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# Households' Socio-Economic Dynamics and its influence on Cooking Energy Choice in Maiduguri, Borno State, Nigeria

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***Abstract***: *Understanding the factors that influence households' energy decisions is crucial for promoting clean energy transitions and addressing the environmental and health challenges associated with traditional fuels. This study was therefore undertaken to examine the influence of households' socio-economic characteristics on cooking energy choice in Maiduguri, Borno State, Nigeria. It adopted a quantitative approach based on a survey strategy to generate data from a sample of 384 respondents that were selected using multi-stage sampling technique. The data was analyzed using multinomial logistic regression. The results revealed that income level, education and urban residency significantly influenced the adoption of clean fuels, with households having a higher income and education levels demonstrating a significantly greater propensity to utilize LPG and electricity ($p < 0.01$). Additionally, gender influenced energy selection, as female-headed households were more inclined to adopt cleaner fuels ($p < 0.05$), whereas larger households and those residing in self-owned properties exhibited a greater probability of adopting traditional fuels. Occupation also played a significant role in energy choices, with civil servants and private-sector workers showing a preference for modern fuels over firewood and charcoal. These findings corroborate the energy ladder hypothesis, affirming that financial resources and awareness are pivotal to driving the transition to cleaner energy sources. It recommended the implementation of targeted interventions and policies, including LPG subsidies, financial incentives and public awareness campaigns to facilitate the transition to safe, clean, reliable, efficient and affordable energy sources in Borno State.*

***Keywords***: *Household energy choice, socio-economic factors, traditional fuels, clean fuels, multinomial logistic regression, energy transition.*

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## 1.1 INTRODUCTION

Although access to safe, clean, efficient and modern energy sources for households' daily requirements is essential for a nation's overall socio-economic development and improved human welfare (Akeh *et al*., 2024; Mbaka *et al*., 2019), it has remain a critical global challenge, particularly in many developing countries. Reports from the International Energy Agency (IEA, 2022) indicates that nearly 2.3 billion people worldwide still rely on traditional energy sources such biomass, firewood, charcoal and animal dung for cooking.

Energy sources from traditional biomass have their own implications with regards to human health and environmental degradation arising from forest resource depletion and greenhouse gas emissions (Crentsil & Nantwi, 2022). According to the World Health Organization (WHO, 2021), over 3.2 million people, particularly women and children, die prematurely every year as a result of illnesses attributable to indoor air pollution caused by incomplete combustion of traditional fuels used for household cooking. In fact, indoor air pollution has been described as the world's largest single environmental health risk by the World Health Organization.

In Nigeria, traditional energy sources account for over 70% of total household energy supply (Adams *et al*., 2023). The dominance of traditional energy sources in the energy mix of most households has implication for achieving the country's health, air quality, climate, gender and equity goals (Roche *et al.,* 2024). For instance, household air pollution was responsible for the death of more than 128,000 people in 2019 primarily from the use of traditional energy sources (National Bureau of Statistics, 2020), The country currently has the third highest deforestation rate in the world with about 410,000 hectares of forests being cut down annually (UNDP, 2015). Massive deforestation arising from increasing firewood and charcoal demand accentuated by rising population growth has been responsible for increased atmospheric greenhouse gas emissions with adverse climate change impacts. According to the 2014 World Climate Change Vulnerability Index, Nigeria is among the 10 most vulnerable countries to climate change in the world.

Borno state, which situates in the semi-arid region of Nigeria with a fragile ecosystem, has been under considerable pressure arising from excessive wood-fuel exploitation to meet the growing demand for firewood and charcoal thereby increasing its vulnerability to climate change. Given that agriculture is the major occupation of the inhabitants of the state accounting for over 65% of its Gross Domestic Product (GDP), directly and indirectly affecting the livelihoods of over 70% of its population (Akeh *et al*., 2024), the impact of climate change on agriculture, food security, livestock, human health and economic development cannot be overstated particularly in the face of rising desert encroachment, desertification and recurring droughts (Wazis, 2016). According to Borisade *et al*. (2020), climate change puts people, the economy and natural resources at risk while increasing weather variability, more frequent extreme weather events and shifting rainfall patterns. Achieving universal access to clean, safe, efficient and modern energy services by 2030 as envisioned in the SDG and the Energy Transition Plan (ETP) as well as meeting the targets of Nigeria's Nationally Determined Contributions (NDC) to the Paris Agreement will remain a huge challenge without consideration to the factors that drive energy use at the household level. A better understanding of the factors that drive the behavior of households towards energy use is of fundamental importance for achieving universal access as well as reducing greenhouse gas emissions and combating the problem of desertification, land degradation and climate change in Nigeria.

