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## Article

# Determinants of households' energy consumption in Kebbi State Nigeria

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## DEVELOPMENT ECONOMICS | RESEARCH ARTICLE

# Determinants of households' energy consumption in Kebbi State Nigeria

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**Abstract:** This study aims to scrutinize the determinants of household energy consumption needs in Kebbi State, Nigeria. The data for the study were sourced from household heads within the study area. The paper analyzes the determinants of household energy consumption using six energy consumption indicators (household expenditure on energy, electricity, LPG, kerosene, charcoal, and biomass). To analyze the data, the study used descriptive statistics and binary logistic regression (which has rarely been used in this kind of study) which broaden our understanding of social, economic, and environmental perspectives on energy usage. Our empirical strategy indicates that all the instruments used are appropriate based on Cronbach's alpha scale value of greater than 0.9. Education level was found to be a significant factor in energy expenditure by household, electricity, LPG, and kerosene usage, while negatively correlated with biomass usage. A binary logit regression model revealed that household head income, availability of different energy choices, reliability, and affordability are the major determinants of household energy consumption needs. Findings further show that low-income household heads which account for more than 60% of the respondents rely heavily on the traditional methods of biomass to meet their energy needs. The finding further revealed that 72.80% of the respondents confirmed that accessibility is one of the driving forces which determines their energy choice. Based on the findings, the study therefore, recommends the need to ensure the availability and affordability of safer forms of energy as well as invest more in making renewable energy available and affordable.

**Subjects:** Development Studies; Sustainable Development; Energy Industries & Utilities

**Keywords:** energy consumption; households' energy consumption expenditure; logit regression model; Kebbi State Nigeria

**JEL Classification:** O13; P28; Q42; Q43; Q47

## 1. Introduction

Energy plays a significant role if not the most significant ingredient in the growth and development of any economy (Elfaki et al., 2021). Energy commodities aid economic development by accelerating productivity, income, and employment generation (Rapu et al., 2015). The importance of energy in market liberalization and globalisation of the world economy can be associated with

the 1990s economic development experiences, which lead to the betterment of the well-being of citizens, especially among developing economies. Availability and access to energy are prerequisites for any nation to attain industrialisation (Rapu et al., 2015).

Households in developing nations often choose from the available energy types at their disposal based on its availability and affordability, unlike their counterpart in the developed states with almost hundred percent electrification. They mostly choose solid fuels like biomass against liquid fuels like liquid petroleum gas. They are also left to decide whether to use electricity, LPG, kerosene, charcoal, or biomass based on their income and its availability. Equally, households are left to decide whether to electrify or not (Toole, 2015). The quantity and quality of energy consumed by the households are directly correlated with location, gender, economic, environmental, and health implications. Choosing whether to collect or purchase a particular type of fuel has an opportunity cost and it falls on female folks disproportionately, who are in most instances left with the responsibility of collecting the fuel (Heltberg, 2004). The process of fuel collection consumes most of their time which would have been used for other productive activities, like education or income-generating activities. Female folks in most instances bear adverse health consequences resulting from the household choice of fuel compared to their male counterpart (Heltberg, 2005).

Between 2010 and 2035, OPEC projected that the energy demand world over would increase by 52% (El-Badri, 2013). On the other hand, renewable energy sources would increase by more than 7% and account for less than 3% of the global energy needs by 2035. In addition, demand for biomass is expected to remain stable at about 9%, and nuclear energy is likely to remain a little below 6% within the period under review. However, the market is expected to be dominated by fossil fuels though with a decline contribution projected from 82% to 80% during the same period. Oil demand is expected to continue to dominate the major share of energy demand, which is forecasted to decline from 33% to 27% between 2010 and 2035, this can be attributed to nations' transition to climate-friendly energy sources. Coal demand is anticipated to drift around 27%, while natural gas contribution is projected to increase from 22% to 26% within the same period. Crude oil global refinery demand is expected to decline from 78 mb/d in Q1 of 2015 to 77.3 mb/d in the Q2 of the same period and is further expected to decline by 2035 (IEA, 2015).

It is a known fact that the usage and production of any form of energy have health and environmental impacts. Some recent studies by Ibrahim et al. (2021) and Ibrahim et al. (2022) have supported this claim. However, the extent and degree of energy use impact are what differ from one type to another. For instance, soil erosion, deforestation, and desertification are among the environmental threats posed by fuel wood usage. Fuel wood usage contributes to a large extent to the accumulation of CO<sub>2</sub> emissions, through the process of burning Dziubinski and Chipman (1999). In addition, cooking smoke from traditional biomass stoves causes huge health-threatening challenges to their users, especially women, and children. Furthermore, 90% more wood than necessary is burned through traditional biomass usage thereby costing poor families and institutions money that could be put to better use on health, education, and other basic needs (Eleri et al., 2012). The National Bureau of Statistics estimate of 2019 revealed about 67.5% of the total population of Kebbi State is poor. This poor population spent 4.3% of their expenditure on different energy sources (NBS, 2019).

Developing countries like Nigeria are faced with a lot of challenges in their quest for energy transition. Energy consumption by households in this regard has both environmental, health, economic, and social implications. Successive administrations have ruled out many strategies and programmes aimed at addressing some of these challenges among which are subsidies, financial incentives, distribution of modern cooking stoves, and rural electrification programmes with little success recorded (Heltberg, 2005; Kowsari & Zerriffi, 2011). However, in some of these nations, adequate access to sufficient and continuous energy supply is lacking for almost 90% of the population. Therefore, a large number of the population rely on traditional biomass as their main energy source (Barnes & Floor, 1996; Link et al., 2012).

