Evaluating renewable energy choices among rural communities in Nigeria. An insight for energy policy

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Abstract

Purpose – This study aims to examine the effects of policy incentives and cost on the choice and use of renewable energy in North-Central Nigeria.

Design/methodology/approach – The data for this study are collected from a sample of 290 respondents drawn from across 6 states in North-Central Nigeria, including the Federal Capital Territory. This study uses descriptive statistics and multinomial logistic regression to analyze the data.

Findings – The findings reveal that there is a huge potential demand for renewable energy sources (particularly solar photovoltaic) in the rural communities in Nigeria. It also indicates a positive and highly significant relationship between the level of awareness, availability and income and the use (consumption) of renewable energy sources among the rural communities. Furthermore, the cost of installation and maintenance of renewable energy, its reliability and availability are significant determinants of renewable energy choices among rural inhabitants in Nigeria.

Practical implications – The authors submit that inefficient policy strategies, high cost of installation and lack of awareness remain the major hindrances to the use of more efficient renewable energy sources. From a policy point of view, a viable strategy for effective use of renewable energy sources is the involvement of government, development partners and agencies for the funding of renewable energy technology in the rural sector of the country. The usage of modern renewable energy would increase if policy incentives are aimed at covering parts of the maintenance and installation cost of renewable energy users. The authors recommend that apart from creating awareness on the benefits of renewable energy, policymakers should provide a desirable policy environment for private energy firms to supply renewable energy at an affordable cost to the rural communities in Nigeria.

Social implications – A majority of the rural households in Nigeria, as shown in this article, are poor and therefore use firewood as their main source of cooking energy because of the cost of renewable energy.

JEL classification – O38, P25, P28, Q42, Q48

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Originality/value – Despite the abundance of renewable energy sources and government effort at improving renewable energy use, more than 15 million people live without access to electricity and 54 million are without modern energy services for cooking and lightening in Nigeria. A total of 61% of these people live in rural areas. Therefore, this study is novel in providing energy policy insights for rural communities in North-Central Nigeria.

Keywords Renewable energy, Rural energy use, Policy incentives, Solar photovoltaic, Biomass, Hydropower, Cost, Regression, Mail questionnaires

Paper type Research paper

1. Introduction

Availability, affordability and reliability are three essential ingredients inherent in the choice of energy consumers. The determinant of energy choice remains a highly contestable discussion in academic literature. In recent times, environmental consideration is often put forward as justification for the need to shift from fossil fuels to renewable energy (RE henceforth), yet a number of factors tend to inhibit the incursion of RE in most nations. For developing countries such as Nigeria, arguably, energy is inevitable for poverty alleviation and the production of goods and services. The success of the United Nations' Sustainable Development Goals (SDGs) (2018) depends, among other factors, on access to a clean and sustainable energy source. However, according to a World Bank report (2018), more than 15 million people live without access to electricity and 54 million are without modern energy services for cooking and lightening in Nigeria. A total of 61% of these people live in rural communities far-flung from national electricity grid [International Energy Agency (IEA), 2017]. Although there is abundance of RE sources such as sunlight, hydro, geothermal, biomass and wind, government efforts at improving RE use in the rural areas has not produced the desired outcome. While the call for RE use to curb climate change has increased in Nigeria, what are of utmost concern for consumers is the affordability and the reliability of its supply.

This paper explores these issues by examining the effects of policy incentives, cost, availability and reliability of RE supply on RE use among rural populations in the North-Central states of Nigeria. This is vital for two reasons: first, the Nigerian government pledged her commitment to ensuring the security of energy supply and encouraging the use of RE in the United Nations Framework Convention on Climate Change (UNFCCC). The commitment aimed at mitigating climate change, provide clean energy and reduce greenhouse gas emission (UNFCCC, 2015). With about 60% of its population living in rural areas, it is crucial to examine the willingness and response of this populace to the prospect of conversion from conventional and traditional energy sources to RE. Second, laying a clear-cut plan toward achieving the objectives of securing energy for all citizens is predicated on understanding the best policy that will ensure maximum response from citizens. For instance, detailed data on how rural populations can participate in the development and use of RE is necessary for effective policy implementation. Moreover, strategies on how the rural communities will be carried through the process of change in energy use from traditional (use of wood for fuel) to the more efficient and modern use of renewable technology are important.

