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Towards an understanding of household renewable energy transitions

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ABSTRACT

Purpose: 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 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 process transition has been met with setbacks and at a slow pace.
Method: Between 2018 and 2022, a country-level survey was administered to households in Nigeria, and 746 responses were collected.
Findings: The study indicates that energy stacking is 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 (LPG) and fuel-based generators for solar panels.
Originality/value: This study makes a valuable contribution to existing literature on household energy transition in developing countries by uncovering the spatial heterogeneity of households in their pursuit of successful energy transition. We reveal how participants' cultural preferences may influence their decision to use traditional cooking methods instead of electricity. Thus, shedding more insights into the fluidity of energy stacking behaviour in the Nigerian context.
Practical implications: This paper presents a novel investigation into the underlying factors of household energy transitions in Nigeria. It identifies factors influencing the transition process and household energy motives that could potentially inform and influence the Nigerian government's policy decisions on energy transition.

Introduction

The growing awareness of the impacts of climate change has driven a global reassessment of current energy forms and global energy consumption patterns, driven mainly by fossil fuel consumption (Jones et al., 2023). 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 (Abulibdeh, 2022; Shabir et al., 2023). Against this backdrop, most societies are beginning to recognise the need to transition towards cleaner energy and sustainable energy consumption patterns. Therefore, it is without a doubt that the decarbonisation of societies is crucial to mitigating the impacts of climate change (Saraji & Streimikiene, 2024; Liu et al., 2024; Zhou et al., 2024). 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 (IEA, 2022). While these fuels have contributed to meeting the global energy demand, their extensive use comes with significant concerns (Al-habaibeh et al., 2020; Nalule, 2020; Wang et al., 2020). 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 (Xin et al., 2023; Wang et al., 2020). Secondly, reliance on fossil fuels also raises serious energy security concerns due to potential energy supply gaps, volatile oil prices, trade imbalances leading to inflation, and adverse economic impacts on the productivity and competitiveness of nations (Xin et al., 2023). These concerns around the reliance on fossil and traditional biomass fuels have led to an urgent need for a transition towards renewable energy sources. Renewable energy is naturally sourced, sustainable and can be reproduced faster than they are consumed (Nduka, 2021). Thus, energy transition involves a society's shift in consumption patterns and behaviour from traditional and other fossil fuels to sustainable energy sources (Gallo et al., 2016; Kamali & Streimikiene, 2024; Köhler et al.,2020).

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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 polluting fuels fossil and traditional biomass fuels for daily energy needs (Emodi et al., 2022). 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 daily household energy needs (Emodi et al., 2022). 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 (Guta et al., 2022). Sadly, smoke and particulate matter $PM_{2.5}$ from HAP contribute to approximately 70% of deaths among children aged five years and below and women in Sub-Saharan African countries (Bickton et al., 2020). Consequently, transitioning to less polluting energy sources becomes a critical priority for improving these countries' environmental and public health outcomes (Li & Shao, 2023).

More so, the energy transition in the West differs from that of LMICs like Nigeria. For example, while strong institutional frameworks and policies drive the decision to transition at macro levels following government directives (Simon & Schweitzer, 2023), individual households make this decision at LMICs (Oyeniran & Isola, 2023). Individual households' choices in Western countries are mainly limited to energy suppliers but are encouraged to support the transition to renewable energy by installing solar panels. The energy generated from solar helps to reduce electricity bills in some ways while excess energy is transmitted to the national grid, and payments are received in return (Strielkowski et al., 2019).

In reverse, energy is self-generated in LMICs. People power their homes and businesses using electricity from privately acquired petrol or diesel generators (Oyeniran & Isola, 2023). There is no robust institutional framework, and the national grid cannot support the transmission of power across households (Nduka, 2021). Nigeria cannot increase power generation to all households in the short and long term. Thus, an understanding of energy transition and households' perceptions is needed to reduce pollution and transition towards renewable energy in the country.

Nigeria, the most populated country in Sub-Saharan Africa, has one of the largest economies in Africa. Nevertheless, 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 (Nduka, 2021). The limited access to clean cooking fuel and electricity is exacerbated by rising population growth, which creates a surge in energy demand (Nduka, 2021; Zhang et al., 2023). Also, regardless of the abundance of natural resources, only 61% and 6% have access to electricity from the national grid and clean cooking equipment (Dioha & Emodi, 2019). Unfortunately, accessibility to clean and modern energy sources fails 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 into the national grid by 2030 (Nduka, 2021; Dioha & Emodi, 2019). 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.

