassan [49].

However, the major limitation of this study is that it only focused on six LGAs out of the 23 LGAs of Kaduna state, Nigeria. Future studies can explore a larger sample size to cover the entire state and if possible, the whole country. Secondly, the study could not ask questions on household income. This was assessed based on the enumerator's perception following the type of household and energy choice. Although the study assessed the presence of bio-based fuels such as briquettes and biogas, they were not included as variables in the modeling phase due to restrictions in terms of the number of independent variables, and because none of the households used these energy types. Future studies can model these bio-based options to explore more information on why they are still not in use in most households despite the progress recorded in terms of scientific research.

5. Conclusion

This study assessed household cooking energy use and the various demographic and socioeconomic factors influencing their choices. The outcome of the descriptive analysis revealed charcoal and fuelwood as the most used form of cooking energy in Kaduna State, Nigeria. The choice of the stated energy types was mainly influenced by their cost and availability. The findings from the multinomial logit regression suggest that the independent variables significantly impact the outcome categories (primary energy choice).

Furthermore, the study found out that although traditional cooking energy options such as charcoal and fuelwood are the most used forms of cooking energy in the surveyed areas, cleaner options such as electricity and LPG were present in most of the households in the urban parts of the State. Therefore, the energy use pattern in the study area conforms better with the fuel stacking theory than the energy ladder theory. These findings can be crucial for policymakers and organizations working on promoting clean and sustainable energy production and use, climate change mitigation, and the reduction of indoor air pollution. Similarly, it would serve as a guide in tracking the advances in cooking energy consumption and its related impact towards achieving carbon neutrality or net zero emissions in the future.

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CRediT authorship contribution statement

S.U. Yunusa: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **E. Mensah:** Supervision, Conceptualization. **K. Preko:** Supervision, Conceptualization. **S. Narra:** Writing – review & editing, Supervision. **A. Saleh:** Writing – review & editing, Supervision. **Safietou Sanfo:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.nexus.2024.100310.

Appendix

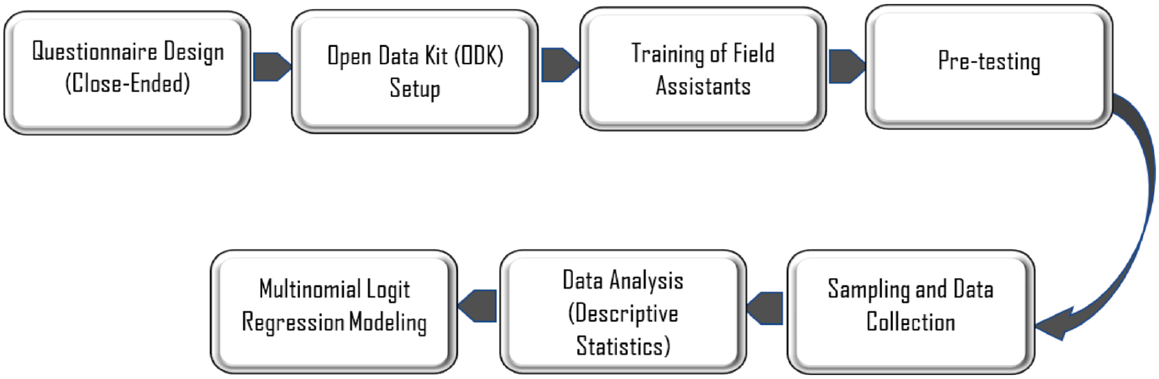

Fig. A1. Flowchart of the household survey.

References

[1] United Nations UN, Progress towards the sustainable development goals,. https://doi.org/10.1017/S0020818300010845.

[2] H. Li, X. Leng, J. Hu, A. Cao, L. Guo, When cooking meets confucianism: exploring the role of traditional culture in cooking energy poverty, Energy Res. Soc. Sci. 97 (2023) 102956, https://doi.org/10.1016/j.erss.2023.102956.

[3] International Energy Agency (IEA), CO2 emissions in 2022,. https://doi.org/10.1787/12ad1e1a-en.