Empirical research linking the responses and willingness of final users to RE incentives in the rural areas of Nigeria remains scanty. This study complements existing literature by unveiling several insights on RE use in Nigeria. For instance, previous studies link RE use to income (Tugcu *et al.*, 2012; Aliyu *et al.*, 2018). Inherent in these studies is the assumption that consumers have attained a certain level of income or at least live above the poverty line,

whereas in reality, most people living in the rural areas where the bulk of RE use is required still live below the poverty line. Second, despite its benefits, the rates at which people adopted the use of some RE technology in rural communities in Nigeria are far less explored. For instance, United Nation Environmental Protection (UNEP) (2017) pointed out that risk factors such as high cost and maintenance of RE technologies, high cost of loan and inadequate skilled labor affects the competitiveness of RE in developing countries. However, we hypothesize that these challenges notwithstanding; the level of awareness also affects the use of RE. The dearth of information on the availability of RE explains why despite the government's effort to promote its usage by providing efficient cooking stoves and solar photovoltaic (PV) panels, participation is not extensive. Hence, there is a need to assess empirically the factors that could be the proximate cause for the under-utilization of RE sources in Nigeria. More so, the absence of a specific study on the implications of these issues on the predominantly agrarian economy of the North-Central states of Nigeria (the food belt of the country) underscores the need for this paper.

We used multinomial logistic regression to capture the responses of RE use to cost, incentives and reliability of RE sources in rural Nigeria. Our estimates show that there is a strong relationship between the level of awareness, availability of RE sources and RE use in Nigeria. The study also shows that although many users prefer the use solar PV as an alternative to their current energy sources, they are however constrained by installation and maintenance costs of solar PV. Many rural dwellers prefer the use of traditional energy sources such as firewood because of the reliability of supply. We show that poor policy limits rural sector response to government incentives toward shifting from traditional energy to modern and clean energy sources.

The organization of this paper is as follows: after the introduction, Section 2 discussed the RE potentials in Nigeria; Section 3 reviews the theoretical and empirical literature on RE; Section 4 presents the data and the methods used in data collection; it also develops the multinomial logistic regression that is used to analyze the collected data. The results of the logistic regression are presented in Section 5, whereas Section 6 contains the summary, concluding remarks and recommendations of the study.

2. Renewable energy potentials in Nigeria

Tapping into the abundant supply of RE sources is imperative for Nigeria to drive toward achieving sustainable development. This is because exploiting energy from RE sources is vital for energy efficiency, conservation and preserving the environment.

Recently, Nigeria has increased investment in RE sources, though most investments in RE are carried out by government with little private participation. The capacity and potential for generating RE in Nigeria are shown in Table 1 and discussed below.

Hydropower is the major RE that has hitherto been put to use in Nigeria because of the abundance of small and large rivers. However, hydropower generation is still underexploited despite the potential of large and small hydropower. The large hydropower in Nigeria has the potential of generating 11,250 MW but the present production capacity is 1,900 MW. Small hydropower stations have the potential of generating 3,500 MW, but the present electricity production stands at 64.2 MW. Despite being the most used RE source in Nigeria, hydropower mostly supply energy to the national grid. Because of high initial cost of building and generating energy from hydro, hydropower projects are predominantly handled by the government for supply to national grid. This makes the construction of small hydropower generation for rural settlements is still low, as the construction of small dams is quite difficult and has no economic benefit because of the nature of scattered settlements

Resource type	Reserves		Production	Domestic utilization (natural unit)	2030 projection Expected increase (%)
	Natural units	Energy units			
Small hydropower	3,500 MW	0.34 (over 40 years)	30 MW	30 MW	7.07
Large hydropower	11,250 MW	0.8 (over 40 years)	1,938 MW	1,938 MW	7.07
Wind	2–4 m/s at 10 m height (main land)	0.0003 (4 m/s @ 12% probability, 70 m height, 20 motor, 0.1% land area, 40 years)	–	–	0.25
Solar radiation	3.5–7.0 kWh/m^2/day	4.2 million MWh/day using 0.1% land area	6 MWh/day	6 MWh/day	5.90
Biomass fuel wood	11 million hectares of forest and wood land	Excess of 1.2 m ton/day	1.2 million ton/day	1.2 million ton/day	2.78
Animal waste	211 million of assorted animals	–	0.781 million tons of waste/day	None	2.78
Energy crops and agricultural residue	28.2 million hectares of arable land	–	0.256 million tons of assorted crops/day	None	2.78

Table 1.
Capacity and potential for generating renewable energy in Nigeria

prevalent in most rural areas in Nigeria. Although the marginal cost over time is low, the potential for hydropower growth is 7.07%.