This study makes a valuable contribution to the existing literature on household energy transition in developing countries by uncovering the spatial heterogeneity of households in their pursuit to achieve successful energy transition - a facet often understudied in most prior studies in this domain. Recognising the spatial diversity of households is important due to evident disparities in energy use patterns between rural and urban households in most developing countries. These disparities arise from variations in various socioeconomic 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 (Emodi et al., 2022). More so, developing innovative solutions for the transmission of energy requires an understanding of factors driving in the LMIC context (Dogan et al., 2022; Shabir et al., 2023) like Nigeria. Therefore, the objective of this study is to investigate the energy transition process and the factors that influence it 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?

The rest of the study is structured as follows: first, the theoretical approach to energy transition is presented, followed by an explanation of energy transition patterns in Nigeria, which allowed us to hypothesise households' energy transition behaviours. Next, the methodology is presented, followed by the results. Discussions and conclusions are presented at the end.

Theoretical approach to energy transition

Energy transition is a pivotal instrument within the broader framework of global policy initiatives addressing climate change (Thomas et al., 2022). It reinforces the need to transition from traditional carbon sources of energy to sustainable energy sources (Gallo et al., 2016). This involves substituting traditional biomass fuels with renewable sources of energy (Cherwoo et al., 2023). Nevertheless, in contrast to our comprehension of climate change, there exists a notable dearth of knowledge regarding the interconnected phenomena of energy transitions and the determining factors that may influence the trajectory of sustainable energy transition on a global scale (Sovacool et al., 2021). Therefore, gaining insights into the essence of energy transition and the diverse transition pathways observed in energy systems across various countries and contexts becomes imperative (Capurso et al., 2022; Cantarero, 2020). This understanding contributes to realising a comprehensive global energy transition and facilitates tailored approaches for regional energy transitions within distinctive landscapes, such as Nigeria.

In a broader sense, energy transitions refer to a gradual shift from one type of energy source, system, or demand to another (Child & Breyer, 2017; Sovacool et al., 2021; Sovacool & Geels, 2016). However, different definitions of energy transitions entail shifts in fuel sources and technologies, with a predominant emphasis on a sustained, long-term transition from carbon-emitting fuels to environmentally friendlier renewable energy sources. A more expansive understanding of energy transition incorporates not only a transition in primary energy supplies and fuel sources but also shifts in the patterns of energy utilisation and behaviour among members of society (Oyeniran & Isola, 2023; Verbong & Geels, 2010). This implies that energy transition broadly involves alterations in the human behaviour associated with energy, including knowledge, values, or motivations, and dependence on economic systems and markets, shifting from one form of energy source or technology to another.

This broad view of energy transition has led to various interpretations of the concept in the past decade, resulting in weak and strong

interpretations of the concept and pathways that can facilitate a successful transition (Sarrica et al., 2016; Seghezzo, 2009). This suggests that the energy transition is a multi-faceted phenomenon, exhibiting variations across countries, regional boundaries, markets, available energy resources, cultures, and households. Sovacool and Geels (2016) affirm that energy transitions represent a complex process involving multiple actors. The transition process involves interactions among entities such as firms, households, policymakers, social movements, scientific communities, and special interest groups. Importantly, these actors are expected to differ from country to country. This implies that there is no singular or universal approach to successfully transitioning towards renewable energy.

Despite these competing views on energy transition, extant studies adopt the view that sustainable energy transition involves socio-technical changes that occur at multiple levels factors (Geels et al., 2017; Sareen & Haarstad, 2018; Geels, 2019). This gave rise to the Multi-Level Perspective (MLP) theory of energy transition. The MLP assumes that energy transition occurs because of an interplay of development across multiple tiers: niche innovations at the micro-level, socio-technical regimes at the meso-level, and the expansive socio-technical landscape at the macro-level (Geels, 2019). It highlights technological transitions and the intricate interplay of societal, political, economic, and environmental factors (Geels et al., 2017; Sareen & Haarstad, 2018). The MLP approach to energy transition has been widely applied in various energy transition theories, particularly in electricity supply, cooking fuel and household transition studies (Gazull et al., 2019; Hölsgens, Lübke and Hasselkuß, 2018; Skjølsvold et al, 2018; Verbong & Geels, 2007). This indicates that the MLP approach to energy transition offers valuable insights into the intricate and dynamic nature of transitions in energy systems.

