STUDY OF THE UNDERLYING FACTORS DRIVING HOUSEHOLD RENEWABLE ENERGY TRANSITIONS IN NIGERIA

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ABSTRACT

Nigeria has in abundance various forms of energy resources that can drive sustainable development in various sectors of the country. Energy resources such as crude oil, natural gas, coal and renewable energy resources like solar, wind, large and small hydro are all in abundance in Nigeria making it a country full of potential in the rapidly growing global energy sector. Despite the country's sizable energy resources, most Nigerian households lack reliable access to electricity and clean cooking fuels due to ill-managed grid-based infrastructure, vandalism, and disruptions in gas supply. With a population of over 200 million, 60% of Nigerian households rely on conventional energy resources, known to be contributors to climate change. To address these challenges, the Nigerian government is currently pursuing its Renewable Energy Master Plan of transitioning to renewable energy resources to mitigate household dependence on conventional energy resources and diversify the country's energy mix. However, the transition process has been met with setbacks and advances at a slow pace. Therefore, this paper investigates the underlying factors of household energy transitions in Nigeria by identifying barriers to the transition process and household energy motives. Based on country-level panel data collected between the years 2018 and 2022, the study indicates that energy stacking is very much prevalent in urban and rural households, characterised by significant consumption inertia of conventional and traditional solid biomass fuels, followed by partial substitution of firewood for liquified natural gas and fuel-based generators for solar panels. The study identified various transition barriers categorised under five underlying factors of household renewable energy transition: economic, policy, legal, technical, market, and household demographic factors. But the study concludes that policy and legal factors such as renewable energy subsidies could encourage household transition to renewable energy sources and mitigate barriers to the transition process.

Keywords: renewable energy, energy transitions, energy stacking, Nigeria, transition barriers.

1 INTRODUCTION

The growing awareness of the impacts of climate change has driven a global reassessment of current energy forms and global energy consumption patterns, which are largely driven by fossil fuel consumption. The continuous combustion and reliance on fossil fuels to meet global energy demands have had detrimental impacts on the environmental, social and economic well-being of all life forms on Earth. It is against this backdrop that most societies are beginning to recognise the need to transition towards cleaner forms of energy and sustainable energy consumption patterns. Therefore, there is no doubt that the decarbonisation of societies is crucial to mitigating the impacts of climate change. The push for decarbonisation arises from the global dependence on fossil and traditional biomass fuels, which collectively account for around 80% and 65% of the global energy supply, respectively [1]. While these fuels have contributed to meeting the global energy demand, their extensive use comes with significant concerns [2]–[4]. Firstly, the combustion and consumption of both fossil and traditional biomass fuels are known contributors to climate change and various environmental problems, including air pollution, droughts, sea level rise, and the depletion of natural resources [4], [5]. Secondly, reliance on fossil fuels also raises serious energy security concerns due to potential energy supply gaps, volatile oil prices, trade imbalances

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leading to inflation, and adverse economic impacts on the productivity and competitiveness of nations [5]. These concerns around the reliance on fossil and traditional biomass fuels have led to an urgent need for transition towards renewable energy as an alternative to fossil and traditional biomass fuels.

Transitioning to less polluting fuels is particularly important for low- and middle-income countries (LMICs) like Nigeria. This is because approximately 2.6 billion people in LMICs mainly depend on high polluting fuels fossil and traditional biomass fuels for daily energy needs [6], [7]. Within this demographic, sub-Saharan African countries play a significant role, with about 67% of households in the region depending primarily on traditional biomass fuels for their daily household energy needs [7]. This heavy dependence on traditional biomass fuels like firewood and charcoal exposes households in the region to household air pollution (HAP) and various environmental risks. Research has shown that exposure to HAP from these fuels is linked to detrimental health outcomes, including an increased risk of still and preterm births, respiratory infections, and higher mortality rates in both children and adults [8]. Sadly, smoke, and particulate matter $PM_{2.5}$ from HAP contribute to approximately 70% of deaths among children aged 5 years and below and women in sub-Saharan countries [9]. Consequently, the transition to less polluting energy sources like solar energy becomes a critical priority for improving environmental and public health outcomes in these countries.