Among clean RE sources in Nigeria, solar PV remains the second highest level of power generation from renewable source after hydro (Ozoegwu *et al.*, 2017). In homes, solar PV is becoming the most preferred energy sources, especially for light appliances, because of its reliability. The potential for solar energy is high because of abundant supply of sunlight across the country. The estimated solar energy potential is 4.2 million MWh/day using 0.1% land area (Ozoegwu *et al.*, 2017). However, generated energy from solar is only 6 MWh/day which is infinitesimal compared to the potential (Ozoegwu *et al.*, 2017). The initial cost of solar PV constitutes a major hindrance to adoption and wide spread use especially in the rural areas of the country (Ozoegwu *et al.*, 2017). Major concentration of the use of solar is on street light and individual homes for lighting; however, projected growth of solar energy is 5.07% by 2030. The growth is expected to meet the energy needed for heating and lighting of animal pens, drying of agricultural produce, pumping of water and irrigation, street lighting and the likes.

Energy from wind provides great potential for clean and efficient energy, especially in most part of northern Nigeria. Wind velocity ranges from 2 to 4 m/s and this has huge capacity to generate electricity; however, present generation stands at 10 MW. The expected growth for wind energy by 2030 is put at 0.25%, which is small relative to other RE sources. Energy from biomass in Nigeria is from animal waste, municipal waste, firewood, residue from crops and energy crops. Apart from firewood, most waste products are never converted to energy. Despite the abundance of biomass, it the least source of energy especially for households.

The report in Table 1 indicates low utilization and conversion of RE sources into efficient energy for use. This is despite the continual increase in energy demand over the years,

increase in population and economic activity. This study opined that if the Nigeria government must achieve its commitment to the UNFCCC of 16% RE generation by the year 2030, then RE potentials must be turn into reality. The government is also increasing the level of investment in RE so as to make investment in RE attractive to both private and foreign investors (ECN, 2014). Arguably, the study assumes that one way to attain this target is to increase the use of RE in the country especially in the rural areas. This is important for two reasons:

(1) First, it ensures economic growth and increase the standard of living in the grass root sector.

(2) Second, it will help the country to meet the Intended Nationally Determined Contributions target to the UNFCCC.

3. Literature review

Several studies have shown that there is a strong link between rural electrification and rural economic growth (Ahlborg *et al.*, 2015; Kaufman and Sequra-Ulbiergo, 2001; Apergis and Danuletiu, 2014). For instance, Apergis and Danuletiu (2014) studied the relationship between RE and economic growth across 80 countries. They found a positive causality running from RE to economic growth. Similarly, Jebli and Youssef (2013) studied the relationship between RE, trade and output among 11 African countries from 1980 to 2008. The study found that RE consumption had a positive and significant impact on output although there is no causal relationship between RE consumption and output in the selected countries. The findings of these two studies suggest the importance of RE to economic growth. However, establishing the long-run causal relationship between RE and economic growth may be difficult now because apart from hydro, the adoption of RE in many countries is slow and quite recent to enable a robust result in a causality estimate among the variables. Besides the individual effect and specific peculiarity, the adoption of RE especially among developing nations on a large scale is insignificant.

Kardooni *et al.* (2016) investigated the impact of cost and knowledge on the perceived usefulness of RE technology in Peninsular Malaysia. The result of their study shows that the cost of RE technology has an indirect effect on attitudes toward the use of RE in the region. Similarly, Stigka *et al.* (2014) studied the social acceptance of RE sources as a substitute for fossil fuels in electricity generation. Using the contingent valuation method to analyze arrays of literature, the study found that the willingness to pay and use RE technology is affected by the level of education, interest in environmental issues and knowledge of RE sources. Ngala *et al.* (2007) used the cost–benefit analysis to study the viability of wind energy as a power generation source in the Borno state of Nigeria. The authors observed that the high cost of renewable technology is not the only factor inhibiting the implementation of a RE project in Nigeria, more cogent is a shortage of skilled personnel. Probably, the shortage of skilled personnel and the cost of maintenance account for the poor patronage of RE technology among most rural communities, especially given the low level of people living in rural areas.

United Nation Environmental Protection (UNEP) (2017) reported that the low participation and commitment to RE by most African countries is because of the belief that environmental pollution is carried out by developed countries as Africa as a whole contributes only about 3.6% of world environmental carbon pollution. However, many African countries have renewed commitment to reducing carbon emission. For instance, Nigeria has pledged to RE mix of 16% to its total energy consumption by 2030 (FME, 2015). Namibia is committed to increasing the share of RE in electricity production from 33% to

70% by the year 2030 and Kenya is committed to increasing RE use by 30% by the year 2030 (UNFCCC, 2015).