In line with the energy ladder hypothesis, several studies have been carried out in states and regions of Nigeria aimed at informing policymakers on issues of energy and factors that determine household energy needs. However, most of such studies were not carried out in Kebbi State. Particularly, most of those studies were conducted within the metropolis of either a particular local government or state headquarters analyzing households' energy consumption pattern [see Ogunniyi et al. (2012)], the effect of households' socioeconomic characteristics on the choice of cooking fuel [see Baiyegunhi and Hassan (2014)], factors responsible for energy consumption by household [see Bamiro and Ogunjobi (2015)], urban household cooking energy choice [see Bisu et al. (2016)] and energy use patterns in residential areas [see Irimiya et al., 2013]. Another study by Wang and Zhang (2021) has provided a decoupling effect of renewable consumption on economic growth. However, from the foregoing literature, we observed that Kebbi state is faced with the threat of deforestation and yet a large number of the population relies on fuel wood as their main source of energy. Government efforts in dealing with the energy situation in the state have not yielded much, and this can be attributed to the low income of households and issues related to the availability of cleaner energy forms.

It is against this background that, this study aims to investigate the determinants of household energy consumption in Kebbi state, Nigeria. To this end, the study examines the socio-economic variables that determine household energy consumption in Kebbi state. The study was motivated based on the available literature which shows few empirical studies concerning energy usage that were carried out in the study area specifically. Finally, this paper is going to serve as an empirical guide for policymakers, non-governmental bodies, and stakeholders in Kebbi State toward the achievement of the SDG in the State.

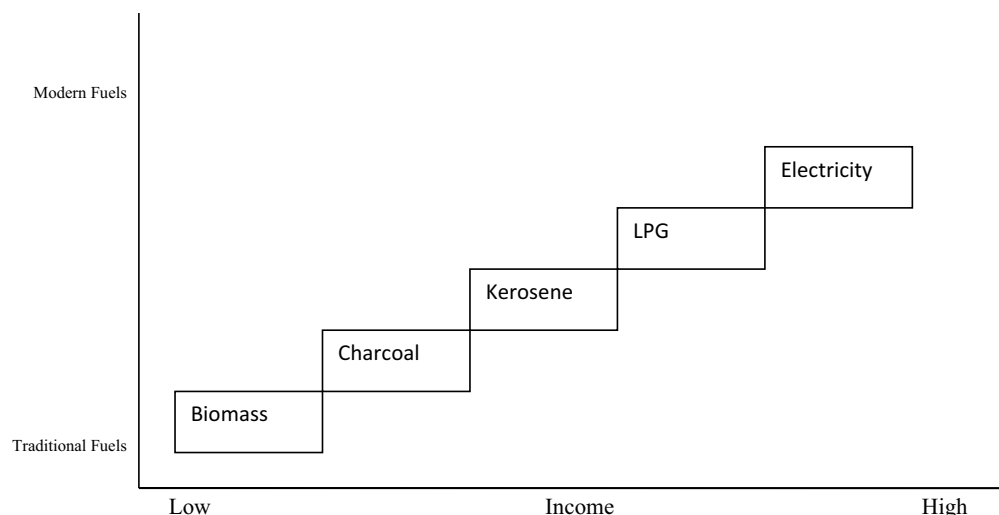
## 2. Theoretical framework

Discussion on the energy ladder began to take centre stage in the 70s and 80s with the perception of the fuelwood crisis (Kowsari & Zerriffi, 2011). Over time, studies reveal a hierarchy linking different forms of fuel with which a household aligns as a result of improvements in economic conditions. Kroon et al. (2013) establish a relationship between consumer theory and the energy ladder with the assumption that households act as utility-maximizing consumers. That is, as consumer experiences an increase in their income, they tend to purchase fewer inferior commodities and more of some other goods. Concerning the energy ladder, it implies that a rise in household income means the movement of household energy choice to the higher position within the ladder in ascending order. The hierarchical position of a fuel type is mostly associated with its cost vis-à-vis its efficiency and cleanliness (United Nations, & United Nations Development Programme, 2001). Several authors made a distinct classification of the ladder notably among them was UNDP's World Energy Assessment which describes the presence of three distinct ladders (Cooking, lighting, and Mechanical uses) (UN and UNDP, 2001). Kroon et al. (2013) also made three classifications (primitive, transition, and Advanced), Hosier and Dowd (1987) describe five ladders (gathered fuel wood, purchased fuel wood, transition fuels, kerosene, and electricity). In addition, Reddy (1995) presents six forms of energy on the ladder which are dung/waste, fuelwood, charcoal, kerosene, liquid petroleum gas (LPG), and electricity, respectively. This study will, however, adopt Reddy's classification but with modifications by incorporating dung/waste and fuel wood as biomass. Figure 1 is a diagrammatic showcase of the ladder.

Figure 1 shows the relationship between economic status measured as income and household choice of energy. It is also assumed that the ladder operates both at small and large scales. On a small scale, households are placed at either the higher hierarchy or the bottom of the ladder based on their income and development. Consequently, higher income levels mean cleaner and more efficient energy choices. Energy consumption increases with the overall growth and development of society as well as increased dependence on modern fuels at the macro level (Kroon et al., 2013). Therefore, the model establishes a hierarchy that is in ascending order and follows the characteristics of different fuel types at any level, like biomass, charcoal, kerosene, LPG, and electricity. Its merits and demerits are relative to absolute.

**Figure 1. Diagrammatic showcase of the energy ladder hypothesis.**

Source: Authors' computation.



At the bottom of the energy ladder hierarchy lies biomass. Simply put, it refers to any natural, flammable material. Fuelwood is perhaps the most known and used form of biomass, but grass, residues of crops, and animal dung equally form part of biomass (UN and UNDP, 2001). Dung usage shows the highest level of fuel poverty in the household and it is the least desirable among different classifications of biomass (UN and UNDP, 2001). While Fuelwood is described as the most efficient and desirable form of biomass, although not economic, but can simply be burned within an open fire. It is also regarded as a significant factor in tasty meals. Biomass and fuelwood users usually believe that its usage increases the taste and aroma of food more than other forms of fuel (Masera et al., 2000). Household biomass usage is usually due to its accessibility as well as less or no cost in some instances, especially in rural areas.