Nigeria being the most populated country in sub-Saharan Africa (SSA) has the largest economy in Africa, yet the country is home to the largest number of households living in abject energy poverty. About 75% (150 million people) and 40% (80 million people) of households in Nigeria lack access to clean cooking fuel and electricity supply respectively [10]. This situation of limited access to clean cooking fuel and electricity is exacerbated by a rising population growth, which creates a surge in energy demand [10]. But unfortunately, accessibility to clean and modern energy sources fail to keep pace with the escalating energy demands in Nigeria. To solve this energy challenge, the Nigerian government aims to encourage household energy transition to cleaner and more efficient energy sources such as electricity, improved cookstoves, and the introduction of renewable energy sources like solar energy into the national grid by 2030 [10], [11]. Achieving this goal of transitioning households from conventional energy sources to clean and modern alternatives demands robust political and social determination, accompanied by well-integrated policies. However, these efforts and policies must stem from a comprehensive understanding of the factors that underlie household energy transitions, because only through such understanding can effective and targeted actions be developed and implemented.

Therefore, the purpose of this study is to investigate the energy transition process and the influencing factors in Nigeria. The novelty of this study is categorised in two ways. First, this study makes a valuable contribution to existing literature on household energy transition in developing countries. Previous studies on household energy transition in developing countries predominantly focused on rural households, relying mainly on micro-level data while this study investigates household energy transitions at a national level by using macro-level data sourced from Nigeria's six geopolitical zones. This approach offers conceptual innovation by providing a more comprehensive insight into the energy transition landscape within Nigerian households, thereby facilitating more informed policy formulation. Secondly, this study also acknowledges the spatial heterogeneity of households in their pursuit to achieve successful energy transition – a facet often under-studied in most prior studies in this domain. Recognising the spatial diversity of households holds importance due to evident disparities in energy use pattern between rural and urban households in most developing countries. These disparities arise from variations in various socio-economic factors such as income, gender, and lifestyle. Therefore, it becomes evident that this spatial

heterogeneity plays a pivotal role when examining the progression of household energy transition, particularly within developing nations [7]. This study fills this gap by investigating household energy transitions within rural and urban settings in Nigeria. In doing this, this study answers the following research questions:

1. What are the current household energy challenges in Nigeria?
2. What are the explanatory drivers influencing household energy transitions in Nigeria?

2 CURRENT STATE OF HOUSEHOLD ENERGY TRANSITION IN NIGERIA

Recently, there has been a growing recognition of the need for a widespread transition towards renewable energy, coinciding with the adoption of significant international treaties like the Paris Agreement 2016 and the United Nations COP26 2021. These treaties have a primary objective of promoting an active transition away from the production and utilisation of fossil fuels in favour of renewable energy sources, with the overarching goal of curbing carbon emissions. This transition also calls for a gradual yet profound and sustained change from relying on fossil fuels to adopting more sustainable energy sources. As part of this shift, societies, organisations, and households must also undergo a transformation in their perceptions and attitudes towards energy [12], [13].

Nigeria as the most populous country in SSA is not left out in the pursuit of transitioning to renewable energy technologies. Nigeria is committed to achieving gradual transition to renewable energy through the design of policies and programmes targeted at achieving carbon neutrality by 2060, introducing clean, modern energy services and poverty alleviation. Examples include: the Nigeria Energy Transition Plan 2022, National Adaption Strategy and Plan for Action Climate Change for Nigeria (NASPA-CNN) 2021 and National Renewable Energy and Energy Efficiency Policy (NREEEP) 2015. However, despite these policies and the vast energy resources comprising both conventional and renewable energy resources, Nigeria stands as a significant player in the global energy market [14]. Yet, Nigeria ranks as one of the countries with the least access to electricity in the SSA region [15].