Cost is also identified as an important determinant of RE use. For instance, Dike *et al.* (2017) observed that high cost and poor installation of solar PV are the main setbacks to the effectiveness of solar energy system in Nigeria. They attributed the ineffectiveness of solar system to importation of substandard products, inferior design, poor maintenance of solar systems and ill-trained technicians. Owusu and Asumadu-Sarkodie (2016) identified market failure, lack of information and access to raw material for future renewable resource deployment as challenges that inhibit the sustainability of RE in most African countries. The study further opined that want of government will and poor financing result in high cost and low use of RE in a large number of African states.

The place of price in energy choice and use is vital, especially among households. Mensah and Adu (2015) examine the dynamics of cooking fuel choice among Ghanaian households. The study reveals that price, reliability of supply and income are the driving force of households' energy choices for cooking. In a related study, Inhoffen *et al.* (2019) investigated the effect of minimum prices and social interaction on RE programs in Germany. They observed social interaction rather than rational economic decisions affects the installation of PV systems in southern Germany, resulting in the installation of PV systems in areas where they produce inefficient energy.

Lin and Chen (2018) also studied the relationship between electricity prices and innovation in RE in China. The study revealed that higher electricity price makes RE competitive and increases innovation of RE technology in the long run.

Aliyu *et al.* (2018) reviewed the energy policy frameworks of South Africa, Egypt and Nigeria to evaluate the prospects of four RE sources – hydro, solar, wind and biomass – in each of the countries. The study revealed that South Africa performs better in terms of using RE sources in meeting the energy challenge of its citizens. The study also showed that although Nigeria has great potentials in RE sources, it is still weak in terms of appropriating energy from RE sources. The authors concluded that proper energy technology, awareness and skills for harnessing RE are necessary for achieving the various RE policies in each country.

Stenzel and Frenzel (2008), in their study of the expansion of wind energy in Germany, pointed out that countries in the EU mostly adopt RE technologies that are cheap and environmentally friendly. The adoption of new RE technology becomes risky when its ability is uncertain. For instance, wind energy had a major expansion in Spain compared to the UK because of the low cost of the technology used and the types of policy implemented. In Nigeria, RE from solar and biomass constitutes a major source of energy especially for the rural sector for heating and lighting of animal pens, drying of agricultural produce, pumping of water and irrigation, street lighting and the likes; the use of renewable is still infinitesimal relative to urge potential. Thus, the development of renewal energy will boost the rural economy.

The studies reviewed thus far showed the importance of government policies to RE use. It also indicates that studies on the response to policy incentives in the rural areas of Nigeria are scarce. Also, one major drawback observed in the empirical literature is the generalization of responses to RE use as a whole or in part to government policies, an omission this study seeks to address by analysing the response of the rural consumers.

4. Data source and methods

The data used for this study was obtained from 290 respondents across six North-Central states of Nigeria and the Federal Capital Territory (FCT) Abuja. The North-Central states

are Benue, Niger, Kwara, Nasarawa, Kogi and Plateau. According to the National Population Commission (2006), the total population of the study area is 20 million. Using Freund and Williams (1983) formula, 290 wards were determined as the sample size. Questionnaires were then administered for the collection of relevant information regarding the use of RE.

Based on the theoretical framework, we assume households are expected to gain utility in choosing a RE source. The expected utility gained for choosing a RE source is specified thus:

$$V_{ij} = X_i\beta + \varepsilon_i \tag{1}$$

where V_{ij} is the utility gained from using RE j by household i. X_i is the vector of explanatory variables such as the income of the household, the cost of RE and others. ε_i is the random error that captures the unobserved characteristics of households. ε_i is assumed to be independently and identically distributed. β is the coefficient for the vector of explanatory variables.

This study uses the multinomial logistic regression model to determine the probability of the household's choice of RE. Households' energy needs include energy needed for cooking, lighting, heating and other domestic use. The multinomial logit model is suitable in estimating the probability of household selecting a particular energy source for its domestic use given other household energy choice. Thus, we apply the multinomial logit model to investigate the effect of the cost of RE, consumer awareness, education and income of household head on the choice of RE in the North-Central states of Nigeria. The use of logit regression demands that the dependent variable is a binary digit. In this case, the dependent variable is the probability of choosing RE sources. We coded the responses 1 if the respondent chooses a particular RE source and 0 if otherwise. RE sources used in this study are solar PV, wind, hydro and biomass. The choice of these RE sources is based on the RE sources common in Nigeria for cooking, lighting and other residential use. Because we use the multinomial logistic regression, we run the regression for the probability of choosing each of the RE sources concerning a baseline choice category. The general model for the logistic regression is stated thus:

$$Pr(R_{ij} = 1/Y_i,\ E_i,\ C_i,\ A_i) = \frac{\exp(\beta_0 + \beta_1 Y_i + \beta_2 E_i + \beta_3 C_i + \beta_4 A_i)}{1 + \exp(\beta_0 + \beta_1 Y_i + \beta_2 E_i + \beta_3 C_i + \beta_4 A_i)} \tag{2}$$