[4] M.A. Clark, N.G.G. Domingo, K. Colgan, S.K. Thakrar, D. Tilman, J. Lynch, I. L. Azevedo, J.D. Hill, Global food system emissions could preclude achieving the 1.5° and 2 °c climate change targets, Science (80-.) 370 (2020) 705–708, https://doi.org/10.1126/science.aba7357.

[5] D. Guta, J. Baumgartner, D. Jack, E. Carter, G. Shen, J. Orgill-Meyer, J. Rosenthal, K. Dickinson, R. Bailis, Y. Masuda, H. Zerriffi, A systematic review of household energy transition in low and middle income countries, Energy Res. Soc. Sci. 86 (2022) 102463, https://doi.org/10.1016/j.erss.2021.102463.

[6] S.U. Yunusa, E. Mensah, K. Preko, S. Narra, A. Saleh, S. Sanfo, M. Isiaka, I.B. Dalha, M. Abdulsalam, Biomass cookstoves : a review of technical aspects and recent advances, Energy Nexus 11 (2023) 100225, https://doi.org/10.1016/j.nexus.2023.100225.

[7] S.U. Yunusa, E. Mensah, K. Preko, S. Narra, A. Saleh, S. Sanfo, A comprehensive review on the technical aspects of biomass briquetting, Biomass Convers. Biorefinery (2023), https://doi.org/10.1007/s13399-023-04387-3.

[8] T.S. Nababan, The factors affecting the household energy consumption, energy elasticity, and energy intensity in Indonesia, SSRN Electron. J. (2015), https://doi.org/10.2139/ssrn.2974347.

[9] M.O. Dioha, A. Kumar, Exploring sustainable energy transitions in Sub-Saharan Africa residential sector: the case of Nigeria, Renew. Sustain. Energy Rev. 117 (2020) 109510, https://doi.org/10.1016/j.rser.2019.109510.

[10] M. Sedighi, H. Salarian, A comprehensive review of technical aspects of biomass cookstoves, Renew. Sustain. Energy Rev. 70 (2017) 656–665, https://doi.org/10.1016/j.rser.2016.11.175.

[11] Clean Cooking Alliance CCA, Climate, environment, and clean cooking, 2021. https://cleancooking.org/the-issues/climate-environment/(accessed Oct. 05, 2022).

[12] O. Stoner, J. Lewis, I.L. Martínez, S. Gumy, T. Economou, H. Adair-Rohani, Household cooking fuel estimates at global and country level for 1990 to 2030, Nat. Commun. (2021) 12, https://doi.org/10.1038/s41467-021-26036-x.

[13] A. McCarron, I. Uny, L. Caes, S.E. Lucas, S. Semple, J. Ardrey, H. Price, Solid fuel users' perceptions of household solid fuel use in low- and middle-income countries: a scoping review, Environ. Int. 143 (2020) 105991, https://doi.org/10.1016/j.envint.2020.105991.

[14] G. Boafo-Mensah, K.M. Darkwa, G. Laryea, Effect of combustion chamber material on the performance of an improved biomass cookstove, Case Stud, Therm. Eng. 21 (2020) 100688, https://doi.org/10.1016/j.csite.2020.100688.

[15] S.O. Jekayinfa, J.I. Orisaleye, R. Pecenka, An assessment of potential resources for biomass energy in Nigeria, Resources 9 (2020), https://doi.org/10.3390/resources9080092.

[16] I.D. Ibrahim, Y. Hamam, Y. Alayli, T. Jamiru, E.R. Sadiku, W.K. Kupolati, J. M. Ndambuki, A.A. Eze, A review on Africa energy supply through renewable energy production: Nigeria, Cameroon, Ghana and South Africa as a case study, Energy Strateg. Rev. 38 (2021) 100740, https://doi.org/10.1016/j.esr.2021.100740.

[17] O.B. Okedere, F.B. Elehinafe, S. Oyelami, A.O. Ayeni, Drivers of anthropogenic air emissions in Nigeria - a review, Heliyon 7 (2021) e06398, https://doi.org/10.1016/j.heliyon.2021.e06398.

[18] P.K. Adom, S. Adams, Energy savings in Nigeria. is there a way of escape from energy inefficiency? Renew. Sustain. Energy Rev. 81 (2018) 2421–2430, https://doi.org/10.1016/j.rser.2017.06.048.