A step further on the ladder is Charcoal, a form of solid fuel derived from fuelwood through a process of transformation of a substance produced by the action of heat which leaves nearly pure carbon. Both charcoal and biomass share several health and environmental effects, they can also be produced at home, even though the process of heating fuelwood to produce charcoal leads to the emission of more carbon monoxide which exceeds that of biomass, which to a large extent increases carbon emission relative to wood (UN and UNDP, 2001). In terms of taste, charcoal is also believed to preserve the meal taste more than the modern fuel formed by its users (Nansaior et al., 2011).

Kerosene is at the centre of the ladder. It is extracted during the refinement of crude (Lam et al., 2012). Formally, kerosene is seen as the proportion of crude oil that boils when heated between 145 and 300°C (Lam et al., 2012). Compared to biomass and charcoal, kerosene is seen as more efficient and cleaner with less damaging impact on health and the environment. However, the duo is said to have less cost than kerosene, equally in terms of availability it differs from one location to another. Kroon et al. (2013) posited that households faced with uncertainty on supply or fear of price changes usually stock the product in large volumes, which low-income households cannot afford.

Just like kerosene, LPG is also extracted from crude oil. Its content includes butane, propane, or a combination of both. In terms of efficiency and cleanliness, LPG is by far better than the three forms of energy beneath it on the ladder. Specifically, less sulfur dioxide is released by LPG than the other three (UN and UNDP, 2001). The price and cost of the cylinders and other accessories required for LPG use further distance many households from venturing into its usage, especially households in rural settlements where availability alone is a predicament not to talk of their economic status. UN and UNDP (2001) believe that since LPG is derived from crude, and the

crude price is exogenously determined thereby making it vulnerable to price changes, its price can therefore be subjected to volatility.

At the top of the ladder lies electricity. Electricity is generated on either a large or small scale, the former is generated from sources like hydro, gas, coal, and nuclear, while the latter is from renewable energy like solar, wind, or a generator set among other sources (Ruijven et al., 2008). Electricity is the most efficient and clean form of energy of all the other forms on the ladder, socioeconomic well-being of a household in terms of safety and health is directly correlated with electricity usage. However, many communities are yet to be connected to the national grid, and even the connected face epileptic supply, the collapse of the grid, and exploitive charges especially households on postpaid that received estimated bills every month on the energy in most instances didn't consume. In addition, households may need to pay a certain exploitative fee before they get connected and such a prohibitive fee may limit access to some households (Arthur et al., 2010). Failure of the national grid or continuing blackouts hinder the benefits of access to electricity come with (Heltberg, 2005).

Kayode et al. (2015) Summarize some factors that determine household energy choices; endogenous factors (household characteristics that include economic, non-economic behavioural, and cultural characteristics). These characteristics are mostly affected by many factors which include income, expenditure, size of household, sex, age, education, lifestyle, social status, and ethnicity among others. So also, exogenous factors (external conditions) are factors like energy supply, physical environment policies, and energy device characteristics. In addition, factors like climatic conditions, market and trade policies, public policy, energy policy, ecological location, subsidies, affordability, availability, accessibility, and reliability of energy supplies. Others are the complexity of the operation, cost, and payment method among other factors.

### 3. Empirical literature

Wang et al. (2023) explore whether nuclear energy can promote economic growth without increasing carbon emissions. The second-generation panel unit root test, panel cointegration test, panel fully modified ordinary least squares, and Heterogeneous Dumitrescu and Hurlin causality test were employed. Findings based on panel data from 24 countries with nuclear energy from 2001 to 2020 show that both nuclear energy and renewable energy can curb carbon emissions. Interestingly in some countries, nuclear energy reduces carbon emissions more significantly than renewable energy. Increased oil consumption increases economic growth, and increases carbon emissions as well. Increased natural gas consumption boosts economic growth but adds less to carbon emissions. The study, therefore, recommends under the premise of safety, nuclear power should be seriously considered and re-developed. In the case of Atit (2022) used time-series and decomposition analysis in determining the forces responsible for energy changes covering the periods of the "Tom Yum Kung" crisis and COVID-19 pandemic. Findings from the study confirm that value addition in economic sectors leads to other factors requiring additional energy, while energy intensity is on the contrary. The study posits that more value-added production and improving energy efficiency will result in the decoupling of energy consumption concerning GDP and a more rapid climax demand for energy in the study area. Gollagari and Rena (2013) analyze energy consumption and economic growth in India using cointegration and vector error correction methods (VECM) between 1981 and 2010. Empirical findings reveal that both at aggregate and disaggregate levels causal relationship exists between gross domestic product and energy consumption. With increased energy efficiency, however, findings concluded that India is energy insecure as GDP and energy consumption are bidirectionally linked in aggregate. Ackah and Asomani (2015) in the analysis of renewable energy demand in Ghana with the aid of a general unrestricted model. Findings revealed that economic and non-economic factors affect renewable energy demand. Additionally, acceptability and affordability are low among the populace, and subsidies may encourage and stimulate demand. Wang, Li, et al. (2022) analyze the impact of population aging on the relationship between economic growth and carbon emissions, and the relationship between energy consumption and carbon emissions. Using panel data from 36 OECD



countries from 1996 to 2016, the panel threshold regression model was developed. The empirical results show that population aging is an important factor that affects the relationship between economic growth and carbon emissions, as well as energy consumption and carbon emissions.