Despite the robustness of the MLP theory, its applicability within the context of developing countries like Nigeria is scarce and has always been a point of debate (Osunmuyiwa et al., 2018; Geels, 2019; Belaid & Al-sarihi, 2024). A critique of the MLP theory is that it tends to overlook socio-technical regimes, especially in neglecting the political dimensions of transition (Geels, 2019). Furthermore, it is faulted for not adequately addressing the role and impact of collective actors that have the potential to influence the process of energy transition. (Geels, 2019; Osunmuyiwa et al., 2018). Nevertheless, in addressing this criticism, several studies have extended and enriched the MLP theory, offering nuanced conceptual frameworks that incorporate a deeper understanding of the political dimensions and the diverse roles played by various actors in shaping energy transitions. This study addresses some of the limitations of the MLP theory by reviewing the influence of actors in the political landscape, urban landscape and other factors that can influence household energy transitions.

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 (Xu et al., 2023). These treaties aim to promote an active transition from producing and utilising fossil fuels to favour renewable energy sources, aiming to curb 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 transform their perceptions and attitudes towards energy (Munro, 2019; Pandey & Sharma, 2021).

Nigeria is the most populous country in Sub-Saharan Africa (SSA), with a cultural and institutional environment similar to other countries in SSA (Pepple et al., 2024). People in the region face severe energy poverty due to the lack of access to electricity. 70% of the energy consumption in SSA comes from households sourced from traditional fossil fuels (Dioha & Emodi, 2019). A major challenge impacting sustainable energy development is the lack of information on developing sustainable energy policy pathways that address the complexity of household transition behaviour (Dioha & Emodi, 2019). Thus, the Nigerian context adds to the significance of our study. Nigeria is committed to gradually transitioning to renewable energy by designing policies and programmes targeting carbon neutrality by 2060, introducing clean, modern energy services and poverty alleviation. Examples include the Nigeria Energy Transition Plan 2022, the National Adaption Strategy and Plan for Action Climate Change for Nigeria (NASPA-CNN) 2021 and the 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 (Okolie et al., 2019). Nevertheless, Nigeria ranks as one of the countries with the least access to electricity in the Sub-Saharan African region (Odetoye et al., 2022).

Energy transition in Nigeria is crucial to achieving economic development and carbon neutrality. However, the current forms of energy services have not met energy demands. Nigeria has an estimated 12,533 MW of electricity generation potential but only generates 4500 MW of electricity for a population of over 200 million people (Adewuyi et al., 2020; Adoghe et al., 2023). An all-time peak generation of about 5400 MW was recorded in 2019 but was still inadequate, considering a national electricity demand of approximately 20,000 MW (Adewuyi et al., 2020). To meet 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 survival level, most Nigerian household energy demand is mainly for cooking activities, with about 96% of Nigerian households (192 million people) relying on traditional biomass fuels like charcoal and firewood. Burning firewood and charcoal is considered a contributor to CO_2 emissions. 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). Implying that households can utilise cleaner modern fuels once they can afford them. However, using this model alone to analyse household energy-switching behaviour is not without its critics. Some studies criticise the energy ladder model based on its theoretical context and other socio-economic influencers of household switching behaviour (Yadav et al., 2021; Heltberg, 2005; Masera et al., 2000). 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 inefficient and efficient fuels to meet their energy needs (Heltberg, 2005). For example, households will use firewood/charcoal fuels for cooking activities and electricity for lighting and refrigerating, thus showing that multiple factors often influence this energy stacking behaviour (Yadev et al., 2021). This means that analysing 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 (Baiyegunhi & Hassan, 2014; Nwaka et al., 2020; Oyeniran & Isola, 2023). However, recent studies by Oyeniran and Isola (2023) and Emodi

