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Spatial and Temporal Analysis of Energy Consumption by Nigerian Households

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ABSTRACT

To actualize the SDGs by 2030, it is imperative to assess the successes of nations (especially developing ones) in achieving the set goals. One of such goals is guaranteeing access to dependable, friendly and inexpensive energy for all. Although energy is an essential need of every household, many households in Nigeria are deprived of contemporary energy access. This study aims at ascertaining the prevalence of energy deprivation, the determinants of energy deprivation, energy choices and intensity of energy consumption in Nigeria. The study utilized two rounds of the Nigerian General Household Survey (NGHS) data for comparison and estimation. While both the NGHS 2015/16 and NGHS 2018/2019 were used for estimating the prevalence of energy deprivation, only the NGHS 2018/2019 was utilised in estimating the determinants of energy deprivation, choices and intensity of energy consumption. The study replicated and utilized the multidimensional energy deprivation index (MEDI) in estimating energy deprivation prevalence in Nigeria. Also, multivariate Probit and censored Tobit models were utilized in analysing determinants of energy deprivation and choices and energy consumption intensity respectively. The study found that there is a high prevalence of energy deprivation in Nigeria. In addition, there is a significant difference in energy deprivation across the various geopolitical zones in Nigeria. Energy deprivation is more widespread and intense in Northern Nigeria than in the Southern Nigeria. Similarly, the North East and North West zones appear to be the most vulnerable to energy deprivation with rural households being more energy deprived than their urban counterparts. Furthermore, the study revealed that energy deprivation and energy choices in Nigeria are driven by several factors including residential location, attributes of the head of household such as age, education, wealth ownership, availability of social safety net, access to loan and lending rate, energy options, access to internet and social insurance. The intensity of energy consumption is also influenced by household size, floor size, and ownership of cooling/heating devices and acquisition of new electronics devices. The study recommends, among other things, that the Nigerian government should establish microgrids as well as deregulate power generation and ownership to enhance energy availability and efficiency in the country

Keywords: Energy Deprivation, Energy Consumption, Household, Nigerian General Household Survey Nigeria.

DEDICATION

I would love to dedicate this work to God almighty, for his infinite grace throughout this work. And to my adoring parents, Mr & Mrs Benjamin Okparaladi, for their unlimited prayers and supports towards the success of this work.

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CHAPTER ONE

1.0. Introduction

Energy is the lifeblood of all contemporary economies (Keho, 2016). It is an important commodity whose type and quantity consumed by households are directly linked to improvements in quality of life (Ouedraogo, 2013). Due to variations in socio-economic position, background disparities, and differing final uses, households make energy consumption decisions by simultaneously choosing a combination of distinct energy sources. For example, a household could choose electricity or kerosene for lighting, while it may opt for traditional fuels or electricity or liquefied petroleum gas or kerosene for cooking, either solely or in a mixture of the various options (Acharya and Marhold, 2018). The choice, inter-swapping of fuel, and substitution behaviour and the ensuing combination of distinct energy sources to meet the energy demands of the households is contingent on several factors. These factors include government energy-related policies, affordability and availability of the different energy sources as well as various household socioeconomic and demographic features (Jeong et al., 2011).

On the flip side, the majority of the world's CO2 emissions are accounted for by households (Jones and Kammen, 2011). In Nigeria, the household sector share of CO2 emissions is greater than the world standard owing to the nation's small per capita consumption of contemporary energy (Saibu and Omoju, 2016). This emission is majorly caused by private back-up generators. Owing to poor electricity provision in Nigeria, roughly three in five Nigerian households have purposively installed generators to minimize welfare losses. Therefore, carbon emissions emanating from Nigeria's household sector are far bigger than those from other sectors in the country, causing continued health-related problems for individuals over a long time (Awofeso, 2011). In fact, on a daily basis, there are several documented deaths cases linked to fume inhalation discharged by environmentally unfriendly generators utilized majorly in Nigerian homes (Ogundipe, 2013; Oseni, 2016).The current level of emission makes Nigeria one of the highest emitting countries in Africa. With her present status as the economic giant in Africa, an increase in investment and economic activities is anticipated to result in surge in energy use and CO2 emission (Gertler et al., 2013).