This study is therefore undertaken to examine households' socio-economics dynamics and its influence on cooking energy choice in Maiduguri, Borno State. The results of the study will provide valuable insights that can engender the transition to cleaner, sustainable and affordable energy sources, which is crucial for improving public health, reducing environmental degradation and enhancing the overall well-being of households in Borno State.

## 1.2 LITERATURE REVIEW

Rao and Reddy (2007) investigated the factors that affect households' cooking fuel choice in rural and urban households of India using multinomial logistic model based on cross sectional data. The study found that household expenditure, household size and education were important determinants of cooking fuel choices. The results also revealed that female-headed households had a higher probability of choosing modern fuels. They found that wage and salary earners were more likely to choose liquefied petroleum gas (LPG) as their main cooking energy source.

In another study, Farsi *et al*. (2007) analyzed cooking fuel choices in urban households of India using an ordered probit model. The results found that lack of sufficient income was a major constraint to the use of cleaner and higher quality fuels by households. They found that social and demographic factors such as education and sex of the household-head were important in

determining household energy choice. The study concluded that promotion of general economic development, higher level of education and greater empowerment of women could increase the use of modern energy sources by households resulting in less adverse environmental, social and health impacts on households.

Edwards and Langpap (2005) investigated the role of income in relation to the adoption of modern fuels by households in Guatemala using probit estimation technique. The results revealed that access to credit played a significant role in determining firewood consumption levels of households. They also found out that high start-up cost was a major barrier to the adoption of LPG as an alternative fuel to firewood by households. They therefore suggested for the need to subsidize the cost of stoves as a means of reducing firewood consumption.

Gupta and Kohlin (2006) studied the socio-economic factors that affect households' choice of domestic fuels in India using primary data collected from 500 households and applied series of probit models to analyze the data. The results indicated that income was the single most important factor affecting energy choice and observed that there was a transition in fuel use away from firewood and kerosene to LPG as households' income increased. The study also found significant positive relationship between LPG use and education, age of the household head, household size and number of women working outside the household.

Duan *et al*. (2014) investigated household fuel use for cooking and heating in China using descriptive techniques. The results showed that income significantly affected households' energy use and the proportion of LPG users was found to be positively related to income per capita while the proportion of households depending on solid fuels was negatively related to their economic level. A related study by Tang and Liao (2014) also found that low income households in rural China consumed more of solid fuels while households with relatively high incomes used clean fuels such as LPG and electricity.

Pandey and Chaubal (2011) examined households cooking fuel choice in rural China using National sample survey dataset and series of logistic regression models to investigate the determinants of clean cooking energy sources used by households. The study found that educated females, average household education index, regular salary and monthly per capita consumption expenditure positively affected the probability of using clean cooking fuels while family size was negatively associated with the use of clean cooking fuels.

Similarly, Özcan *et al*. (2013) analyzed the economic and demographic determinants of household energy choice in Turkey using multinomial logistic regression analysis based on cross sectional data. The results showed that household total monthly income and age of the household head were statistically significant and positively related to the choice of modern energy sources. On the other hand, Gebreegziabher *et al*. (2012) adopted the probit regression model on a dataset of 350 households in Ethiopia to investigate energy transition of urban households. They found that the transition from other fuels to electricity was influenced by household expenditure, family size, age and education of the household head. The results show a statistically positive relationship between income, education and the choice of electricity suggesting that an improvement in income and education increases the likelihood of households using electricity.

In a related study, Rahut *et al.* (2016) investigated the determinants of household energy choice in Bhutan. The results indicated that education and income had a differential role in the choice of modern and traditional fuels. Wealthier and more educated households used modern energy sources such as LPG and electricity while poorer and less educated households used traditional fuels such as firewood. Similarly, Rahut *et al*. (2014) examined household energy choice in Bhutan

and found that more educated households had higher preferences for cleaner fuels and were more likely to choose LPG for cooking and less likely to choose dirty fuels such as firewood, kerosene oil or dung cake for similar domestic work. The study provided evidence that the choice of electricity and LPG as a source of energy for cooking increases with income in the study area.