Kayode et al. (2019) analyze household energy consumption in Nigeria. The ordinal logistic regression model revealed that the hierarchical nature of the energy ladder doesn't hold in the study area as there is no direct causality between the increase in income and energy consumption expenditure. So also, the empirical finding suggests that education is significant and higher levels of education have a greater probability of using modern fuels by households. The study concluded that there exists an abuse of electricity among the populace and recommended increasing awareness of the importance of energy savings among the population. Wang et al. (2019) uncover the effects of energy prices (EP), urbanization (URN), and GDP on per capita energy consumption (EC) with considering the income gaps between countries. The paper adopted the Granger causality test approach and the impulse response function analysis by using long-term time series data on EC, EP, URN, and GDP during 1980–2015 in 186 countries. The results indicated a long-term co-integration relationship among these variables. In low-middle and high-income countries, Granger causality test showed a bidirectional causality between urbanization and energy consumption. The study supports the finding that urbanization is an important factor affecting energy consumption per capita, although its contributions vary across income groups, which offers a new pathway to control the excessive growth of energy consumption. Gozgor et al. (2018) investigate the relationship between economic growth and energy consumption in 29 organizations of economic corporations and development (OECD) nations. The study employed panel quantile regression (PQR) as well as panel autoregressive distributed lag (ARDL). The study found that higher economic growth is positively correlated with both renewable and non-renewable energy consumption. The study enjoins all stakeholders in the energy sector to invest more in ensuring energy sufficiency with special attention on renewable energy. Dzioubinski and Chipman (1999) identify trends in energy consumption and production using ARD. Findings reveal that there exists a huge gap in energy consumption between developing and developed nations. In addition, developed nations are characterized by more efficient energy use and energy-based living standards which are major opposing trends that affect household energy consumption. Though the study opined that there are often contradictory governmental policies that persuade household energy consumption, the study concluded with mixed results as such government policies should not only be on paper but implemented to a logical conclusion.

Kurniawan and Managi (2018) assess the correlation between trade openness, coal consumption, and urbanization in Indonesia using ARDL. The study reaffirms that in the long run, all the variables are cointegrated with structural breaks presence. The findings also revealed that urbanization, economic growth, and trade openness are fundamental factors in coal consumption that amplify coal usage while decreasing the share of secondary industry reduce it. Thus, for its significance in the energy mix, Indonesia needs to reduce extreme coal consumption to augment environmental safety. Salahuddin and Gow (2019) assess the effects of energy consumption and economic growth on environmental quality in Qatar from 1980 to 2016 using the ARDL and the Toda-Yamamoto causality test. Results reveal a negative long-run effect of energy consumption on all three indicators of environmental quality. Bidirectional causality also exists among all three variables. Wang, et al. (2022b) analyze the impact of urbanization on the coupling of economic growth and environmental quality by expanding the traditional environmental Kuznets curve (EKC) theory by adding social indicators. Using panel data from 134 countries from 1996 to 2015, the threshold regression model was used to investigate the non-linear causality between the variables. The results revealed urbanization strengthens the positive correlation between the economy and carbon emissions and ecological footprint. The paper concluded that; there is a non-linear relationship between economic growth and environmental quality. An empirical analysis by Ogunniyi et al. (2012) using an almost ideal demand system (AIDS) model analyzed households' energy consumption patterns in Ogbomoso Metropolis, Nigeria. The study reveals that because of its accessibility, kerosene is the most highly consumed and preferred form of energy in the study area. In



another study, Baiyegunhi and Hassan (2014) analyzed the effect of households' socioeconomic characteristics on the choice of cooking fuel in the Giwa local Government in Nigeria using the multinomial logit (MNL) model as an empirical tool. Findings conform with, the "energy stacking" theory as two or more forms of fuels are often used alongside each other. However, fuel wood is largely the most used and preferred form of cooking energy the study posited. Bamiro and Ogunjobi (2015) investigate factors responsible for energy consumption by household in Ogun State, Nigeria, and observed that prices of wood and kerosene, and family size are major factors that significantly and positively drive the preference for fuels. Additionally, the finding revealed that households' monthly energy expenditure is dependent on different forms of fuel available.

Irimiya et al. (2013) examined energy use patterns in residential areas of Kano and Kaduna States, Nigeria, by comparing their energy consumption pattern. An analysis of variance (ANOVA) was conducted at 0.05% which indicates a significant difference in the energy consumption between the conventional and green features in the six study areas. Horst and Hovorka (2008) examined the energy ladder for household energy use and establish that households do not follow the predictions of the model. This implies that household doesn't simply change from one form of fuel to another with a change in their income. Also, the study posits that households use multiple energy sources as they are not entirely inter—substitutable. The authors concluded that fuel wood choice by households across income levels lends to its strategic significance as an energy source for particular applications. Wang, et al. (2022a) study the influence mechanism of renewable energy and economic growth from the two dimensions of natural resources and institutional environment. Resource dependence and anticorruption regulations are mainly selected as the intermediary variables. The hypothesis is tested by using the panel data (from 2002 to 2018) of 104 selected countries and regions. The results show that resource dependence and anticorruption regulations are important intermediary factors affecting both renewable energy and the economy.

Kwakwa et al. (2013) examined households' fuel choices in Ghana and found that fuels are used for cooking, warming the house, heating water, lighting, ironing, entertainment, cooling the house, and washing amidst some associated challenges. The top three energy types were electricity, charcoal, and firewood. A logit regression model revealed that the factors accounting for energy choice included income, education, family size, and employment. Bisu et al. (2016) Urban household cooking energy choice: an example of Bauchi metropolis, Nigeria. Determined the cooking energy consumption pattern of the household and factors that influence cooking energy choice. Two-step random sampling was used along with a semi-structured questionnaire to collect data. Descriptive statistics, T-test, and regression analyses were also used. The results show that biomass fuel is still being used heavily, while the use of LPG has improved. Electricity and solar energy are only used by households as secondary cooking energy. The fuel use patterns are characterized by multiple fuel use, conforming more to the fuel stacking hypothesis than the energy ladder hypothesis. Changes in household size, dwelling ownership status, change of season, income, level of education, dwelling location, availability, and affordability are the factors that were found to influence household cooking energy choice. The study concludes that the heavy use of biomass for cooking in the Bauchi metropolis is not environmentally healthy and requires serious attention recommended encouraging the availability and use of efficient and environmentally friendly energy sources should be formulated and implemented. Okwanya et al. (2020) examine the effects of policy incentives and cost on the choice and use of renewable energy in North-Central Nigeria. The study uses descriptive statistics and multinomial logistic regression to analyze the data. Findings revealed that there is a huge potential demand for renewable energy sources (particularly solar photovoltaic) in rural communities in Nigeria. It also indicates a positive and highly significant relationship between the level of awareness, availability, income, and the use (consumption) of renewable energy sources among rural communities. Concluded that the cost of installation, maintenance, reliability, and availability are significant determinants of renewable energy choices among rural inhabitants in Nigeria.