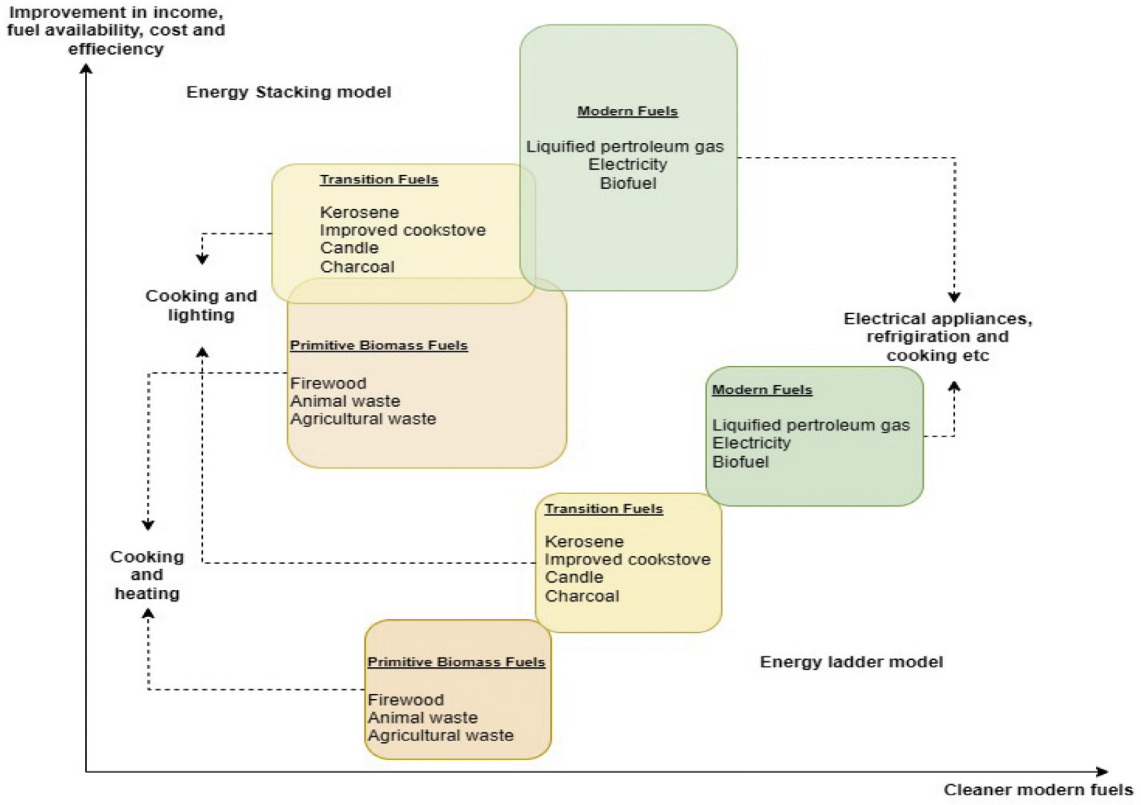

Fig. 1. Household energy switching model (Masera et al., 2000).

et al., (2022) revealed that some Nigerian households were not moving upward the energy ladder as expected. Instead, households were moving downwards, signifying a reverse transition toward using traditional biomass fuels. This reverse transition behaviour is often linked to declining household income, unemployment, household size and educational status, which can all be impacted by the broader economic conditions in a country (Emodi et al., 2022). This indicates 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 often influenced by factors other than household income level. Contrary to the phenomenon of the energy ladder model, energy stacking, or multiple fuel use, is very prevalent in most Nigerian households. This implies that households use a portfolio of fuels ranging from traditional biomass to clean modern fuel. This is irrespective of their household income level and other socio-economic variables. Oyeniran and Isola (2023) and Kowsari and Zerriffi, (2011) 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. Maconachie et al. (2009) 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. However, the complexity of household transition behaviour transcends decisions relating to challenges but may be more socio-culturally nuanced. Thus, more research into energy transition behaviour in a socio-technical context is required (Geels, 2019). As such, this study investigates household energy transition behaviour through the MLP theory lens with the following hypothesis:

H1- *The challenges of availability and cost of traditional energy sources will influence household energy transition behaviour in Nigeria*

H2- *Increase in household income will influence household energy transition behaviour in Nigeria*