The logistic regression can thus be expressed as follows:

$$\text{Log}\left[Pr\left(R_{ij} = \frac{1}{Y_i},\ E_i,\ C_i,\ A_i\right)\right] = \beta_0 + \beta_1 Y_i + \beta_2 E_i + \beta_3 C_i + \beta_4 A_i \tag{3}$$

where R_{ij} is the probability that household i uses RE source j. $R_{ij} = 1$ if household i chooses RE source j and zero otherwise. Y_i is the income of the household, E_i is the level of education, C_i is the cost of RE and A_i is the awareness of RE sources. The choice of the explanatory variables is based on two complementary theories: the Von Neumann-Morgenstern (1944) Expected Utility Theory (NMEUT) and choice awareness theory by Lund (2000). The NMEUT explains optimal decisions under risks and uncertainty. It states that expected utility (returns) influences the investment decision of an individual. Expected utility is the average utility the individual stands to gain from all his/her investment given his/her utility function. Expected returns is maximized when expected benefit is higher than expected cost. An individual will invest only when the expected utility of such investment is higher than

investing on other alternative project/venture. Because the individual tends to act rational, he/she tends to choose a project (in this case, investment in energy source) with high expected returns. In terms of investment in energy, because the initial investment in energy is sunk cost, a rational investor considers two things: the initial cost and the long-run payback or returns. High initial cost put off a risk-averse investor even when future benefit is high. Thus, the NMEUT identifies the relevance of cost in the choice decision and thus provides the basis for the inclusion of cost as a determinant of choice and usage of RE sources considered in this study.

The theory of choice awareness explains how societal perception and choice of energy use is affected by people's awareness about the existing alternatives to their current energy source. According to the theory, public participation and decision are determined by their awareness of energy options. The theory describes the possibility of implementing change in energy use such as the transition from fossil to RE. Public discussion of alternatives raises public awareness of choice of energy and brings household to the point that, as a consumer, they do have a choice. The theory posits that transition from fossil to RE involves concrete public discussion that will influence the general perception of choice in the society where households begin to see other alternatives to existing fossil energy sources. Hence, awareness is included in the regression model of this study as one of the explanatory variables. In addition, empirical studies have identified the included explanatory variables in this study as important drivers of energy choice and demand (Inhoffen *et al.*, 2019; Kardooni *et al.*, 2016; Stigka *et al.*, 2014; Adu, 2015; Ngala *et al.*, 2007).

5. Results and discussion

5.1 Preliminary analysis

To examine the validity of the instrument used in the research, we conducted the common method bias test to examine the variances in the responses that may result from a faulty research instrument rather than the predisposition of the respondents. The questionnaire was self-designed and may be susceptible to the common method bias. As a result, we conducted Harman's single-factor test for common method bias.

Table 2 contains the result of the common method bias test and it shows that there is no common method bias in the responses. This is indicated by the cumulative single-factor loading (35.68%) which is less than 50% threshold for which an instrument is considered to have common method bias. Therefore, the responses generated with the research instrument in this study are valid for discussion and policy inferences.

Table 3 contains the demographic and socioeconomic characteristics of the respondents. The result shows that most of the respondents, selected from across North-Central Nigeria (six states and FCT), are males (70.7%), youths – between the ages 18–40 (74.8%), married (66.6%) and who practice either Christianity (54.8%) or Islam (43.4%). The distribution of demographic characteristics is a fair representation of the active population of the rural communities in the country. Most of the rural communities are patriarchal settings with dominant youth population and active religious participation and dominance of early

Table 2. Common method bias test

Total variance explained						
	Initial eigenvalues			Extraction sums of squared loadings		
Component	Total	% of Variance	Cumulative (%)	Total	% of Variance	Cumulative (%)
Single factor	8.564	35.684	35.684	8.564	35.684	35.684