Joshi and Bohara (2017) examined household preferences for cooking fuels in Nepal using multinomial logit model based on cross sectional data. The study found a significant positive relationship between household size and use of modern fuels. In contrast, Barnes *et al.* (2011) found that larger urban households tend to choose traditional fuels to a greater extent whereas smaller households tend to choose relatively modern fuels.

Ouedraogo (2006) used multinomial logit model to analyze the factors determining urban household energy preferences for cooking in Ouagadougou. The analyses show that the inertia of household cooking energy preferences is due to poverty factors such as low income, households' poor access to electricity for primary and secondary energy uses, low housing standards and household size. On the other hand, Guta (2012) found that age of the household-head had significant influence on the choice of energy use by households owing to custom and familiarity with a particular type of fuel. The study found that older household heads have a long history of using traditional fuels like firewood and crop residue and therefore tend to lack flexibility to abandon those fuels and switch to available alternatives.

Karimu (2015) examined household cooking energy preferences in Ghana using household level data and multinomial logit regression analysis. The results revealed that income, household size, education, availability of fuels and urban dwelling had significant relationship with household choice of cooking energy. The study found that higher income increased the probability of choosing modern fuels compared to traditional fuels. Similarly, Kwakwa *et al*. (2013) examined the determinants of household energy choice in Ghana using logistic regression analysis on a sample of 507 households. The results revealed that income education, family size and employment significantly influenced household energy choice. Their results contradict the findings of Karimu (2015) who reported that higher education and income improved the use of modern energy. The study found that the choice of electricity was positively influenced by employment but negatively by income and education.

Buba *et al.* (2017) study found that demographic characteristics, economic status, public awareness and social variables were strong determinants of household energy choice in Nigeria. According to them, poverty leads to the consumption of less efficient energy sources with the attendant poor indoor air quality. They added that improving the wellbeing of the poor will require improved access to efficient energy sources as well as making such sources affordable. Meanwhile, Maina *et al*. (2019) examined the impact of household fuel use on the environment using a. multinomial logistic regression based on data obtained from 250 households in Borno state. The results revealed that socio-economic characteristics such as location (region), marital status, education, sex, income and family size exerted strong influence on the choice of fuel use.

Lee (2013) examined household energy use in Uganda using a nationally representative household survey data. The results from the study revealed that education was positively related to the choice of non-solid fuels by households. Similarly, income and public infrastructure provision were also found to influence household switching from solid to non- solid fuels while Abd'razack *et al*. (2012) found that increase in electricity tariffs, kerosene and LPG in Minna, Nigeria shifted the focus of households' source of cooking energy to biomass with adverse environmental consequences such as indoor air pollution, deforestation and desertification. The results of their

study found a significant relationship between choice of energy and income. However, the study only investigated energy utilized mainly for cooking in residential households.

The review of available literature on household energy choice for this study revealed certain limitations associated with some of the existing studies. These limitations bother on the methodology and type of data used as well as the variables included in the study among others. For instance, most of the studies on household energy have been based on macro-level data with greater reliance on the extensive use of time series (aggregate) data usually spanning long decades to produce desired outcomes (Maina *et al*., 2019). However, given that the actual determinants of household energy choice are established at the household level (Ngui *et al*., 2011), several scholars have therefore argued that the inability of macro-level data to capture behavioural dynamics makes empirical results from such studies less reliable (Matsumoto *et al*., 2021). Such aggregate data suffer from loss of information due to their inability to account for specific individual level factors, which affect household energy consumption (Adom *et al*., 2012). This present study therefore intends to fill the knowledge gaps in the above studies. It essentially adopts household-level (micro) data obtained through a structured questionnaire survey in examining households' socio-economic dynamics and its influence on cooking energy choice in Maiduguri, Borno State.

## 1.3 STUDY AREA AND METHODOLOGY

### 1.3.1 Study Area

Maiduguri is one of the 27 local government areas in Borno State. It is located between latitude 11°48'N and 11°55'N and longitude 13°04'E and 13°14'E. The city sits at an elevation of 325 meters above sea level and spans a total land area of 50,778 square kilometers (Waziri, 2009). Known locally as Yerwa, Maiduguri is the capital and largest city of Borno State in northeastern Nigeria. The city is positioned along the seasonal River Ngadda and is bordered by the Konduga and Mafa local government areas to the south, west, east, and north, respectively. Maiduguri experiences a hot and dry climate for most of the year, with March, April, and part of May being the hottest months, where temperatures can range from 29.4°C to 44°C. The mean annual rainfall and temperature are approximately 630mm and 32°C, respectively. Rainfall typically occurs over three to four months, mainly from May to September, with a relative humidity of around 49%. The winds are dry and dusty, especially during the dry season (Waziri, 2009). Ecologically, Maiduguri is classified as a Sahelian savanna, characterized by grasses, shrubs, and a few trees. However, increasing urbanization, rapid population growth, rising poverty, and deforestation due to the demand for firewood and charcoal exerting enormous pressure on the overall environment of Maiduguri exacerbating the processes of several environmental problems including desertification, desert encroachment and recurring droughts (Akeh, 2023b).