Materials and methods

A country-level exploratory study surveying households across the four major regions in Nigeria was conducted between 2018 and 2022. The dataset encompassed a wide spectrum of socio-economic factors, energy consumption patterns, and matters about renewable energy across these diverse households. These households were categorised into urban and rural settings based on their residential locations. Urban households were those mainly in big cities with higher household incomes, while rural households were those in villages. This was important to allow us to understand and uncover how income may inform energy transition behaviour. We randomly sampled 5000 households electronically using a bulk SMS data company to administer the survey. The purpose of the study was clarified to the recipients, who were given a chance to enter for a weekly shop voucher draw. 1003 responded to the text, and the survey was sent to them to complete. Consent was received prior to completing the survey. 257 was removed due to incomplete information. The survey questionnaire contained a mix of open, closed, and multiple-choice questions, facilitating qualitative and quantitative data analysis. Open-ended questions allowed participants to provide more information about their energy transition experience. We particularly found it useful as it provided more context to the survey response and supported our analysis. Sample open-ended questions include: what are the current power supply challenges? Here, we found two key themes mainly linked to availability and cost. We designed the survey question using literature evidence from Oyeniran and Isola's (2023), Emodi et al. (2022), Yadev et al. (2021).

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, and views on renewable energy. We took this approach due to the lack of a validated scale on household renewable energy during data collection in 2018. Fundamentally, renewable energy research is still emerging (Berka & Creamer, 2018; Benedek

et al., 2018). Before data collection, we ensured the scale's validity by following the five steps suggested by Ventura-León et al. (2023). First, we read existing research on household use of renewable energy in the LMICs. Second, we drafted the questionnaire. Third, the questionnaire was discussed with subject experts at a UK university and thereafter given to an independent expert for review. This helped to ensure content validity and inter-rater reliability. Fourth, a pilot test was conducted before the survey was administered to households.

We also analysed the validity and reliability of the scale using SPSS. The results showed that the items were loading on each construct hypothesised. 7 items were used as follows: availability of traditional energy sources (2 items with Cronbach α of 0.91), cost of traditional energy source (3 items with Cronbach α of 0.94) and income level (3 items with Cronbach α of 0.98). We retained all items as the alpha coefficient reported a reduced score when items were deleted (Olclkers & Zyl, 2016). We also determined the sample adequacy using the Kaiser-Meyer-Olkin measure of sample adequacy, which reported a score of 0.8, suggesting that our sample was adequate. Average variance extracted analysis was further conducted to determine the validity of the measurement scale, which reported a range of 0.55 to 0.83, with results > 0.50 considered acceptable (Pepple & Davies, 2019; Zahoor et al., 2021). In the next section, we present our findings on the factors driving household energy transitions, household energy use, household fuel preference used for different household activities, and the likelihood of using renewable energy in households.

Results

The results of this study on the factors that drive household renewable transition for urban and rural households in Nigeria are presented in the following sections below. The researchers performed a statistical test on the variable shown in Table 1 and other questions asked of respondents. The descriptive summary of data shown in Table 1 reveals that there are 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 between 25-34 years (51.6%), followed by 18 - 24 years old (28.7%). While 65 years and above was the smallest fraction of responses, consisting of 0.27%. As regards the educational level of households, Table 1 reveals that surveyed households possess an array of qualifications such as BA/BSc, Diploma, MA/MSc, Primary school, and Secondary school. However, a large share of respondents held a bachelor's degree. In Nigeria, individuals between 18 and 34 years of age typically work to provide income for households. Regarding home location, approximately 95.1% of respondents are urban dwellers, while 4.9% live in rural areas. Regional distribution of households shows that the largest number of respondents are from the Western region (36.2%), followed by the Southern region (29.2%), the Northern region (27.7%) and lastly, Eastern households (6.0%).

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	505	68
	Rural	241	32
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

Table 2
Influence of energy availability on household energy transition.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	447.636[a]	25	.000
Likelihood Ratio	99.976	25	.000
N of Valid Cases	746		

[a] 24 cells (66.7%) have an expected count of less than 5. The minimum expected count is .01.

Descriptive summary of data

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

Factors influencing household energy transitions in Nigeria

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

From the table, the χ^2 -the 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 significantly impact households' willingness to embrace renewable energy as a renewable source holds. This indicates that households who face power cuts are more inclined to transition to renewable energy as a practical renewable alternative. Qualitative comments from our survey highlight the challenges of lack of access to energy supply:

> Respondent 040 - "The current electricity problem makes me feel unsafe and insecure when I am on my way home from work. Especially at night as the streets are not illuminated, the streetlights do not work"
> Respondent 004 - "We do not have a steady power supply in our area... once they take the light, everywhere gets dark, and we feel unsafe as it is when it is dark. Criminals operate."
> Respondent 200 - "..."The electricity from NEPA (national grid) is out almost every day, and it can be off for hours and sometimes all day. This is frustrating and makes it hard to get anything done in the house and at work."
> Respondent 683 - "I run a small business selling cold drinks, and the constant electricity outages are killing my productivity and increasing my costs because I have to use the generator to power my fridge, and the cost of petrol is unaffordable for me."