Variable	Frequency	Valid (%)	Cumulative (%)
State (region)			
Benue	52	17.9	17.9
Federal Capital Territory	12	4.1	22.1
Kogi	52	17.9	40.0
Kwara	39	13.4	53.4
Nasarawa	43	14.8	68.3
Niger	53	18.3	86.6
Plateau	39	13.4	100.0
Total	290	100.0	
Gender			
Female	85	29.3	29.3
Male	205	70.7	100.0
Total	290	100.0	
Age			
18–30	84	28.9	28.9
31–40	133	45.9	74.8
41–50	55	19.0	93.8
51 and above	18	6.2	100.0
Total	290	100.0	
Religion			
African traditional religion and others	5	1.7	1.7
Christianity	159	54.8	56.6
Islam	126	43.4	100.0
Total	290	100.0	
Marital status			
Married	193	66.6	66.6
Single	97	33.4	100.0
Total	290	100.0	
Level of education			
Informal/adult literacy	7	2.4	2.4
Junior secondary school	23	7.9	10.3
None	4	1.4	11.7
Primary	17	5.9	17.6
Senior secondary school	85	29.3	46.9
Tertiary institution	154	53.1	100.0
Total	290	100.0	
Level of income			
Less than ₦10,000	97	33.4	33.4
₦10,000 – ₦29000	78	26.9	60.3
₦30,000 – ₦49,000	67	23.1	83.4
₦50,000 – ₦69,000	27	9.3	92.8
₦70,000 and above	21	7.2	100.0
Total	290	100.0	
Occupation			
Farming	99	34.1	34.1
Civil service	80	27.6	61.7
Trading	70	24.1	85.8
Others	41	14.1	100
Total	290	100.0	

Table 3.
Demographic and socioeconomic characteristics of respondents

marriages. For instance, in most of the rural areas, only married and religious adults are considered responsible. The distribution equally shows the eminent potential need for energy. This is because the youths are the largest consumers of energy all around the world. The results further indicate that about 53.1% of the respondents attended tertiary institutions and mostly engage in farming (34.1%) and civil services at the local governments and state levels (27.6%). Also, the result shows that most of them earn less than ₦10,000 (less than $28) per month, whereas 26.9% of them earn between N10,000 and ₦29,000 ($28 and $80) monthly. This implies that the majority of the respondents live on less than 1$ per day, whereas few live on an average of $1.8 (less than $2) per day. The result implies that the majority of the rural dwellers in the study area are extremely poor. Hence, the prevalence of extreme poverty in the rural communities of North-Central Nigeria is portrayed by the result. This socio-economic structure is important in developing effective strategies for RE use in the rural sector of Nigeria.

The level of use of RE sources in the rural communities was also examined and their responses are provided in Table 4. The result demonstrates that most (75.5%) of them use biomass. This enormous use of biomass is indicated by the use of firewood as the main source of cooking energy. About 64.1% of them use firewood for cooking. Few of them, 9.7%, 10.3% and 13.1%, use charcoal, gas and kerosene, respectively, whereas negligible number (2.8%) of them use electricity for cooking. Moreover, the majority (50%) of them use the lantern as a source of light, whereas 46.6% of them use electricity. It is important to note here that the electricity is provided by small power generators, which cost about N15,000 (about $40) to acquire. They rely on the small generators because most of the communities are not connected to the national power grid, and as such, there is no alternative source of electricity for them.

Having assessed the level of use of RE in the study area, we examined the reasons for the enormous use of firewood instead of the improved sources of RE such as solar PV, wind turbine and hydropower. The result shows that the majority of them (59.7%) do not prefer their current source of energy to RE. They are using the current source mainly because of its availability and affordability. They can easily fetch firewood from their farms and use it for

Table 4. Renewable energy use

Source of energy	Frequency	Valid (%)	Cumulative (%)
Biomass	219	75.5	76.2
Hydropower	29	10.0	86.2
Solar PV	34	11.7	97.2
Wind	8	2.8	100.0
Total	290	100.0	
Source of cooking energy			
Charcoal	28	9.7	9.7
Electricity	8	2.8	12.4
Firewood	186	64.1	76.6
Gas	30	10.3	86.9
Kerosene	38	13.1	100.0
Total	290	100.0	
Source of light			
Electricity	135	46.6	46.9
Firewood	9	3.1	50.3
Lantern	146	50.3	100.0
Total	290	100.0	

cooking. It is also indicated that their current source of energy is not efficient compared to other sources of energy. This implies that other sources of energy such as solar PV will be preferred when cheaply provided in the communities.

A question was asked on the preferred choice of the respondents if they are provided with different options of RE sources. The responses indicate that the majority (66.9%) of them chose to use solar PV in their homes as a renewable source of energy. This shows that the rural communities of North-Central Nigeria prefer solar PV to other sources of RE. Meanwhile, it is pertinent to know the factors that hinder them from using their preferred source of RE. In this regard, separate questions were asked on the effect of the cost of RE, the culture of the people and other hindrances. The result reveals that the cost of RE, lack of government incentives and lack of information on how it works are the major hindrances of the use of the preferred source of RE. Further, it is indicated that culture does not hinder the use of RE in the study area. In addition, the cost of installation was considered by the majority (45.5%) of them as the only disadvantage of the renewable sources of energy over the current sources of energy use in the communities.