## 4. Methodology

### 4.1. Sampling and data sources

Located in northwestern Nigeria, Kebbi state is bordered to the east by Sokoto, Zamfara by the north, and Niger state to the south, while national borders are in its west sharing a border with the Benin and Niger Republic. Formed on 27 August, with Birnin Kebbi as the state's capital. Kebbi is the 22<sup>nd</sup> most populous out of the 36 states in Nigeria, with an estimated population of about 4.4 million as of 2016 and the 10th largest in terms of area (NBS, 2019). Primary data were obtained from 386 household heads via the use of a stratified random sampling technique, while each local government serves as a stratum. Data was obtained from the head of households with the aid of a well-structured questionnaire. The data collected include: the socioeconomic characteristics of household heads, energy supply factors, and preferences of fuel choices. The option of a questionnaire avail the study the opportunity to interact and obtain first-hand information from household heads concerning their energy needs and usage.

### 4.2. Analytical technique

The study used descriptive statistics to analyze the socioeconomic characteristics of household heads and energy supply factors, while binary logistic regression models were applied to analyze determinants of household energy usage and the determinants of household energy consumption expenditure, respectively. The novelty of the binary logistic regression model in this study is its ability to allow dependent variables to take the form of either one or zero while allowing independent variables to be both continuous and discrete. The study further incorporates six different binary logistic models and their analyses were carried out for all the different forms of fuel as depicted in the energy ladder model in Figure 1. Thus, the logit model by Gujarati (2004) is expressed as;

$$P = E\left(Y = \frac{1}{X_i}\right) = \frac{1}{1 + e^{-(\beta_1 + \beta_2 X_i)}} \quad (1)$$

For ease of expression if  $z = \beta_1 + \beta_2 X_i$

$$P = \frac{1}{1 + e^{-zi}} = \frac{e^z}{1 + e^z} \quad (2)$$

If  $P$  stands for the probability of occurrence (say energy-type usage as a result of affordability), the probability of not occurrence can be expressed as:

$$1 - P = \frac{1}{1 + e^{-zi}} \quad (3)$$

Thus, the odds ratio between the two probabilities can be expressed as;

$$\frac{P}{1 - P_1} = \frac{1 + 1 + e^{-zi}}{1 + e^{-zi}} = e^{zi} \quad (4)$$

Where;  $P_1/(1 - P_1)$  represents the odds ratio of the reason behind the usage of a particular energy type. Meaning, the ratio of the probability that a household uses a particular energy type because of that reason to the probability of otherwise. Taking the natural log of Equation (4) we get the following expression as thus;

$$L_i = \ln\left(\frac{P_i}{1 - P_i}\right) = Z = \beta_1 + \beta_2 X_i \quad (5)$$

Where;  $L$  means the log of odd ratio, Equation (5) represents what is known as the logistic model which is used when the dependent variable takes a binary value of 0 or 1.

Drawing from these the model is rewritten as;

$$\ln\left(\frac{F_{\text{conspExponEnrgyi}}}{1 - F_{\text{conspExponEnrgyi}}}\right) = \beta_0 + \beta_1 \text{gender}_i + \beta_2 \text{income}_i + \beta_3 \text{education}_i + \beta_4 \text{household location}_i + \beta_5 \text{monthly expenses}_i + \beta_6 \text{marital status}_i + e_t \quad (6)$$

Where;  $\ln\left(\frac{F_{\text{conspExponEnrgyi}}}{1 - F_{\text{conspExponEnrgyi}}}\right)$  stands for the probability of household consumption expenditure on one type of energy or another.  $\beta_0, \beta_1, \beta_2, \dots, \beta_6$  are the constant and coefficients for gender, income, education (disaggregated into secondary and post-secondary, respectively), household location, monthly expenses, and marital status respectively, while  $e_t$  is the error term.

$$\ln\left(\frac{F_{\text{ELECTRICI}}}{1 - F_{\text{ELECTRICI}}}\right) = \beta_0 + \beta_1 \text{marital status}_i + \beta_2 \text{age}_i + \beta_3 \text{income}_i + \beta_4 \text{household location}_i + \beta_5 \text{education}_i + \beta_6 \text{family size}_i + \beta_7 \text{price of electricity deflated}_i + e_t \quad (7)$$

Where;  $\ln\left(\frac{F_{\text{ELECTRICI}}}{1 - F_{\text{ELECTRICI}}}\right)$  stands for the probability of a household consuming electricity as a source of energy or not  $\beta_0, \beta_1, \beta_2, \dots, \beta_5$  are the constants and coefficients for marital status, age, income, household location, education (disaggregated into secondary and post-secondary, respectively), family size, and price of electricity deflated, respectively, while  $e_t$  is the error term.

$$\ln\left(\frac{F_{\text{LPGI}}}{1 - F_{\text{LPGI}}}\right) = \beta_0 + \beta_1 \text{gender}_i + \beta_2 \text{age}_i + \beta_3 \text{income}_i + \beta_4 \text{education}_i + \beta_5 \text{family size}_i + \beta_6 \text{price of lpg deflated}_i + e_t \quad (8)$$

Where;  $\ln\left(\frac{F_{\text{LPGI}}}{1 - F_{\text{LPGI}}}\right)$  stands for the probability of households consuming liquefied petroleum gas (LPG) as a source of household energy or not.  $\beta_0, \beta_1, \beta_2, \dots, \beta_6$  are the constant and coefficients for gender, age, income, education (disaggregated into secondary and post-secondary, respectively), family size, and price of LPG deflated, respectively, while  $e_t$  is the error term.