[19] R. Kowsari, H. Zerriffi, Three dimensional energy profile:. a conceptual framework for assessing household energy use, Energy Policy 39 (2011) 7505–7517, https://doi.org/10.1016/j.enpol.2011.06.030.

[20] I.W. Oyeniran, W.A. Isola, Patterns and determinants of household cooking fuel choice in nigeria, Energy 278 (2023) 127753, https://doi.org/10.1016/j.energy.2023.127753.

[21] S.U. Yunusa, M. Isiaka, A. Saleh, Development of double burner natural-draft biomass cookstove, Agric. Eng. Int. CIGR J. 24 (2022) 194–206.

[22] R. Bailis, I. Mutisya, S. Hounsell, K. McLean, Low-cost interventions to reduce emissions and fuel consumption in open wood fires in rural communities: evidence from field surveys, Energy Sustain. Dev. 63 (2021) 145–152, https://doi.org/10.1016/j.esd.2021.06.005.

[23] V.H. Honkalaskar, U.V Bhandarkar, M. Sohoni, Development of a fuel efficient cookstove through a participatory bottom-up approach, Energy. Sustain. Soc. 3 (2013).

[24] B.E. Shari, M.O. Dioha, M.C. Abraham-Dukuma, V.O. Sobanke, N.V. Emodi, Clean cooking energy transition in Nigeria: policy implications for developing countries, J. Policy Model. 44 (2022) 319–343, https://doi.org/10.1016/j.jpolmod.2022.03.004.

[25] M. Imran, A. Zahid, S. Mouneer, O. Özçatalbaş, S. Ul Haq, P. Shahbaz, M. Muzammil, M.R. Murtaza, Relationship between household dynamics, biomass consumption, and carbon emissions in pakistan, Sustainability 14 (2022), https://doi.org/10.3390/su14116762.

[26] I.D. Nwaka, K.E. Uma, G.N. Ike, Determinants of household fuel choices among Nigerian family heads: are there gender-differentiated impacts? Environ. Sci. Pollut. Res. 27 (2020) 42656–42669, https://doi.org/10.1007/s11356-020-09554-x.

[27] E.N. Ogbeide-Osaretin, Analysing energy consumption and poverty reduction nexus in Nigeria, Int. J. Sustain. Energy (2020), https://doi.org/10.1080/14786451.2020.1815744.

[28] Y. Chen, S. Li, T. Zhou, X. Lei, X. Liu, Y. Wang, Household cooking energy transition in rural mountainous areas of china: characteristics, drivers, and effects, J. Clean. Prod. 385 (2023) 135728, https://doi.org/10.1016/j.jclepro.2022.135728.

[29] X. Zhu, Z. Zhu, B. Zhu, P. Wang, The determinants of energy choice for household cooking in china, Energy 260 (2022) 124987, https://doi.org/10.1016/j.energy.2022.124987.

[30] M. Ankrah Twumasi, Y. Jiang, B. Addai, D. Asante, D. Liu, Z. Ding, Determinants of household choice of cooking energy and the effect of clean cooking energy consumption on household members' health status: the case of rural Ghana, Sustain. Prod. Consum. 28 (2021) 484–495, https://doi.org/10.1016/j.spc.2021.06.005.

[31] K. Bakhsh, A. Sadiqa, M.A. Yasin, S. Haider, R. Ali, Exploring the nexus between households' choice of cooking fuels, sanitation facilities and access to information in pakistan, J. Clean. Prod. 257 (2020) 120621, https://doi.org/10.1016/j.jclepro.2020.120621.

[32] J. Ali, W. Khan, Demographic, social and economic factors affecting the adoption of green toilets among rural households in India, Environ. Dev. Sustain. 26 (2024) 5117–5138, https://doi.org/10.1007/s10668-023-02927-5.

[33] S. Aziz, S. Barua, S.A. Chowdhury, Cooking energy use in bangladesh: evidence from technology and fuel choice, Energy 250 (2022) 123696, https://doi.org/10.1016/j.energy.2022.123696.

[34] A.P. Ifegbesan, I.T. Rampedi, H.J. Annegarn, Nigerian households' cooking energy use, determinants of choice, and some implications for human health and environmental sustainability, Habitat Int 55 (2016) 17–24, https://doi.org/10.1016/j.habitatint.2016.02.001.