The level of government engagement on the provision of RE was also assessed. This was done by examining the availability of government projects on RE in the communities. The result unveils that the majority (62.4%) of the communities do not have government projects using renewable sources of energy. However, few (37.2%) affirm the presence of government projects such as school libraries, clinics and boreholes using solar PVs as the source of energy. We have visited some of the places for confirmation.

5.2 Results of regressions analysis

To evaluate the impact of cost on the use of different types of RE in rural communities in North-Central Nigeria, multinomial logistic regression was used. Choosing biomass as the base (reference) category, the result is presented in Table 5. The result shows that the coefficients of all the explanatory variables (education, income, awareness and cost) are positive and statistically significant for wind. Similarly, education and cost, as well as awareness and cost, are highly significant for solar PV and hydropower, respectively. This connotes that level of education, income, awareness and cost are significant determinants of the use of RE sources in the study area. The result indicates that, with an increase in the level of education, income, level of awareness and cost of energy, there is more likely that the rural dwellers will use other sources of RE instead of biomass. Alternatively, it suggests that they use biomass because of poverty (low level of income), low level of education, lack of awareness and low cost of biomass. It is not necessarily that they prefer biomass to the other sources of RE. With higher levels of income, education, awareness and cost, there is more

Variables	(1) Wind	(2) Solar PV	(3) Hydropower
Education	14.06*** (1.051)	1.011 (0.748)	1.257** (0.622)
Income	0.774*** (0.139)	0.0119 (0.242)	−0.252 (0.227)
Awareness	12.61*** (1.111)	14.19*** (0.700)	0.708 (0.875)
Cost	0.472** (0.210)	1.870*** (0.374)	0.860*** (0.249)
Constant	−82.59*** (5.458)	−10.12* (6.129)	−15.23*** (4.535)

Notes: Robust standard errors in parentheses; ***, ** and * denote 1%, 5% and 10% level of significance, respectively
Source: Authors' computation

Table 5. Determinants of the use of renewable energy with biomass as base outcome

likelihood of using wind, solar and hydropower instead of biomass. Also, with more awareness about RE, the rural dwellers are more likely to use wind, solar and hydropower instead of biomass. This implies that the use of biomass is a result of its lower cost relative to the cost of the others. So, other things being equal, a rise in the price of biomass will result in more likelihood of using other sources of RE.

In Table 6, where hydropower is the base category, all the independent variables (education, income, awareness and cost) are statistically insignificant for wind. The level of education and cost are negatively related and statistically significant for biomass, wherea the cost is positively related and statistically significant for solar PV. This means, with higher levels of education and the cost of RE, there is less likelihood that biomass will be used instead of hydropower. On the other hand, there is more likelihood that solar PV will be used instead of hydropower.

The result in Table 7 shows that cost is the only significant determinant of RE use when solar PV is considered as the base category. The coefficient of cost is negative and statistically significant at 1% level for hydropower and biomass. This demonstrates that the higher the cost of RE, the less likelihood that hydropower and biomass will be used instead of solar PV. In summary, the logistic regression results show that education, income, awareness and cost of installation are the significant determinants affecting the choice and use of RE in rural communities in North-Central Nigeria. The result implied that cost is the most important determinant (significant for all base categories), whereas solar PV is the preferred source of RE for the rural dwellers in North-Central Nigeria.

5.3 Summary of findings

5.3.1 Awareness about renewable energy sources

- Most of the people in the rural communities are aware of the existence of RE sources and know its difference with non-RE but they do not have access to it.
- Their awareness is limited to solar PV as the only source of RE. Even biomass that is mostly used in the communities as a source of cooking energy is not known as a source of RE.
- Radio and television are the only sources of their information about RE.

5.3.2 Choice and use of RE

- There is no supply of national grid electricity in the communities.
- Firewood is the main source of cooking energy in rural communities.
- Lantern is the major source of light in the communities.

Table 6.
Determinants of the use of renewable energy with hydropower as base outcome

Variables	(1) Wind	(2) Solar PV	(3) Biomass
Education	12.806 (1,775.1)	−0.2459 (0.8378)	−1.2574* (0.6660)
Income	1.0263 (0.9460)	0.2641 (0.2795)	0.2521 (0.2357)
Awareness	−11.903 (2,994.0)	−13.483 (758.09)	0.7085 (1.1675)
Cost	−0.3878 (1.0167)	1.0099*** (0.3302)	−0.8602*** (0.2697)
Constant	−67.360 (11,064)	5.1100 (758.11)	15.227*** (4.9310)

Notes: Robust standard errors in parentheses; *** and * denote 1%, and 10% levels of significance, respectively
Source: Authors' computation

- Few of them use small power generators as a source of electricity.
- Solar PV is the preferred choice of RE source in the communities.