Energy transition in Nigeria is crucial to achieving not only economic development and carbon neutrality but also energy sufficiency, because current forms of energy services have not met up with energy demands. Nigeria has an estimated 12,533 MW of electricity generation potential but only generates 4,500 MW of electricity for a population of over 200 million people [16], [17]. An all-time peak generation of about 5,400 MW was recorded in 2019 but was still inadequate considering a national electricity demand of approximately 20,000 MW [16]. To meet up with the electricity deficit, most Nigerian households extensively rely on fossil fuel-based generators to provide electricity for their households, which contributes to the country's CO_2 emission rates. Similarly, to maintain a basic level of survival, most Nigerian household energy demand is largely for cooking activities, with about 96% of Nigerian households (192 million people) extensively relying on traditional biomass fuels like charcoal and firewood for cooking. In Nigeria, the use of firewood and charcoal is mostly with inefficient cookstoves (traditional open three-point stoves) in poorly ventilated kitchens which constitutes a notable contributor of CO_2 emissions. Recent data from the Clean Cooking Fuel Alliance [18], shows that in the year 2023, approximately 83% of Nigerian households (177.5 million people), depend on firewood and charcoal with inefficient cookstoves for their cooking needs. This heavy dependence on these fuels has resulted in extensive deforestation as Nigeria's forests are being overexploited to meet the increasing demand for wood energy from the growing population. Although the suitability of firewood and charcoal as a renewable energy source holds true if trees used in the production of these fuels are replanted, but this is not the case in Nigeria due to the felling of

tress for firewood and charcoal production thus, aggravating rapid rates of deforestation as in 2022 Nigeria had an estimated 3.7% of forest loss annually [19].

To address this energy challenge in Nigeria, most households often switch or transition from one energy source to another to meet their energy needs. Understanding this household energy switching behaviour is better analysed using the framework of the energy ladder model and energy stacking model.

The energy ladder posits that due to socio-economic improvements in households, households move in a linear and upward movement from conventional/traditional fuels to modern energy sources (Fig. 1). This implies that households can utilise cleaner modern fuels once they are able to afford them. However, using this model alone to analyse household energy-switching behaviour is not without its critics. As some studies criticise the energy ladder model based on its theoretical context and other socio-economic influencers of household switching behaviour [20]–[22]. Similarly, several studies have examined other socio-economic influencers of household switching behaviour using the energy stacking model (Fig. 1). This model suggests that households do not switch from conventional/ traditional fuels to modern energy sources in a linear upward motion but simultaneously use both inefficient and efficient fuels to meet their energy needs [22]. For example, households will use firewood/charcoal fuels for cooking activities in addition to using electricity for

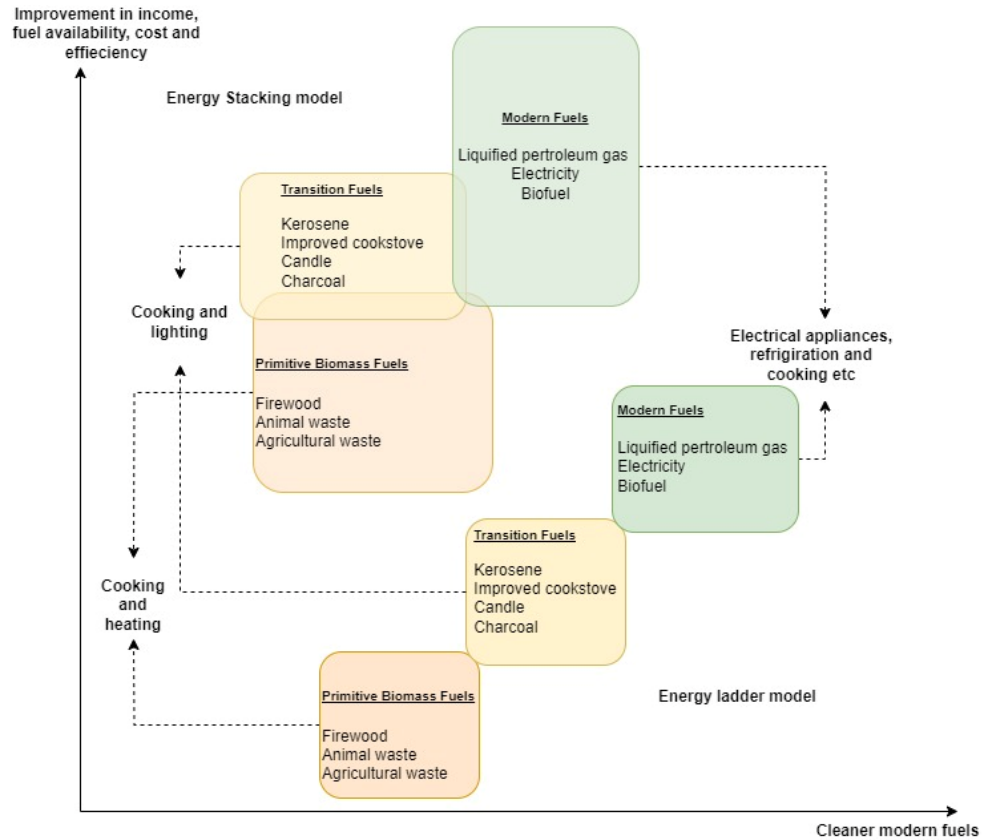

Figure 1: Household energy switching model [20].