Additionally, testing the relationship between fuel price/cost and the likelihood of transitioning to renewable energy supported the

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
N of Valid Cases	746		

[a] 11 cells (45.8%) have an expected count of less than 5. The minimum expected count is .04.

Table 4
Influence of increase in household income on household energy transition.

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	432.181[a]	20	.000
Likelihood Ratio	133.275	20	.000
N of Valid Cases	746		

[a] 8 cells (26.7%) have an expected count of less than 5. The minimum expected count is .42.

assumption that the fuel price will significantly influence households transitioning to renewable energy sources (Table 3).

The results from Table 3 imply that households will naturally be motivated to consider renewable energy sources when considering fuel prices. Thus, hypothesis 1 is supported. Comments below narrate participants' views about the cost of available energy sources:

> Respondent 400 – "Electricity bills are going up and up, and yet we don't get enough power supply to justify these costs."
> Respondent 315 – "Most times NEPA gives us estimated electricity bills, that shows what we have not used and if I don't pay they will cut off my light"
> Respondent 733 - "We spend so much on petrol for generators because the electricity from NEPA (national grid) is so unreliable. It is becoming difficult running the generator for my business and at home."

In addition to fuel prices, surveyed households indicated that increased household income would positively influence their decision to use renewable energy (Table 4).

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). Indicates that increased household income would alter how fuel prices are perceived compared to fossil fuels and renewable energy sources. Therefore, increasing household income could encourage households to consider renewable energy technologies. Hypothesis 2 is thus supported.

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. 2 and 3).

Figs. 2 and 3 illustrate a reversal in the transition trend concerning utilising multiple fuels for diverse domestic activities. The comments below explain this in more depth:

> RP650 - "Generators cannot power our heavy appliances, so I only use them when we have power available from the national electricity grid, which is almost unavailable." (urban household)
> RP700 – "We mainly use gas for our cooking, but sometimes use kerosene stoves due to the unavailability of gas in the market. In fact, every household, as far as I know, has a kerosene stove for backup in my neighbourhood" (urban household)
> RP546 - "Let me be honest, food cooked with firewood has this unique taste especially our local delicacy; even though we use kerosene stoves, when it is possible, I still prefer firewood, especially when we travel to the village." (urban household)
> RP150 - "In our village, you must have a generator to survive because the light from the national grid is not available" (rural household)
> RP 450 - "Kerosene stoves are majorly used for cooking, but sometimes when you want to cook something really fast, you can use gas, but not everyone can afford it."

This does not align with findings from the literature that challenge the conventional notion of households progressing towards cleaner and more energy-efficient fuels. Instead, there is a downward shift, particularly in rural areas, where households revert to traditional biomass fuels. This underscores the influence of various factors on household energy transitions, contradicting the assumption of the energy ladder model, which primarily links such transitions to income levels.

Discussion

Our findings are consistent with existing research on the factors influencing energy transition behaviour in Nigeria and SSA contexts. Similar to Emodi et al. (2022), we found that the unavailability of electricity influenced household energy transition behaviour. This