Energy utilization in Nigeria varies from traditional and sustainable energy sorts like firewood and electricity and liquefied petroleum gas respectively. Nigeria is a party to the Kyoto Protocol and Paris Climate Agreement on CO2 reduction and renewable energy (RE) promotion. To achieve this, the country in 2015 launched the National Renewable Energy and Energy Efficiency Policy (NREEEP) to stimulate RE development. The country has also been committing vast funds into sustainable energy by offering household and community-level grants for RE like biogas, solar among others. Through the NREEEP, Nigeria's objective is to boost the household's sustainable energy access, improve the economic potentials arising from the energy access as well decrease health-related dangers linked with the utilization of traditional and fossil fuels (Omoju et al., 2020).

It is appropriate to posit that reducing consumption from traditional energy sources could decrease health challenges like bronchitis, asthma, acute respiratory infection among others and also lower greenhouse emissions (Sovacool, 2012). Though the energy utilization behaviour of households is linked to the accessibility of energy sources and various functions of the household ranging from cooking, lighting, heating among others needs distinct sources of energy (Acharya and Marhold, 2018). For example, in Nigerian urban regions, kerosene, electricity and liquefied petroleum gas are the primary energy sources for cooking functions. This may not be unrelated to the fact that it could be very hard for urban residents in Nigeria to use firewood because of limited space in urban centres. Conversely, most rural Nigerian households utilize non-clean energy sources like leaves and firewood as their primary cooking energy source (Ozughalu and Ogwumike, 2018). This could be as a result of a lack of rural electrification in Nigeria. Additionally, lack of economic opportunities may further limit them from having an income that could be used in purchasing and sustaining modern energy. Nigeria's rural regions are not linked to the national grid and the bulk of Nigeria's population resides in rural areas (Dimnwobi et al., 2016; Nwokoye et al., 2017).

The utilization of traditional energy has numerous negative effects. Firstly, environmental stability and biodiversity are affected by the want for biomass. For instance, firewood is a rural household's main biomass but local extensive cutting by unsustainable firewood harvesters endangers domestic ecosystems leading to soil abrasion, and precious species losses (Köhlin et al., 2011). This incidence is prevalent in Nigerian rural regions that out of poverty cut these trees for firewood for domestic purposes. Sometimes these trees and firewoods are sold to provide for other pressing family issues. Secondly, the burning of biomass like leaves and straw contributes significantly to air pollution (Radzi bin Abas et al., 2004).

Thirdly, rural households utilization of traditional biomass for domestic purposes contaminates the air (Fullerton et al., 2008), and this has health implications (Rinne et al., 2007). As observed by WHO (2018), the health consequences include bronchitis as well as children acute respiratory diseases. For instance, in 2010, air pollutions from households majorly caused by solid fuels is responsible for about 4.3% of the world loss of disability-adjusted life years and placed as one of the primary risk component for the world illness burden (Lim et al., 2012). Statistics from the World Health Organisation in 2018 shows that millions of deaths are recorded annually as a result of disease-related to air pollution of the household caused majorly by insufficient solid cooking fuels utilization. Because developing countries households are the ones that utilize traditional cooking fuels, it is expected that the majority of these deaths occurred in these developing countries, with perhaps countries like Nigeria being a major stakeholder. Additionally, smokes from kerosene-powered lamps used in the household can have a diverse effect on the eyes (Bhutto and Karim, 2007). Fourthly, poor biomass utilization and the lack of contemporary energy services will, in the long run, hamper social and economic development in several ways. For example, households who do not have adequate resources to spend on contemporary energy will spend the time that would have been used for productive activities collecting firewood (Kaygusuz, 2011; Pachauri and Spreng, 2004).

Most times, in families, women and children are saddled with these responsibilities of collecting firewood; this might decrease the time for studies and other productive engagements. This scenario is what plays out in Nigeria specifically in the rural region. If biomass is replaced by electricity, the available time for study and work could be increased resulting in better household output and educational accomplishment (Cabraal et al., 2005).

Given this, this study focuses on the spatial and temporal assessments of Nigeria's household's energy consumption.

1.1. Research Problem

Access to sustainable, cheap, dependable and contemporary energy sources is a critical engine of social and economic advancement. The significance of energy to economic advancement is apparent in the various interventions and policies, both at the national and global stages (Crentsila et al., 2019). The importance of energy in reducing poverty incidence, powering national economies and most importantly improving household's welfare and living standards cannot be overstressed. Energy significance is further acknowledged in the United Nations adopted sustainable development goals (SDGs) with most of the goals centred at guaranteeing access to dependable, friendly and inexpensive energy for all (United Nations, 2015).