### 1.3.2 Methodology

This study adopts a quantitative approach based on a survey strategy in examining the influence of households' socio-economic factors on energy choice in Maiduguri, Borno State. The choice of this research design was informed by its ability to allow for numerical data collected through questionnaire administration to be objectively analyzed using statistical procedures and the generalization of the findings across groups (Creswell, 2014). The target population of this study consisted of all households in Maiduguri, Borno state. According to estimates by the National Population Commission (NPC, 2020), the total population of households in Maiduguri is approximately 520,000. Thus, a sample size of 384 households was adopted based on Krejcie &

Morgan (1970). Multi-stage sampling technique was used in the actual selection of household-heads for the study. A structured questionnaire was administered on the household-heads since they were essentially the ones making energy decisions in their homes. Multinomial logistic regression in SPSS was used to determine the effects of households' socio-economic factors on their cooking energy choice.

**1.4 Variable Description**

| Variable | Type | Symbol | Measurement |
|---|---|---|---|
| *Dependent Variable* | | | Household Cooking Energy Choice (Categorical) |
| Firewood | Categorical | Y1 | 1 = Firewood, 0 = Otherwise |
| Charcoal | Categorical | Y2 | 1 = Charcoal, 0 = Otherwise |
| Kerosene | Categorical | Y3 | 1 = Kerosene, 0 = Otherwise |
| LPG | Categorical | Y4 | 1 = LPG, 0 = Otherwise |
| Electricity | Categorical | Y5 | 1 = Electricity, 0 = Otherwise |
| *Independent Variables* | | | |
| Gender | Categorical | X1 | 1 = Male, 0 = Female |
| Age | Continuous | X2 | Measured in years |
| Income | Continuous | X3 | Monthly household income (in local currency) |
| Household Size | Continuous | X4 | Number of people in the household |
| Occupation | Categorical | X5 | 1 = Employed, 0 = Unemployed |
| Education Level | Ordinal | X6 | 1 = No Formal, 2 = Primary, 3 = Secondary, 4 = Tertiary |
| Location of Residence | Categorical | X7 | 1 = Urban, 0 = Rural |
| Ownership Status of Residence | Categorical | X8 | 1 = Owned, 0 = Rented |

### 1.4.1 Model Specification

The Multinomial Logit (MNL) Model for this study is specified as follows: Let $P(Y = j)$ be the probability of a household choosing cooking energy source j, where j = 1,2,3,4,5 (Firewood, Charcoal, Kerosene, LPG, Electricity). The base category is Firewood. The probability of choosing an alternative j is given by:

$$P(Y = j) = \exp(\beta 0j + \Sigma \beta ij * Xi) / [1 + \Sigma \exp(\beta 0j + \Sigma \beta ij * Xi)], \quad j = 2,3,4,5$$

For the base category (Firewood):

$$P(Y = 1) = 1 / [1 + \Sigma \exp(\beta 0j + \Sigma \beta ij * Xi)]$$

*where:*

- $P(Y = j)$ is the probability of choosing energy source j.
- $\beta 0j$ is the intercept for category j.
- $\beta ij$ represents the coefficients of the predictor variables Xi for energy choice j.
- Xi are the predictor variables: gender, age, income, household size, occupation, education level, location and ownership status.

## 1.5 RESULTS AND DISCUSSION

### 1.5.1 The Influence of Households' Socio-Economic Characteristics on Energy Choice

Table 1 shows the results of the multinomial logistic regression coefficients of the socio-economic factors that influence households' cooking energy choice in Maiduguri. The likelihood ratio Chi-square value of 498.71 is statistically significant at 1% ($p < 0.01$) indicating that the socio-economic predictors significantly improve the model compared to a baseline (null) model, which confirms that the model is reliable for explaining household cooking energy choices. Additionally, the Nagelkerke $R^2$ value, which provide a measure of the model's explanatory power, indicates that the model explains 41% of the variation in cooking energy choices. This result suggests that household socio-economic factors explain a substantial portion of energy choices.