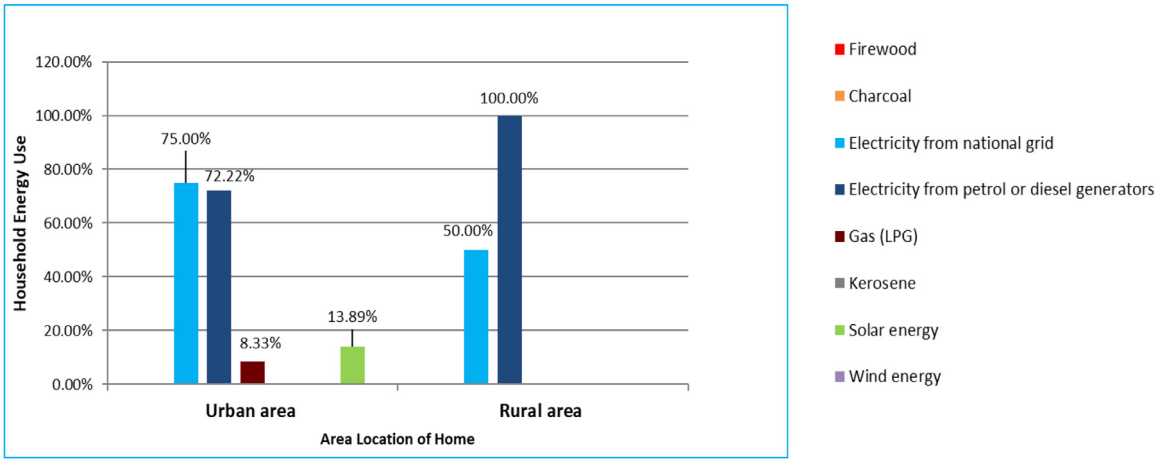

Fig. 2. Household fuel use for lighting and home appliances.

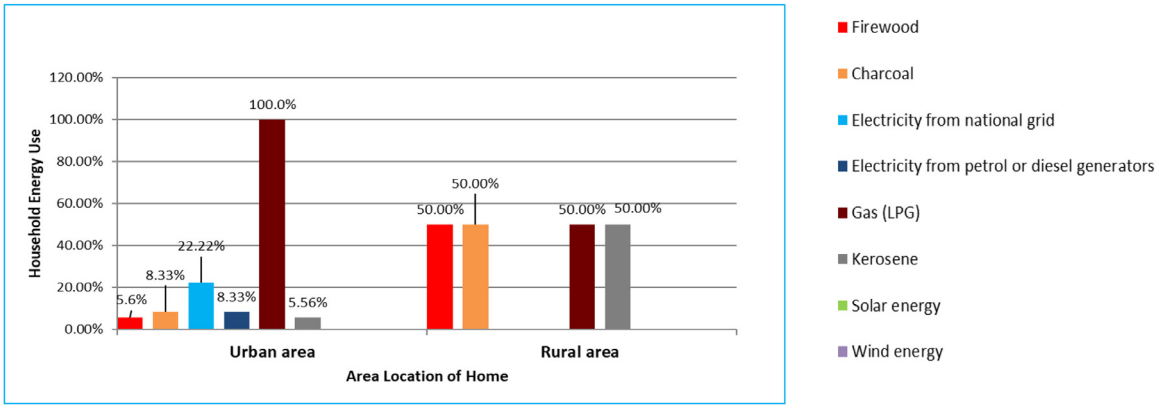

Fig. 3. Household fuel use for cooking activities.

may be due to the lack of electricity transmission and distribution infrastructure (NEPA- an acronym for National Electricity Power Company that manages the transition and distribution on the electricity grid), which makes it difficult for households to access electricity (Oyeniran & Isola, 2023). However, given the fluidity of energy stacking behaviour, we further investigated the energy consumption behaviour of urban and rural households to determine whether income levels may inform the transition to cleaner energy sources. We found that both rural and urban households used multiple energy sources and argue that there are other factors besides the availability and cost of traditional energy that are peculiar to the Nigerian context that may account for using a mix of different energy sources to meet household needs. Interestingly, for income, we found that households were willing to transition to renewable energy if they could afford it, consistent with (Kowsari & Zerriffi, 2011). However, these views were not backed by household actions, as we found evidence of energy-stacking behaviour in urban and rural households.

Energy stacking behaviour has been mainly investigated and informed by instrumental factors such as price (Oyeniran & Isola, 2023; Emodi et al., 2022). However, qualitative comments from free text provide more insights, highlighting context-specific factors such as culture (taste of local food cooked with charcoal) and the need to protect household appliances, which are more factors that inform household stacking behaviour. We provide more insights into the energy stacking model by uncovering how income may not be the only determinant for switching to cleaner energy sources. This suggests that in the Nigerian contexts and, by implication, LMICs, the theorisation of the energy ladder may not hold. Instead, we found evidence of energy stacking behaviour. Although households desire to transition to cleaner energy sources if their income increases, this was not expressed in their behaviour.

Among all the households surveyed, electricity emerged as their primary energy source. However, most households within this group revealed that their electricity supply frequently comes from various 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 seek greener and more cost-effective alternatives. The government is encouraged to implement a national orientation campaign on the dangers of fossil fuel use. Also, given household sentiment on the unique taste of local food cooked using charcoal, such orientation must tackle cultural sentiments about the taste and quality of local foods.