lighting and refrigerating. Multiple factors often influence this energy stacking behaviour [21]. Therefore, this implies that an analysis of the factors that drive household energy transitions should consider the different variables that influence household energy transitions.

Several studies have reported that Nigerian household energy switching behaviour follows the energy ladder model, as households move in a unidirectional motion from traditional biomass fuels to modern fuels in alignment with their socio-economic status [23]–[25]. However, recent studies by Oyeniran and Isola [25] and Emodi et al. [7] revealed that some Nigerian households were not moving upward the energy ladder as expected. Instead, households were moving downwards signifying a reverse transition towards the use of traditional biomass fuels. This reverse transition behaviour is often linked to factors such as declining household income, unemployment, household size and educational status, which can all be impacted by the broader economic conditions in a country [7] thus, indicating that household energy transition is also influenced by other factors, contradicting the assumption of the energy ladder model, which exclusively attributes household energy transition to income levels. In Nigeria, household energy transition is, most of the time, influenced by several factors other than household income level. Contrary to phenomenon of the energy ladder model, energy stacking, or multiple fuel use is very much prevalent in most Nigerian households. This implies that households use a portfolio of fuels ranging from traditional biomass to clean modern fuel irrespective of their household income level and other socio-economic variables. Research in Oyeniran and Isola [25] and Kowsari and Zerriffi [26] revealed that most Nigerian households use a mix of fuels to meet their daily energy needs in response to changes in fuel price, seasonal availability of fuel, accessibility, convenience, and energy policy. In fact, Maconachie et al. [27] found that most middle-income households in Nigeria favoured firewood and charcoal over LPG for cooking due to oil price fluctuations, availability of LPG and access to LPG stations. As such it has become customary to analyse household energy transitions using a variety of metrics and their impacts across different household locations.

3 MATERIALS AND METHODS

The data used for this study comes from a country-level household survey data collected from 2018 to 2022. The study included a randomly selected sample group of household participants, totalling 746 households from different regions of Nigeria, encompassing the northern, southern, eastern, and western parts of the country. The dataset encompassed a wide spectrum of socio-economic factors, energy consumption patterns, and matters pertaining to renewable energy across these diverse households. These households were further categorised based on their residential locations into urban and rural settings. Recognising the importance of addressing the data collection approach's limitations in this study is essential to the credibility of this study. Therefore, it is essential to note that longitudinal research often grapples with issues such as a substantial drop-out rate among respondents, potentially diminishing the utility of previously gathered data. Also, the researchers acknowledge the time-consuming and costly nature of conducting longitudinal studies at the country level. Nonetheless, this form of data remains invaluable for tracking temporal shifts and illustrating parallels in household characteristics.

For this study, the investigators employed both electronic means through social media apps like WhatsApp and in-person interactions to administer the survey to the chosen households. The purpose of the study was clarified to the participants, and their consent was obtained before conducting the interviews. The survey questionnaire contained a mix of open, closed, and multiple-choice questions, facilitating the analysis of both qualitative and quantitative data. Data obtained included information on household identity, demographic

characteristics (age, gender, educational status, employment status and income level), household energy use, type of household, household location, views on renewable energy, etc.

For data analysis, a basic statistical analysis was done to analyse, summarise and present findings on the factors driving household energy transitions, household energy use, household fuel preference used for different household activities and likelihood of using renewable energy in households.

3.1 Descriptive summary of data

Table 1 shows descriptive statistics of socio-economic variables from households and household fuel use data for empirical analysis.

Table 1: Descriptive statistics of households.