$$\ln\left(\frac{F_{\text{KEROI}}}{1 - F_{\text{KEROI}}}\right) = \beta_0 + \beta_1 \text{gender}_i + \beta_2 \text{age}_i + \beta_3 \text{marital status}_i + \beta_4 \text{income}_i + \beta_5 \text{education}_i + \beta_6 \text{family size}_i + \beta_7 \text{household location}_i + \beta_8 \text{price of kerosene deflated}_i + e_t \quad (9)$$

Where;  $\ln\left(\frac{F_{\text{KEROI}}}{1 - F_{\text{KEROI}}}\right)$  represent the probability of a household consuming kerosene as a means of household energy or not.  $\beta_0, \beta_1, \beta_2, \dots, \beta_6$  are the constant and coefficients for gender, age, marital status, income, education (disaggregated into secondary and post-secondary, respectively), family size, household location, and price of kerosene deflated, respectively, while  $e_t$  is the error term.

$$\ln\left(\frac{F_{\text{CHARCOALI}}}{1 - F_{\text{CHARCOALI}}}\right) = \beta_0 + \beta_1 \text{age}_i + \beta_2 \text{family size}_i + \beta_3 \text{education}_i + \beta_4 \text{income}_i + \beta_5 \text{secondary edu}_i + \beta_6 \text{post secondary education}_i + \beta_7 \text{price of charcoal deflated}_i + e_t \quad (10)$$

Where;  $\ln\left(\frac{F_{\text{CHARCOALI}}}{1 - F_{\text{CHARCOALI}}}\right)$  represent the probability of households consuming charcoal as a means of household energy or not.  $\beta_0, \beta_1, \beta_2, \dots, \beta_6$  are the constant and coefficients for age, family size, income, education (disaggregated into secondary and post-secondary, respectively), household location, and price of charcoal deflated, respectively, while  $e_t$  is the error term.

education(disaggregated into secondary and post-secondary, respectively), income, secondary and post-secondary education, and price of charcoal deflated respectively, while  $e_t$  is the error term.

$$\ln\left(\frac{F_{Biomass_i}}{1 - F_{Biomass_i}}\right) = \beta_0 + \beta_1 gender_i + \beta_2 age_i + \beta_3 income_i + \beta_4 household\ location_i + \beta_5 marital\ status_i + \beta_6 education_i + \beta_7 family\ size + \beta_8 price\ of\ biomass\ deflated_i + e_t \quad (11)$$

Where;  $\ln\left(\frac{F_{Biomass_i}}{1 - F_{Biomass_i}}\right)$  represent the probability of households consuming Biomass as a means of household energy or not.  $\beta_0, \beta_1, \beta_2, \dots, \beta_7$  are the constant and coefficients for gender, age, income, household location, marital status, education(disaggregated into secondary and post-secondary, respectively), family size, and price of biomass deflated respectively, while  $e_t$  is the error term.

## 5. Results and discussion

### 5.1. Reliability test

The study employed Cronbach's alpha coefficient to assess the reliability and consistency of the variables used in the study. Cronbach's alpha describes the extent to which variables measure a concept, its value ranges between 0 and 1, and the closer the value to 1, the better the result. Gliem and Gliem (2003) state that any value of Cronbach's alpha below 0.5 is unacceptable. Although Santos (1999) posits that any value of Cronbach's alpha from 0.7 is satisfactory for good internal consistency.

Table 1 depicts the coefficients of Cronbach's alpha for all the variables; the least coefficient is 0.9367, while the highest is 0.9471 and the overall test scale stood at 0.9439, which is acceptable (Santos, 1999).

Column 1 of Table 2 shows the results of the marginal effects of household expenditure on energy consumption. The model attempts to analyze determinants of household energy consumption, particularly, the socio-economic factors; the statistically insignificant gender coefficient suggests that gender doesn't play a significant role in determining household energy expenditure within the study area. In comparison to those with below minimum wage income, a household with above minimum wage income generally correlates positively with high expenditure on energy by up to 0.039 units. This contradicts the findings of Kayode et al. (2019). In the case of those that attain any level of formal education, for instance, their coefficient is robustly significant at the 1% level. Interestingly, this fits both sides of the coin. On the one hand, could mean that households with formal education are likely to adopt energy savings measures as they are most likely to be engaged in the use of clean and possibly renewable energy. This aligned with Wang, Wang, et al. (2022) that renewable energy improves environmental quality. On the other hand, formal education, all things being equal, exposes one to understanding the health and environmental implications of using one type of energy over another. This finding conforms with Kayode et al. (2019).

Furthermore, the model shows that although monthly expenditure on other goods does not play a significant role in determining household energy consumption, households' location does, and positively, given the statistical significance of its coefficient at 1% level with a coefficient of 0.002, it implies those urban households are more likely to expend more on energy than those in the rural areas. Additionally, marital status also significantly and positively affects household energy consumption expenditure with a probable prediction of up to 0.027 effects on energy consumption expenditure of a household as a result of marriage. This corroborates the fact that domestic and residential energy is mostly consumed by people with marital status (married).

Column 2 of Table 2 shows the result of the determinant of household energy consumption through electricity usage. Marital status was positive but not statistically significant in the analysis.

**Table 1. Cronbach's alpha test result**

Variable	Observation	Alpha
Price of biomass	386	0.9405
Price of charcoal	386	0.9409
Price of kerosene	386	0.9444
Price of LPG	386	0.9405
Price of electricity	386	0.9369
Family size	386	0.9367
Education (secondary)	386	0.9379
Education (post-secondary)	386	0.9395
Gender of household	386	0.9421
Age of household	386	0.9413
Monthly expenses	386	0.9405
Marital status	386	0.9409
Average monthly income	386	0.9444
Education	386	0.9367
Maximum education of household (Informal)	386	0.9379
Location of household	386	0.9395
Biomass usage	386	0.9443
Charcoal usage	386	0.9433
Kerosene usage	386	0.9446
LPG usage	386	0.9433
Electricity usage	386	0.9471
Consumption expenditure on energy	386	0.9453
Overall test scale		0.9453

However, when checking for nonlinearities, the age coefficient is negative but statistically significant at less than 5% while income just like marital status is found to be positively insignificant, that is, households consume electricity regardless of their income level. However, the location of households and education were both found to be positive and statistically significant at 1%, respectively, which implies that for any unit increase in education or migration from rural to urban location there is a probable increase in electricity usage by 0.025% and 0.022%, respectively. In particular, the coefficient of family size is not only positive but also significant statistically at 10%. This implies that a married household increases the consumption of electrical energy by about 0.025 units. This is in line with the prior expectation because as the family increases the frequency of the family's usage of additional appliances also in tandem. However, the price of electricity contrary to the general notion was found to be positive but insignificant as well. This implies that the household doesn't respond to price changes about their usage as it insignificantly affects household usage of electricity.