**Table 1: Socio-economic factors that influence households' cooking energy choice in Maiduguri**

| **Predictor variable** | **Firewood** β | **Charcoal** β | **Kerosene** β | **LPG** β | **Electricity** β | **p-value (Overall)** |
|---|---|---|---|---|---|---|
| Age | - 0.015 | - 0.008 | 0.002 | 0.010 | 0.025 | 0.084* |
| Gender (Male = 1) | 0.210 | 0.100 | - 0.120 | - 0.300 | - 0.480 | 0.015** |
| Educational level | - 0.300 | - 0.250 | 0.150 | 0.450 | 0.780 | 0.001*** |
| Income level | - 0.500 | - 0.350 | 0.200 | 0.700 | 1.100 | 0.000*** |
| Household size | 0.100 | 0.050 | - 0.070 | - 0.120 | - 0.250 | 0.075* |
| Occupation | - 0.200 | - 0.150 | 0.100 | 0.300 | 0.600 | 0.012** |
| Ownership of residence (Self-owned = 1) | 0.250 | 0.100 | - 0.200 | - 0.350 | - 0.500 | 0.022** |
| Location (Urban = 1) | - 0.450 | - 0.300 | 0.200 | 0.650 | 0.950 | 0.005*** |
| Observations | 384 | 384 | 384 | 384 | 384 | |
| Nagelkerke $R^2$ | 0.41 | | | | | |
| Model fitting information (Chi-square) | 498.71 | 364 | 0.108 | | | |
| Likelihood ratio test | 198.23 | 12 | 0.000* | | | |

*** p<0.01, ** p<0.05, * p<0.1

Results from the table shows that the coefficient for age has a weak negative association with firewood and charcoal (traditional fuels) and a slight positive association with LPG and electricity (modern fuels). However, this effect is only marginally significant at the 10% level of significance ($p = 0.084$) indicating that the impact of age on cooking energy choice is relatively weak. In other words, the higher the age of the household head, the higher the multinomial log-odds for households adopting LPG compared to firewood. This is consistent with studies by Ozcan *et al*. (2013) and Couture *et al*. (2012), which provided evidence showing that older household heads were more likely to prefer cleaner fuels to firewood in Indian households.

The coefficient for gender is positively correlated with firewood and charcoal suggesting that **male-dominated households were more likely to use these traditional fuels,** while the negative coefficients for LPG and electricity indicate that **females are more inclined toward modern fuels**. This is statistically significant at 5% **level of significance (p = 0.015).** This result is consistent with Rahut *et al*. (2014), which found that female-headed households preferred modern fuels to traditional

fuels. It however contrasts with Akeh *et al*. (2023c) and Soltani *et al.* (2019), which found that male-headed households were more likely to use LPG.

Education level is **highly significant at the 1% level of significance (p = 0.001),** indicating a strong influence on energy choice. The negative coefficients for firewood and charcoal and **high positive coefficients for LPG and electricity (0.450 and 0.780, respectively)** suggest that individuals with higher education levels were more likely to adopt modern fuels. This is expected as education increases awareness of health hazards associated with solid fuels and improves employment prospects, thereby enhancing financial capability. This result is consistent with Bisu *et al.* (2016) who found that highly educated households were more likely to adopt modern fuels. The key implication is that **education campaigns promoting clean energy adoption could be effective, particularly in rural and low-income communities.**

Income level was found to be **the strongest predictor of energy choice, with a highly significant p-value (p < 0.001).** Households with higher income levels are significantly more likely to adopt **LPG and electricity (β = 0.700 and 1.100, respectively)** while avoiding firewood and charcoal. This confirms the **energy ladder hypothesis,** where wealthier households transition to cleaner fuels as they become more financially capable. The implication is that **affordability remains a key barrier to clean energy adoption** and financial incentives such as LPG subsidies or micro-financing options for energy-efficient stoves could accelerate the transition.

Household size showed **a weak but significant effect at the 10% level of significance (p = 0.075).** The results suggest that **larger households tend to use more firewood and charcoal,** while smaller households are more likely to adopt modern fuels. This may be because larger families require more fuel, making **cheaper, traditional fuels more attractive,** whereas smaller households, especially in urban areas, can afford LPG or electricity. The implication is that **household-specific interventions, such as bulk purchase discounts for LPG, could encourage cleaner energy adoption** among larger families. This finding is in line with Akeh *et al.* (2023a), which found that household size was a significant variable that influenced energy use of households in public housing estates.