Variable (*N* = 746)	**Measurement**	**Frequency**	**Percentage**
Gender	Male	416	55.8
	Female	323	43.3
Age	18–25	214	28.7
	25–34	385	51.6
	35–44	111	14.9
	45–64	27	3.6
	65 and above	2	0.3
Qualification	BA/BSc	403	54.0
	Diploma	3	4.6
	MA/MSc	220	29.5
	Primary school	1	0.1
	Secondary school	18	2.4
Home location	Urban	705	95.1
	Rural	36	4.9
Region	Northern	207	27.7
	Eastern	45	6.0
	Southern	218	29.2
	Western	270	36.2
Source household electricity	National grid	259	34.7
	Generator (diesel/petrol)	213	28.6
	Renewable energy	13	1.7
	Combination of sources	234	31.4

4 PRESENTATION AND DISCUSSION OF RESULTS

The results for this study on the factors that drive household renewable transition for urban and rural households in Nigeria is presented in the following sections. The researchers performed statistical test on the variable shown in Table 1 and other questions asked to respondents. The descriptive summary of data shown in Table 1, reveals more males (55.8%) than females (43.3%) in households. This data is a true representation of household demographics in Nigeria as most households are male led. The largest age group from the survey is the 25–34 year olds (51.6%) followed by the 18–24 year olds (28.7%). While 65 years old and above was the smallest fraction of responses consisting of 0.27%. As regards

educational level of households, Table 1 reveals that surveyed households possess an array of qualifications such as BA/BSc, Diploma, MA/MSc, Primary school, Secondary school. However, a large share of respondents held a bachelor's degree. In Nigeria, the age group of individuals between 18 and 34 years constitute those who typically work to provide income for households. In terms of home location, approximately 95.1% of respondents are urban dwellers while 4.9% live in rural areas. Regional distribution of households shows that largest respondents are from the western region (36.2%), followed by southern region (29.2%), the northern region (27.7%) and lastly eastern households (6.0%).

4.1 Household energy challenges

As indicated in Section 1, about 75% of Nigerian households lack access to electricity. As such, respondents for this study were asked about the impact of lack of access to electricity on their daily lives. From the survey, 92.7% of households indicated that recurrent blackouts and low access to electricity negatively impacted their ability to perform daily household activities (Fig. 2).

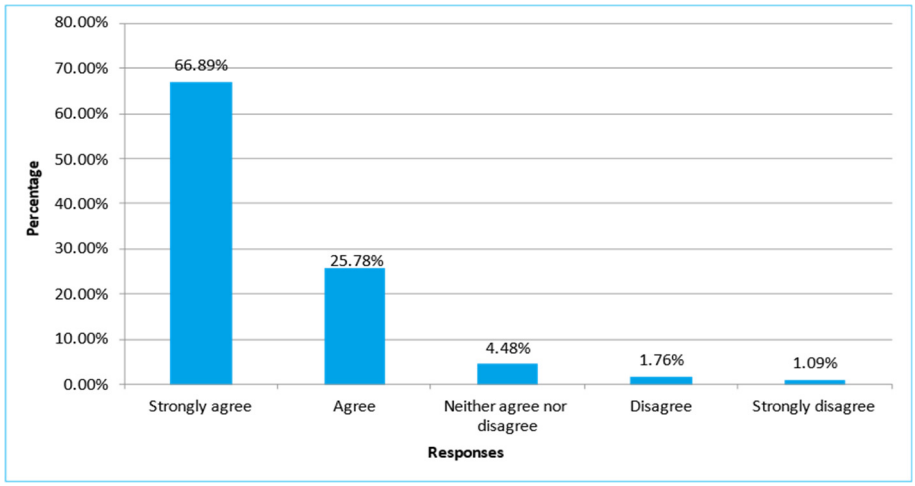

Figure 2: Impact of low access to electricity on household wellbeing.

Given that a large share of respondents expressed that the lack of access to electricity have an impact on the daily lives underscores the severity of the energy challenges confronted by most Nigerian households. The disruptions in electricity, coupled with insufficient supply, frequently lead to negative consequences when it comes to carrying out essential household tasks such as lighting, heating, cooling, cooking, and refrigeration. In fact, one household head suggested that '…some mornings I have to go to the mangrove to collect wood for cooking before I get ready for work… or I do that after work' (RP004).

This statement aligns with conclusions drawn from various studies on household energy transitions in Nigeria, which emphasize that the absence of reliable electricity and clean fuel sources leads to a dependence on conventional fuels such as firewood and charcoal in the majority of developing nations. This reliance, in turn, hampers socio-economic advancement and prospects, particularly impacting women and children who often shoulder the burden of gathering firewood for cooking purposes due to the insufficient availability of electricity.