5.3.3 Reasons for the use of the current source of energy instead of a renewable source of energy

- The use of the current source of energy is because of its availability and affordability rather than preference.
- The high cost of RE.
- Lack of technical know-how about the sources of RE.
- Lack of government incentives and engagement to acquire RE technology.
- Cost of installation, education, income level and awareness are the major determinants of the use of the types of RE sources in the communities.

6. Conclusions and policy recommendations

The implementation of sustainable energy policies is fundamental to achieving developmental objectives in Nigeria. Unfortunately, despite the abundance of RE sources, most of the RE sources such as sunlight, hydro, geothermal, biomass and wind remained underexploited. The government has tried to reverse this tide by committing to clean energy mostly from renewable sources. The rural sector has the highest population and mostly lack access to national grid electricity for its household use. We examine the effects of cost, reliability of RE supply and incentives on responses to RE use among rural communities in the North-Central states of Nigeria. To achieve this goal, we administered 301 and retrieved 290 questionnaires covering the six states of the North-Central region of Nigeria and the FCT. The responses from the questionnaires were used to estimate the probability for households using modern RE in the rural sector. We found that most of the people in rural communities are aware of the existence of RE sources and know the difference between it and non-RE but they do not have access to it. Their awareness is, however, limited to solar PV as the only source of RE. Even biomass that is mostly used in the communities as a source of cooking energy is not known as a source of RE. We find that radio and television are the only sources of their information about other types of RE as most of the respondent has not physically seen wind and hydro as a RE source.

This study shows that there is a huge potential demand for RE sources (particularly solar PV) in rural communities in Nigeria as solar PV is the preferred choice of RE source in the communities. However, because of the high cost of purchase and

Variables	(1) Wind	(2) Hydropower	(3) Biomass
Education	13.052 (1,775.1)	0.2459 (0.8378)	−1.0115 (0.6636)
Income	0.7622 (0.9406)	−0.2641 (0.2795)	−0.01193 (0.2259)
Awareness	1.5798 (3,088.5)	13.483 (758.09)	14.191 (758.09)
Cost	−1.3977 (1.0180)	−1.0099*** (0.3302)	−1.8701*** (0.3073)
Constant	−72.470 (11,090)	−5.1100 (758.11)	10.117 (758.10)

Notes: Robust standard errors in parentheses; *** denotes 1%, level of significance
Source: Authors' computation

Table 7. Determinants of the use of renewable energy with solar PV as base outcome

installation, poverty and lack of government engagement and incentives for the development of RE technology, rural communities still use firewood for cooking. Lantern is the major source of light in the communities and few of them use small power generators as a source of electricity.

Concerning the probability of choosing RE in the rural sector, we find that the cost of installation, education, income level and awareness are the major determinants of the use of the types of RE sources in the communities. The study, therefore, recommends, among others, the creation of awareness on the importance of using clean RE. Creating strong grassroots awareness on the implication of using traditional energy on the environment and health of the user will increase interest in RE in the rural sector. Second, the probability of using modern RE is likely to increase if policy incentives are aimed at covering parts of the maintenance and installation cost of RE users. Our study shows that most respondents are kept from the use of solar PV as an alternative to their current energy source because of the cost of installation and maintenance. Applying such a policy arguably could increase the demand for RE technology in Nigeria and the use of RE in the rural sector. In India, for instance, the government introduced the viability gap funding, where the government pays part of the solar plant cost upfront, thus reducing the cost for private individuals to bear the other part and the running cost (Khana and Barroso, 2015). If this is applied, it will encourage more rural dwellers to use RE from solar PV.

In addition, from a policy point of view, a viable strategy for effective use of RE sources is the involvement of government, development partners and agencies for the funding of RE technology in the rural sector of the country. Unfortunately, this position remains true for the most part of rural communities in Nigerian, as shown in this paper that rural households use firewood as their main source of cooking energy because of the cost of RE.

The results of our study are similar to Mensah and Adu (2015) but differ from other literature such as Adaramola *et al.* (2011). There is a dearth of literature on rural areas' response to RE sources especially in Nigeria and other sub-Saharan African countries. More research on this area would be greatly impactful in exploiting RE as a viable clean and efficient source of power for these countries. For instance, further research could focus on the choice of RE in the rural sector by using longitudinal data that covers the rural sector in Nigeria. Our data only covered six states and the FCT; elaborate data that covers all the 36 states and cut across time will provide more robust analysis and conclusion.

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