Column 3 of Table 2 depicts estimated logit regression results of LPG usage by household. Specifically, the gender variable is negatively related to LPG use and statistically insignificant. The marginal effect after\shows that household age is an influencer in LPG usage as young and middle age adults are over 6% more likely to use LPG than old adults. The change in income is positive and insignificant as well. Another significant predictor in the model is education, as educated are predicted to demand a cleaner energy source at a 0.006 coefficient. The family size coefficient value suggests that households that are large in number have a higher tendency of

**Table 2. Model estimates for the determinants of household energy consumption**

Variable	Household Consumption Expenditure on Energy	Electricity Usage	LPG Usage	Kerosene Usage	Charcoal Usage	Biomass Usage
Gender	0.002 (0.00194)		-0.023 (0.0146)	-0.005 (0.0036)		0.023 (0.093)
Income	0.039*** (0.01385)	0.002 (0.0354)	0.007 (0.0136)	0.001 (0.0037)	0.031*** (0.013)	-0.031 (0.0285)
Education	0.001*** (0.00042)	0.022*** (0.0084)	0.006*** (0.0015)	0.008*** (0.0019)	-0.002 (0.0041)	-0.029*** (0.0040)
Education (secondary)					-0.109** (0.0611)	
Education (post-secondary)					-0.031 (0.0443)	
Household location	0.002*** (0.00064)	0.025*** (0.0072)		0.018*** (0.0048)		-0.025*** (0.0043)
Monthly expenses	0.001 (0.00298)					
Marital status	0.027*** (0.01081)	0.100 (0.3789)		0.060*** (0.0210)		0.145 (0.1024)
Age		-0.033*** (0.0181)	0.065*** (0.0181)	-0.0010 (0.0038)	0.022 (0.030)	-0.063*** (0.0204)
Family size		0.025* (0.0150)	0.023** (0.0134)	-0.016*** (0.0035)	0.024*** (0.007)	0.021*** (0.0093)
Price of electricity		0.096 (0.2053)				
Price of LPG			-0.085*** (0.0133)			
Price of kerosene				-0.011*** (0.005)		

(Continued)



**Table 2. (Continued)**

Variable	Household Consumption Expenditure on Energy	Electricity Usage	LPG Usage	Kerosene Usage	Charcoal Usage	Biomass Usage
Price of charcoal					0.003 (0.0152)	
Price of biomass						0.158*** (0.038)
Constant	6.32e-06*** (8.81e-06)	0.088 (0.4193)	40.325*** (30.2054)	0.537** (0.1763)	1941.569* (10257.95)	0.018*** (0.0100)
Observation	386	386	386	386	386	386

Standard errors in parentheses, also \*\*\* $p<0.01$ , \*\* $p<0.05$ , \* $p<0.1$ .

using LPG by about 0.023 units than those that are smaller in size. The price of LPG is significant but on the negative side as higher prices tend to negatively affect LPG usage by over 8%.

From the kerosene estimated model as presented in column 4 of Table 2, the coefficients of gender and age are both negative but statistically insignificant. However, the coefficient of marital status even though positive and significant implies that there exists a positive relationship between marriage and kerosene usage in the area. This is because being married by a unit increases the probability of high demand for kerosene by 0.060. Income, on the other hand, is neither positive nor significant. Looking at the coefficients of education, family size, and household location, they all matter for kerosene usage. Education and location positively affect kerosene usage while family size reduces kerosene usage by households. For instance, findings indicate that a unit increase in education and location of a household increases the probability of using kerosene in the household by 0.008% and 0.018%, while family size reduces kerosene usage by 0.016%. The coefficients of the price of kerosene are not only statistically significant but negative at a 1% level. The coefficient reveals that with a unit increase in kerosene price, there is a probability of a 0.01% decrease in kerosene usage holding all other variables constant.

In column 5, the estimated model indicates that the age coefficient is insignificant. The level of education and post-secondary education is not only insignificant but negatively correlated with charcoal usage. However, the family size coefficient bounces as robustly significant at 1%. The result shows that there is a positive relationship between family size and charcoal usage as a unit increase in family size increases the likelihood of charcoal usage by 0.024 unit increase. This supports Wang et al. (2023) argument that an increase in coal consumption positively correlates with an increase in carbon emissions but negatively with economic growth. That is, large family size and increased coal usage lead to increased emissions. Furthermore, the income coefficient was found to be significant at 1% indicating a unit increase in income will lead to a probability of 0.03 increase in charcoal usage *ceteris Paribus* as well as secondary education, which is though negative but significant. However, the price of charcoal is positive but statistically insignificant in the result.

Column 6 of Table 2 depicts the results of the marginal effect from the logistics regression. The results show that the gender coefficient is positive and statistically insignificant. The age variable is negative but statistically significant. This implies that a unit increase in age leads to a probable decrease of 0.063 biomass usage. This may not be unconnected with the prior expectation that biomass usage poses a high risk of health-related challenges, especially for old-age households. Income, however, is only positive but insignificant. This indicates that biomass is an energy source for low-income households head in the study area. Location of the household, as well as education, were all found to be negatively significant at 1%, respectively. This shows that rural households as well as households that attained higher levels of education are less likely to use biomass as a unit increase in household location (urban dwellers) leading to a probability decrease in biomass usage by 0.025. This supports the findings of Wang et al. (2019) that urbanization is an essential factor affecting energy consumption. Equally, education will probably decrease biomass usage by 0.029. The marital status is positive and insignificant. The price of biomass is positive and statistically significant. This can be attributed to its availability and affordability by households mostly in rural settlements. From the result, a unit increase in the price of biomass doesn't affect its usage as the probability of a 0.158 increase is predicted in its usage.