4.2 Household energy source

The majority of energy in most Nigerian households is used for domestic activities such as lighting, cooking, cooling, refrigerating and heating. An analysis of household energy source for this study indicates that most households used electricity for their daily household activities when it is available (Fig. 3). But the results also reveal a combination of sources being used in households for different activities.

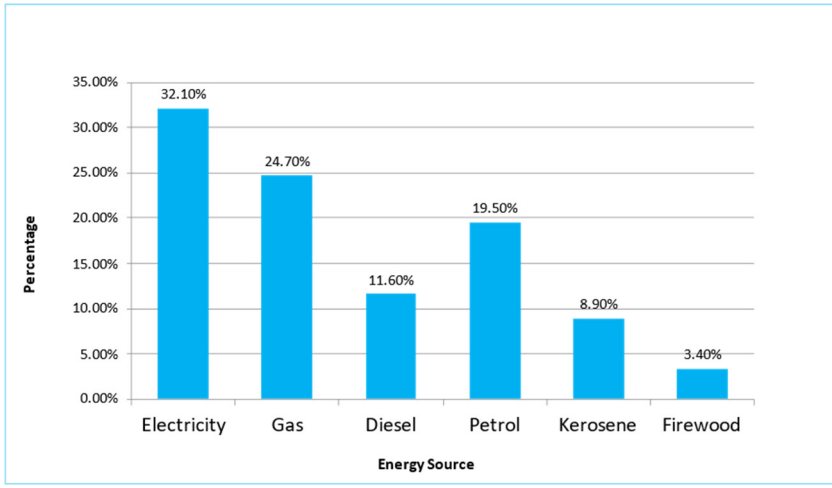

Figure 3: Household energy source.

The observations in Fig. 3 further underscore that households utilise an array of energy sources to fulfil their distinct domestic energy requirements. For instance, electricity serves purposes ranging from illumination and cooling to cooking and refrigeration, while cooking and heating tasks are carried out using gas, kerosene, and firewood. Additionally, other fossil fuel derivatives like diesel and petrol find usage in household generators for electricity production, as well as serving as fuel for vehicles. Because the primary energy source for the respondents was electricity, they were asked about the origin of their electricity supply. This inquiry stemmed from existing literature suggesting limited access to electricity. Consequently, it was of significance to uncover how households produced electricity for their domestic needs (Fig. 4).

Among all the households surveyed, electricity emerged as their primary energy source. However, within this group, 62.5% of households revealed that their electricity supply frequently comes from a blend of sources. These sources encompass electricity from the national grid, personal fossil-fuelled generators, or solar inverters. Considering the electricity supply shortages in Nigeria, households frequently resort to diesel or petrol generators to generate the electricity needed for their domestic requirements. Nevertheless, this practice carries substantial financial and health burdens due to the expenses of acquiring fuel for the generators and the detrimental effects of generator emissions on human well-being consequently making households to seek greener and cost-effective alternatives. Surprisingly, household source of electricity varies significantly between urban and rural households as data from the results show that nearly 100% of rural households relied mainly on fossil fuel powered generators for electricity generation (Fig. 5).

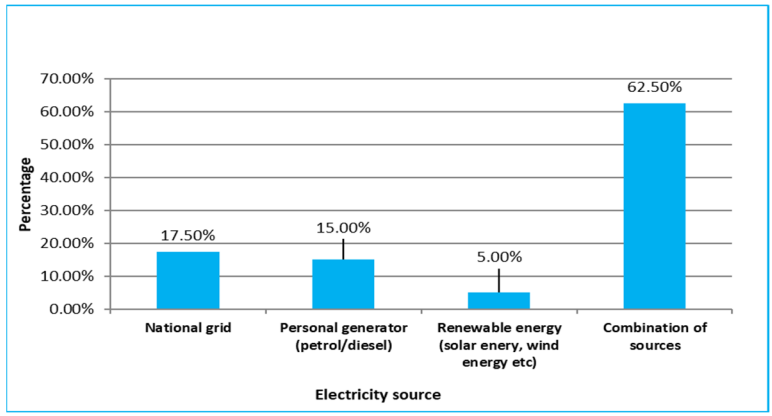

Figure 4: Source of electricity in household.