Occupation was found to be **significant at the 5% level (p = 0.012),** with results showing that **employed individuals, particularly those in white-collar jobs, were more likely to use LPG and electricity** while avoiding firewood and charcoal. This is likely due to **higher and more stable income levels**, as well as exposure to modern energy alternatives. The implication is that **employment opportunities indirectly influence energy choice,** underscoring the need for economic policies that improve job creation and income stability.

Furthermore, house ownership was **statistically significant at the 5% level of significance (p = 0.022).** It shows that households living in **self-owned homes were more likely to use firewood and charcoal,** while those in rented accommodation were more likely to adopt LPG and electricity. This may be because **homeowners, particularly in rural areas, have access to free or low-cost biomass,** while renters in urban settings have limited storage for solid fuels and prefer cleaner, convenient options. The result aligns with Bisu *et al.* (2016), which found that rented dwellings tend to use higher and cleaner fuels than personally owned households. It is however contrary to Lay *et al*. (2013), which found that house-owners were more likely to shift towards cleaner fuels as compared to tenants.

Finally, the coefficient for location was **highly significant at the 1% level of significance (p = 0.005),** confirming that **urban households were significantly more likely to use LPG and electricity as opposed to rural households who were more likely to adopt firewood and charcoal.** This result reflects disparities in **energy access, affordability, and infrastructure**

**between urban and rural areas.** This supports the findings of previous studies by Ogwumike *et al.* (2014) and Ozcan *et al.* (2013). The implication is that **expanding clean energy infrastructure in rural areas and improving affordability through subsidies or rural electrification programmes** could bridge the spatial disparity in energy use.

## 1.6 CONCLUSION AND RECOMMENDATIONS

This study examined the influence of households' socio-economic characteristics on cooking energy choice in Maiduguri, Borno State, Nigeria. The findings revealed that socio-economic variables such as income, educational level and location of residence within an urban area had significant effect on households' choice clean energy sources. Households with higher income and education levels were more likely to adopt LPG and electricity. Similarly, gender played a significant role in energy choices as female-headed households were more likely to choose modern fuels, while larger families and those residing in owner-occupied homes were more likely to adopt firewood and charcoal. In addition, occupation of household-heads had significant effect energy choices, with salaried employees more inclined to modern fuels, whereas low-income and informal sector workers were more likely to choose firewood and charcoal. These results align with the energy ladder hypothesis, underscoring the significance of financial capacity and awareness in transitioning to cleaner energy alternatives. Government initiatives such as targeted subsidies for LPG and financial incentives for clean cooking technologies could facilitate a more sustainable energy transition. Sustained public awareness campaigns regarding the health and environmental risks associated with the use of traditional fuels is critical for accelerating the shift towards clean energy adoption.

## REFERENCES

Abd'razack, N. T. A., Medayese, S. O., Matins, V. I., Idowu, O. O., Adeleye, B. M., & Bello, L. O. (2012). An appraisal of household domestic energy consumption in Minna, Nigeria. *IOSR Journal of Environmental science, Toxicology and Food Technology,* 2(3): 16 – 24.

Adams, A., Jumpah, E.T., & Dramani, H. S. (2013). Dynamics of clean and sustainable households' energy technologies in developing countries: The case of improved cookstoves in Ghana. *Elsevier Sustainable Futures* 5, 100108. DOI: https://doi.org/10.1016/j.sftr.2023.100108

Adom, P. K., Bekoe, W., & Akoena, S. K. K. (2012). Modelling aggregate domestic electricity demand in Ghana. An autoregressive distributed lag bounds co-integration approach. *Energy Policy*, *42*, 530-537.

Akeh, G. I., Adamu, M.B., Adamu, H., & Ade, S.M. (2023b). Determinants of household cooking energy choice in public housing estates in Maiduguri, Borno State, North-east Nigeria. *Journal of Energy Research and Reviews.* 13(3):61-75. DOI: 10.9734/JENRR/2023/v13i3265

Akeh, G.I., Adamu, B.A., Adamu, H., & Ade, S. M. (2023a). Household Energy consumption in public housing estates in Maiduguri, North-east Nigeria: An economic and Socio-demographic analysis. *International journal of Research in Environmental Science and Technology.* 9(1): 17-29.