[35] U.M. Ozughalu, Patterns and determinants of households' energy choices for cooking as well as their implications for poverty eradication in Nigeria, J. Dev. Areas 57 (2023) 175–199, https://doi.org/10.1353/jda.2023.a908652.
[36] D.Y. Bisu, A. Kuhe, H.A. Iortyer, Urban household cooking energy choice: an example of Bauchi metropolis, Nigeria, Energy. Sustain. Soc. 6 (2016), https://doi.org/10.1186/s13705-016-0080-1.
[37] A.H. Danlami, S.D. Applanaidu, R. Islam, An analysis of household cooking fuel choice: a case of Bauchi state, Nigeria, Int. J. Energy Sect. Manag. 12 (2018) 265–283, https://doi.org/10.1108/IJESM-05-2016-0007.
[38] P.A. Adeyemi, A. Adereleye, Determinants of household choice of cooking energy in Ondo state, Nigeria, J. Econ. Sustain. Dev. 7 (2017) 131–142 [Online]. Available: https://www.nice.org.uk/guidance/ng9/resources/bronchiolitis-in-children-diagnosis-and-management-pdf-51048523717%0Ahttps://www.nice.org.uk/guidance/ng9/resources/bronchiolitis-in-children-51048523717.
[39] E. Emagbetere, J. Odia, B. Oreko, Assessment of household energy utilized for cooking in Ikeja, Lagos State, Nigeria, Niger. J. Technol. 35 (2016) 796, https://doi.org/10.4314/njt.v35i4.14.
[40] O.O. Olugbire, F.J. Aremu, O.H. Opute, C.A. Ojedokun, O.O. Olawale, A. Adisa, Determinants of household cooking energy choice in Oyo State, Nigeria, RJOAS 4 (2016) 28–36.
[41] N.A. Onyekuru, C.A. Ifejirika, D.M. Onuigbo, R.A. Mebo, E.C. Eboh, Factors affecting households' choice of cooking energy in enugu state, nigeria, Agro-Science 19 (2020) 6–13, https://doi.org/10.4314/as.v19i4.2.
[42] S. Matsumoto, K. Mizobuchi, S. Managi, Household energy consumption, Environ. Econ. Policy Stud. 24 (2022) 1–5, https://doi.org/10.1007/s10018-021-00331-9.
[43] M.N. Pius, S.A. Yelwa, A.B. Sanda, Assessment of drought across Kaduna State, Nigeria using Modis dataset, J. Geogr. Environ. Earth Sci. Int. 24 (2020) 45–61, https://doi.org/10.9734/jgeesi/2020/v24i630235.
[44] T. Yamane, Statistics, An Introductory Analysis, 2nd Editio, 1967, Harper & Row and John Weatherhill, Inc., Tokyo, 1967.
[45] R.O. Bofah, P. Appiah-Konadu, F.N. Ngwu, Transition to cleaner cooking energy in Ghana, Clean Energy 6 (2022) 193–201, https://doi.org/10.1093/ce/zkac004.
[46] P. Liu, C. Han, X. Liu, M. Teng, Assessing the effect of nonfarm income on the household cooking energy transition in rural China, Energy 267 (2023) 126559, https://doi.org/10.1016/j.energy.2022.126559.
[47] P. Yadav, P.J. Davies, S. Asumadu-Sarkodie, Fuel choice and tradition: why fuel stacking and the energy ladder are out of step? Sol. Energy 214 (2021) 491–501, https://doi.org/10.1016/j.solener.2020.11.077.
[48] I. Kabir, M.R. Yacob, M. Ariffin, D. Emang, A. Adamu, Assessing the extent of traditional biomass cookstove usage and related cooking practices : evidence from rural households in northern Nigeria, IOSR J. Humanit. Soc. Sci. 23 (2018) 39–46, https://doi.org/10.9790/0837-2303013946.
[49] L.J.S. Baiyegunhi, M.B. Hassan, Rural household fuel energy transition: evidence from Giwa Lga Kaduna State, Nigeria, Energy Sustain. Dev. 20 (2014) 30–35, https://doi.org/10.1016/j.esd.2014.02.003.