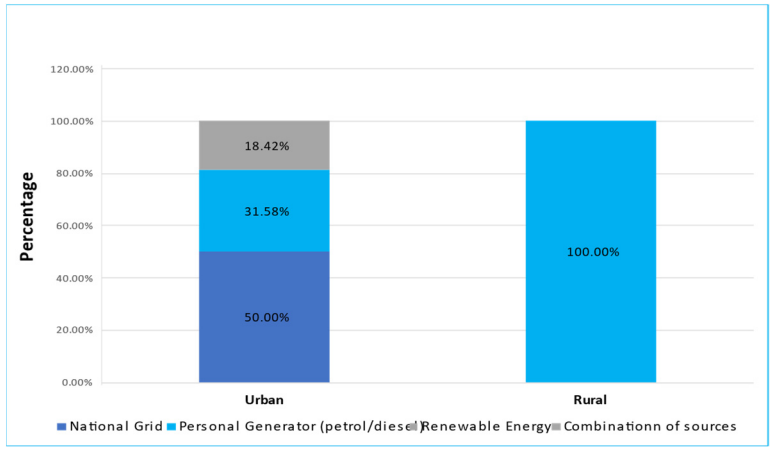

Figure 5: Electricity source between urban and rural households.

4.3 Household energy use pattern

An analysis of the household energy use patterns between urban and rural residents reveals a notable correlation between the energy stacking model and the prevailing trends in energy usage among the surveyed households (Figs 6 and 7).

4.4 Factors influencing household energy transitions in Nigeria.

To test the influence of some of the feasibility predictors highlighted in the research on the acceptance and preference for renewable energy sources, Chi square tests are conducted as shown below. To test the relationship between the lack of access to electricity and occurrence of electricity outage/cuts affecting the daily running of households and the likelihood of transitioning to renewable energy resources (solar energy) shows a significant relationship (Table 2).

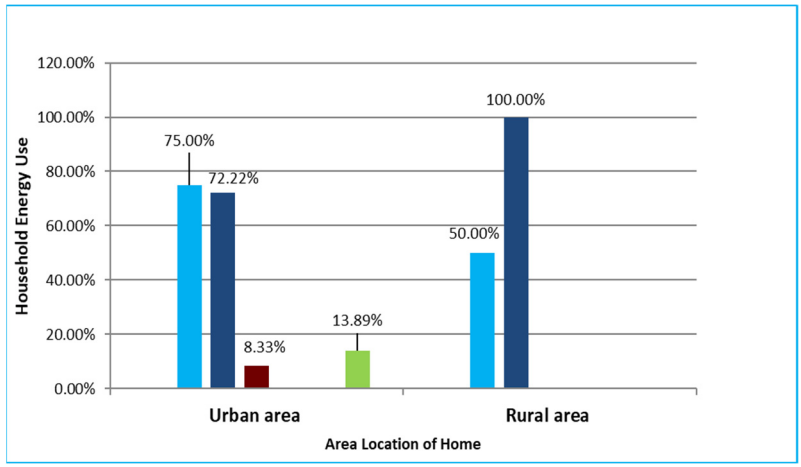

Figure 6: Household fuel use for lighting and home appliances.

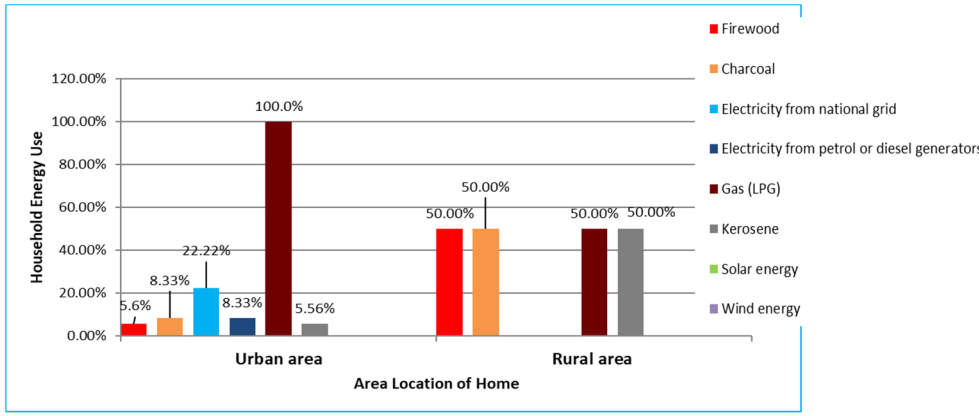

Figure 7: Household fuel use for cooking activities.