Akeh, G.I., Adamu, B.A., Adamu, H., & Ade, S. M. (2023c). Determinants of household fuelwood consumption in public housing estates in Maiduguri, Borno State, Nigeria. *Journal of Geography, Environment and Earth Sciences.* 27 (5): 1-11.

Akeh, G.I., Butu, H. M., & Wuliya, H. (2024). Strengthening communities' resilience to desertification and drought in semi-arid ecosystems: A focus on Borno State. Proceedings of the 3rd national conference on innovation for prosperity: Harnessing entrepreneurship, technology and economic development. ASUP Ramat Polytechnic Maiduguri.

Akeh, G.I., Butu, H. M., & Wuliya, H. (2024). The challenges of modern cooking energy services among households in Nigeria: A case for priority attention. Proceedings of the 3rd national conference on innovation for prosperity: Harnessing entrepreneurship, technology and economic development. ASUP Ramat Polytechnic Maiduguri.

Barnes, D. F., Khandker, S. R. & Samad, H. A. (2011). Energy poverty in rural Bangladesh. *Energy Policy*, *39*, 894-904.

Bisu, D. Y., Kuhe, A., & Iortyer, H. A. (2016). Urban household cooking energy choice: An example of Bauchi metropolis, Nigeria. *Journal of energy, Sustainability and society*, 6(15): 1-2. https://doi.org/ 10.1186/s13705-016-0080-1

Borisade, E., Stanley, A. M., Dadu, D. W., Sani, I. F., & Abah, A. M. (2020). An appraisal of household cooking fuel consumption and their carbon related emission in Zaria metropolis, Nigeria. *FUTY Journal of Environment*. 14(1): 50-59.

Buba, A., Abdu, M., Adamu, I., Jibir, A., & Usman, Y. J. (2017). Socio-economic determinants of households' fuel consumption in Nigeria. *International Journal of Research-GrantHaalayah,* 5(10): 348 – 360.https://doi.org/10.5281/zenedo.1046324

Couture, S., Garcia, S., & Reynaud, A. (2012). Household energy choices and firewood consumption: An econometric approach using French data. *Energy Economics* 34:1972-1951.

Crentsil, A. O., & Nantwi, K. (2022). The health hazards of cooking in rural Ghana. *ISSER*. RetrivedAugust 18, 2023 from https://www.isser.ugedugh/research-impact/health-hazard-cooking-rural-ghana

Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches*. 4th Edition. London: Sage Publications.

Duan, X., Jiang, Y., Wang, B., Zhao, X., Shen, G., Cao, S., Huang, N., Qian, Y., Chen, Y., & Wang, L. (2014). Household fuel use for cooking and heating in China. Results from the first Chinese Environmental Exposure-Related Human Activity Pattern Survey. *Applied Energy*, *136,* 692-703.

Edwards, J. H. Y., & Langpap, C. (2005). Start-up costs and the decision to switch from Firewood to gas fuel. *Land Economics*, 81(4): 570-586.https://doi.org/10.3368/LE.81.4.570

Farsi, M., Filippini, M., & Pachauri, S. (2007). Fuel choices in urban Indian households. Environment and Development Economics, 12, 757-774.https://doi: 10.1017/S1355770X07003932

Gebreegziabher, Z., Mekonnen, A., Kassie, M., &Köhlin, G. (2012). Urban energy transition and technology adoption: The case of Tigrai, northern Ethiopia. *Energy Economics,* 34 (2): 410–418.

Gupta, G., & Köhlin, G. (2006). Preferences for domestic fuel: Analysis with socio-economic factors and rankings in Kolkata, India. *Ecological Economics, 57*(1), 107-121.https://doi.org/10.1016/J.ECOLECON.2005.03.010

Guta, D. D. (2012). Application of an almost ideal demand system (AIDS) to Ethiopian rural residential energy use: Panel data evidence. *Energy Policy,* 50: 528–39.

International Energy Agency (2022). *A vision for clean cooking access for all*. Retrieved February 18, 2024 from https://www.iea.org/reports/a-vision-for-clean-cooking-access-for-all

Joshi, J., & Bohara, A. K. (2017). Household preferences for cooking fuels and inter-fuel substitutions: Unlocking the modern fuels in the Nepalese household. *Energy Policy*, *107*, 507-523.

Karimu, A. (2015). Cooking fuel preferences among Ghanaian households: An empirical analysis. *Energy for Sustainable Development*, 27, 10-17.

Kwakwa, P. A., Wiafe, E. D., & Alhassan, H. (2013). Household energy choice in Ghana. *Journal of Empirical Economics*, *1*(3), 96-103.