Conclusion

The study aimed to investigate household energy transitions within rural and urban settings in Nigeria by examining the factors driving renewable energy transitions in Nigerian households using household survey data collected from 2018 – 2022. This study investigated household energy transitions at a national level by using survey-level data sourced from Nigeria's four major regions. This approach offers conceptual innovation by providing more insight into Nigerian households' energy transition landscape, facilitating more informed policy formulation.

The findings extend Oyeniran and Isola's (2023) study, which called for understanding factors that affect energy transition beyond the choice of cooking fuels. We show how multiple fuels are used in most households consistently (Baiyegunhi & Hassan, 2014; Nwaka et al., 2020), with electricity being the primary energy source for their basic needs (Adewuyi et al., 2020). From the examination of data, this study identified some factors that drive household renewable energy transitions in Nigeria. The results from data analysis show that fuel price and the unavailable power supply are the main drivers that encourage households to consider using renewable energy technologies. Contrary to the energy ladder model (Yadav et al., 2021), the results of this study do not show an upward transition to cleaner fuel for urban households. Instead, findings show urban households using clean, modern fuels and traditional fuels like firewood and charcoal despite their perceived advancement in socio-economic status, contrary to the conventional trajectory observed in many global contexts (Dioha & Emodi, 2019). Our findings show that this reverse transition is mainly due to a lack of access to electricity, economic conditions and, interestingly, cultural issues such as the taste of food cooked with firewood. Thus, we contribute to the literature by showing firstly, how context may influence the acceptance of renewable energy. Specifically, we show that households' acceptance of renewable energy is a fluid process as opposed to the assumption that households in developing countries would transition to renewable energy linearly. The interplay between energy ladder and energy stacking behaviours underpins Nigeria's MLP theorisation of energy transition. Addressing energy transition in Nigeria requires understanding household behaviours in a socio-technical context (Geels, 2019). Second, we provide insights into missing empirical studies which found energy-stacking behaviour (Oyeniran & Isola, 2023; Emodi et al., 2022). We shed more insights into the fluidity of energy stacking behaviour in the Nigerian context by uncovering how participants' cultural preferences may influence their decision to use traditional cooking methods instead of electricity. Thus, contributing to the literature on energy stacking behaviour in Nigeria and, by extension, LMICs.

In Nigeria's context, the energy transition patterns diverge significantly from the general global trends, thereby elevating the

significance of its unique contribution to the discourse. Nigeria's unique trajectory implies that socioeconomic and cultural factors are intricately interwoven into its landscape and influence household energy choices. This observation not only refines our understanding of global energy dynamics but emphasises the need for context-specific analyses. The findings from the experience of surveyed households for this study broaden the understanding of energy transitions, serving as a valuable case study that deepens insights into the complex interplay of factors shaping energy choices in diverse regional contexts. The findings from this study have various policy implications for household renewable energy transitions. First, given the lack of infrastructure to support electricity generation in the LMICs, in the interim, the government can support businesses in investing in the manufacture of eco-friendly cooking stoves and generators and subsidising them to be affordable. This will significantly reduce the carbon emissions generated by households. Second, the government should consider creating energy policies that support widening access to electricity for urban and rural households, recognising the energy challenges of households. Third, introducing market-oriented reforms that bring about energy price caps and subsidies could encourage renewable energy transitions. Lastly, government policies need to be backed by national orientations addressing cultural views that drive energy-stacking behaviour and, thus, hinder energy transition. Our study is not without limitations. First, we acknowledge a limitation in our study's data size and analytical techniques. While our study is exploratory and provides novel insights into household energy transition behaviour, we note that the cross-sectional nature of the data limits the interpretation of transition behaviour and causality conclusions. Future studies should adopt a multisource and possibly provide a longitudinal dimension of the subject. However, our inclusion of open-ended questions provided additional insights into the challenge of energy transition in the Nigerian context, thus supplementing our statistical findings. More so, we ensured that our sample included households across the major regions. Second, data was collected from Nigeria alone. While this may limit our findings in other contexts, we have justified earlier that Nigeria's demography is similar to many countries in Sub-Sahara Africa (Pepple et al., 2024). As such, our findings may have wider implications.

CRediT authorship contribution statement

Daminabo Pokubo: Writing – original draft, Project administration, Investigation, Data curation, Conceptualization. **Dennis Gabriel Pepple:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Amin Al-Habaibeh:** Writing – original draft, Project administration, Investigation, Data curation, Conceptualization.

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