Table 2: Influence of energy challenges on household energy transition.

	Value	df	Asymptotic significance (2-sided)
Pearson Chi-square	447.636[a]	25	.000
Likelihood ratio	99.976	25	.000
Number of valid cases	746		

[a.] Twenty-four cells (66.7%) have an expected count of less than 5. The minimum expected count is .01.

From the table, the χ^2 -value of the cross-tabulation variable is 447.636 with a probability value of 0.000 which is less than 0.01 (99% confidence interval). As a result, the assumption that electricity outages have minimal impact on households' willingness to embrace renewable energy as a renewable source is refuted. Thus, indicating that households who face

power cuts are more inclined to transitioning to solar energy as a practical renewable alternative. Additionally, testing the relationship between fuel price/cost and likelihood of transitioning to renewable energy showed a rejection of the assumption that the fuel price will have no influence on household transitioning to renewable energy sources (Table 3).

Table 3: Influence of fuel price on household energy transition.

	Value	df	Asymptotic significance (2-sided)
Pearson Chi-square	329.201[a]	15	.000
Likelihood ratio	63.103	15	.000
Number of valid cases	746		

[a.] Eleven cells (45.8%) have an expected count of less than 5. The minimum expected count is .04.

The results from Table 3 imply that households will naturally be motivated to consider renewable energy sources like solar energy when they consider the price of fuel. In addition to fuel price, surveyed households also indicated that provision of government subsidy on solar panel and other renewable energy technologies would positively influence their decision to use renewable energy (Table 4).

Table 4: Influence of government on household energy transition.

	Value	df	Asymptotic significance (2-sided)
Pearson Chi-square	432.181[a]	20	.000
Likelihood ratio	133.275	20	.000
Number of valid cases	746		

Note: [a.] Eight cells (26.7%) have an expected count of less than 5. The minimum expected count is .42.

From Table 4, the χ^2 -value of the cross-tabulation variable is 432.181 with a probability value of 0.000 which is less than 0.01 (99% confidence interval). This indicates that government subsidies for solar energy technologies would alter the way fuel price are perceived in comparison between fossil fuels and renewable energy source therefore showing that the provision of incentives by the government for renewable energy technologies could encourage households to consider renewable energy technologies.

5 CONCLUSION

This study examined the factors driving renewable energy transitions in Nigerian households using household survey data collected from 2018 to 2022. The trends show multiple fuel use amongst most households with electricity being the main source of energy for households to meet their basic needs. From the examination of data, this study identified some factors that drive household renewable energy transitions in Nigeria. The results from data analysis shows fuel price as the main driver encouraging households to consider using renewable energy technologies (mainly solar energy). Other factors contributing to household renewable energy transition include energy challenges experienced by households and governmental subsidies. Contrary to the energy ladder model, the results for this study do not show an upward transition to cleaner fuel for urban households. Instead, the findings show urban households using both clean modern fuels and traditional fuels like firewood and charcoal despite their perceived advancement in socio-economic status. This reverse

transition is attributed to lack of access to electricity and other economic conditions. Surveyed households show an acceptance of renewable energy but in a fluid process as opposed to the assumption that households in developing countries would transition to renewable energy linearly. The findings from this study have various policy implications for household renewable energy transitions. First, the government should consider creating energy policies that support widening access to electricity for urban and rural households recognising the energy challenges of households. Secondly, introducing market-oriented reforms that would bring about energy price cap and renewable energy subsidies could encourage renewable energy transitions. In terms of future work and limitations, this study did not investigate the perceptions of Nigerian households on renewable energy transitions. Exploring public perception of renewable energy is crucial, given that public acceptance of renewable energy technologies is fundamental in driving widespread transition towards renewable energy. Also, the analyses for this study were limited based on limited sample size ($N = 746$) which may not be an accurate representation of the current population of Nigeria. Thus, there is need for a more robust collection of data that captures more precisely the energy characteristics of Nigerian households.

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