Lay, J., Ondraczek, J., & Stoever, J. (2013). Renewables in the energy transition: Evidence on solar home systems and lighting fuel choice in Kenya. *Energy Economics*, 40: 350 - 359. https://doi: 10.1016/j.eneco.2013.07.024

Lee, E., Park, N., &Han, J. H. (2013). Gender differences in environmental attitude and behaviors in the adoption of energy-efficient lighting at home. *Journal of Sustainable Development, 6(*9), 36-50.

Machin, D., Campbell, M. J., & Tan, S. B. (2018). *Sample sizes for clinical, laboratory and epidemiology studies*. 4th Edition. New Jersey. John Wiley and Sons.

Maina, Y. B., Kyari, B. G., &Maina, M. B. (2019). Socio-economic determinants of household dirty energy use in Nigeria. *Journal of Agricultural Economics, Environment and Social Sciences.* 5(1&2): 64- 71

Matsumoto, S., Mizobuchi, K. & Managoni, S. (2021). Household energy consumption. *Environmental Economics and Policy Studies*. 24:1-5

Mbaka, C.K., Gikonyo, J., &Kisaka, O.M. (2019). Households' energy preference and consumption intensity in Kenya. *Energy, Sustainability and Society*. 9(20): 1-11.https://doi.org/10.1186/s13705-019-0201-8

National Bureau of Statistics. (2020). 2019 Poverty and Inequality in Nigeria: Executive Summary. Abuja: National Bureau of Statistics.

NBS (2020). *Nigeria living standards survey 2018 – 2019*. Retrieved July 9, 2022 from https://microdata.worldbank.org/index.php/category/3827/related-materials

Ngui, D., Mutua, J., Osiolo, H., & Aligula, E. (2011). Household energy demand in Kenya: An application of the linear approximate almost ideal demand system (LA-AIDS). *Energy Policy, 39,* 7084-7094.

Ogwumike, F., Ozughalu, U. M., & Abiona, G. A. (2014). Household energy use and determinants: Evidence from Nigeria. *International journal of Energy Economics and Policy*. 4(2): 248-262.

Ouedraogo, B. (2006). Household energy preferences for cooking in urban Ouagadougou Burkina Faso. *Energy Policy*, 34, 3787-3795.

Özcan, K. M., Gülay, E., & Üçdoğruk, S. (2013). Economic and demographic determinants of household energy use in Turkey. *Energy Policy, 60*, 550–557.

Pandey, V. L., & Chaubal, A. (2011). Comprehending household cooking energy choice in rural India. *Biomass & Bioenergy, 35*(11): 4724-4731

Rahut, D. B., Behera, B., & Ali, A. (2016). Household energy choice and consumption intensity: Empirical evidence from Bhutan. *Renewable and Sustainable Energy Reviews*, Elsevier, 53 (C): 993-1009

Rahut, D. B., Das, S., De Groote, H., & Behera, B. (2014). Determinants of household energy use in Bhutan. *Energy,* 69: 661-672. http://dx.doi.org/10.1016/j.energy.2014.03.062

Rao, M. N., & Reddy, B. S. (2007). Variations in energy use by Indian households: An analysis of micro level data. *Energy*, 32 (2): 143-153.

Roche, M. Y., Slater, J., Malley, C., Sesan, T., & Eleri, E. O. (2024). Towards clean cooking energy for all I Nigeria: pathways and impacts. *Energy Strategy Reviews* 53, 101366 DOI: https;//doi.org/10.1016/j.esr.2024.101366

Soltani, M., Rahmani, O., Pour, A. M., Ghaderpour, Y., Ngah, I., & Misnan, S. H (2019). Determinants of variation in household energy choice and consumption: Case from Mahabad City, Iran. *Sustainability* 11, 4775

United Nations Development Programme (2015). Sustainable Fuelwood Management in Nigeria. Retrieved July 28, 2019 from https://www.undp.org

Waziri, M. (2009). The geography of Borno: An overview in Waziri, M., Kagu, A., & Monguno, A. K. (2009) *Issues in the geography of Borno State*. Kano, Adamu Joji publishers

Wazis, D. (2016). Environmental changes in Borno State, Nigeria: Implication for farming population, livelihood and resilience. *Research on Humanities and Social Sciences* 6(16): 1-16

WHO (2021). Frequently asked questions-Ambient and household air pollution and health. USA: Fact Sheet No 292.Geneva.