Table 3 shows that for the gender distribution of the respondents, 76.17% are male, while about 23.06% are female. The results also reveal that about 23% of the household head have no formal education, and slightly above 26% of the household head have post-secondary education. There are about 51.04% of the household head with secondary education. This finding indicates that the educational level of the respondents has a significant effect on their choice of energy. The table also shows that 9.5% of the respondents were between the ages of 18 and 25, 20.21% fell between 26 and 35 years, and 27.46% of the respondents were between 36 and 45 years old,

**Table 3. Descriptive statistics of the responses of households head**

Variables	Frequency (n=386)	Percentage
Gender		
Male	294	76.19%
Female	89	23.06%
Unspecified	3	0.78%
Total	386	100%
Age		
18–25	37	9.59%
26–35	78	20.21%
36–45	106	27.46%
46–55	104	26.94%
55 and above	61	15.80%
Total	386	100%
Education level		
Secondary	197	51.04%
Post-Secondary	101	26.17%
Informal	88	22.80%
Total	386	100%
Household Size		
1–3	53	13.73%
4–6	67	17.36%
7–9	118	30.57%
10 and above	148	38.34%
Total	386	100%
Income (in Naira amount)		
0–30,000	263	68.13%
31,000–60,000	81	20.98%
61,000–100,000	23	5.96%
100,000 and above	17	4.40%
Unspecified	2	0.52%
Total	386	100%
Monthly Energy Expenditure (%)		
<1 %	6	1.55%
1–5 %	96	24.87%
6–10 %	199	51.55%
10 % and Above	85	22.02%
Total	386	100%
Availability		
Yes	190	49.23%
No	96	24.87%
Unspecified	100	25.91%
Total	386	100%
Affordability		
Yes	221	57.25%
No	86	22.28%
Unspecified	79	20.47%

(Continued)

**Table 3. (Continued)**

Variables	Frequency (n=386)	Percentage
Total	386	100%
Reliability		
Yes	149	38.60%
No	111	28.79%
Not Sure	98	25.39%
Unspecified	28	7.25%
Total	386	100%
Accessibility		
Yes	281	72.80%
No	97	25.13%
Unspecified	8	2.07%
Total	386	100%

Source: Authors' computation using Stata 15.

while about 27% were between 46 and 55 years of age. 15.8% were found to be 55 years old and above. The age distribution conforms with the study of Wang, Li, et al. (2022) that population aging is an essential factor that affects the relationship between energy consumption and carbon emissions. The result equally showed that 13.73% of the respondents have a household size of about 1–3, 17.36% have a household of about 4–6 people, 30.57% of the respondents have a household size of about 7–9 persons and 38.34% of the respondents have a household size of about 10 persons or more.

Findings from Table 3 further revealed that household head income, level of education, availability of different energy choices accessibility, reliability, and affordability are major determinants of household energy choices as low-income household heads which account for more than 60% of the respondents rely heavily on biomass usage. Table 3 also reveals that 72.80% of the respondents attest to the fact that accessibility is one of the driving forces which determines their energy choice. This aligns with the findings of Ogunniyi et al. (2012) who reveal that because of its accessibility kerosene is the most highly consumed and preferred form of energy in the study area.

## 6. Conclusion and recommendations

The study assessed determinants of household energy consumption in Kebbi State, Nigeria. It widens the understanding of the concept of determinants of energy consumption in general. The appraisal of the causal relationship involving energy consumption and the factors that determine it was the first step. A thorough appraisal of the literature on the determinant of energy consumption revealed that the econometric strategy using a single model in determining factors that influence household energy consumption may not be able to provide explanations that are satisfactory as the literature shows a mix of results that are to some extent not inconsistent with the present-day reality. The hierarchical feature of the energy ladder model set the basis for a structure of household energy consumption in Nigeria, under which income plays a significant role in the determination of the energy path a household may take. This is so, for most households' disposable income is a constraint, many are prone to. Households first decide the amount to expend on energy which will correlate directly with the form of energy that the disposable income can afford. Forecasting energy usage although had always been possible using an econometric approach, the adoption of logistic regression by the study was, however, useful as it allows the analysis of data while taking into cognizance that households use energy differently. The model valor lies in its capacity to identify significant binary dependent variables that influence or leverage

independent variable outcomes and, hence, predict and evaluate the validity of the model. The results have shown how education, income, and location of the household were found to be among the moving forces which informed the household's decision in terms of usage and energy expenditures within the study area.

Therefore, the study concluded that the educational attainment of the household head is a great influencer in predicting the type of energy choice. Additionally, household income in the study area also plays a momentous role in making the household adjust and move from one type of energy to another or increasing the volume of consumption, and this conforms to the energy ladder hypothesis. However, the location of the household was found to be in direct correlation with biomass usage as well as household expenditure on energy, though the former is negatively significant meaning people in the urban areas use less biomass than their rural counterparts, while the latter explains the share among of spending by urban dwellers are much bigger than those in rural.

The study, therefore, recommends an all-inclusive energy transition framework by policymakers that will make energy not only available but also accessible to both rural and urban households. There is also the need for continuous orientation and reorientation on the health and environmental implication of using one type of fuel over another. Equally, the government should intervene and provide subsidies necessary to encourage the populace to adapt to the use of renewable and clean energy.

### 6.1. Areas of future

Future work should focus on an exploration of the determinants of household energy consumption in need in urban areas, semi-urban, and rural regions separately and make a comparison. Going forward studies are equally essential to compare the results of societies and individuals that rely profoundly on traditional biomass as their energy choice, its impact on their health and environment, and households that become accustomed to the use of renewable energy in particular and nuclear energy as a nation.

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