These goals appear unattainable for households in developing nations who depend immensely on firewood and other dirty fuels means for cooking, lighting, and heating, among others. Developing nations' households are usually confronted with various impediments in varying their patterns of energy utilization and transition towards sustainable energy sources. They face a variety of energy sources with changing convenience degrees and their options are limited by the energy source cost and household budget levels (Rahut et al, 2014). One of the most significant challenges faced by households in a developing country is capital. Unlike their counterparts residing in developed countries, individuals in developing countries lack access to economic activities which further limits their access to income. Lack of access to income is tantamount to using cheap energy sources which are very harmful. Roughly 3 billion people in developing nations, particularly in rural regions depend on solid fuels to satisfy their basic energy demands (WHO, 2018). This is worrisome given that this incidence affects the majority of the global population.

The above assertion sums up, to a great extent, the Nigerian energy situation. Nigeria is faced with the issue of insufficient contemporary energy sources access for the majority of the residents which indicates the existence of large energy poverty (Ozughalu and Ogwumike, 2018). For example, data from the National Bureau of Statistics in (2005) and (2010) notes that the majority of the nation's households depended solely on firewood to satisfy their cooking needs. These statistics were further corroborated by the International Energy Agency in 2016 which reveals that 76% of Nigerians household utilized unsustainable energy resources to fulfil their cooking demands.

Additionally, a major pointer of insufficient access to contemporary energy sources in the country is the unreliable grid electricity supply in Nigeria. IEA (2016a) and World Bank (2018) noted that the country's per capita net electricity generation rate is among the world'slowest. For example, in 2014, Nigeria's electric power consumption per capita was 144 kilowatt-hours (kwh) while comparable nations in the 1960s and early 1970s like Singapore and Malaysia have 8844 and 4596 kWh respectively. Similarly, South Africa and China with about a third and multiples of the population of Nigeria respectively consumed 4198 kWh and 3927 kWh per capita respectively (World Bank, 2018). Also, IEA (2016a) aver that just 45% of Nigerians are connected to grid electricity. This statistics is unsurprising because a majority of Nigerians reside in rural regions and most Nigeria rural regions are not linked to the national grid because of the absence of adequate power infrastructures and as such residents in the urban region are prioritized (Mellersh, 2015).

As documented by Sambo (2008), the country's first effort towards electricity generation dates back to the eighteen century when the country started electricity generation in Lagos, Southwest Nigeria. Despite the presence of electricity in the country for over a century, the pace of development of the power sector has been very slow. Unsurprisingly, the continued demand-supply gap continues to be dominant in the nations demand for electricity (Iwayemi, 2008; Sambo, 2008; Dimnwobi et al., 2018). The consequences of this huge gap are enormous despite the various natural resources scattered all over the country which could be harnessed in generating electricity. As a result of this, the nation's development process is greatly hampered (Nwokoye et al, 2017). Therefore, it is unsurprising that households with electricity access encounter constant blackouts and depend on environmentally unfriendly personal generators, with energy commentators referring to Nigeria as a diesel-powered economy. This assertion is corroborated by the World Bank's 2015 Enterprise Survey, which shows that over 71% of businesses in Nigeria have private generators, with electricity self-generation constituting about 59% of Nigeria's aggregate electricity generation.

The foregoing suggests that electricity consumption in Nigeria is abysmally low and there is huge energy poverty prevalence and as such hampers the development of the country (Ozughalu and Ogwumike, 2018). Sufficient access and provision to contemporary energy sources are essential to tackling a wide range of current developmental hindrances like inequality, poverty, climate change, poor education, and health condition. Insufficient supply of and deficient contemporary energy sources access in Nigerian households is responsible for gross inefficiency in meeting the fundamental energy needs of a sector responsible for consuming the majority (77.3%) of electricity generated (IEA, 2016b).

There have been considerable efforts in the energy-related literature to appraise household's energy consumption, but significant gaps still exist. First, to my knowledge, studies on household energy consumption utilizing a comprehensive nationwide-representative household dataset from a two-time phase (General Household Survey 2016 and 2019) covering a large number of households in Nigeria is rare. Second, previous studies only focus on the factors influencing household energy use behaviour without ascertaining the degree of reliance (intensity of consumption) of these households on specific energy sources. This study's outcome will assist the Nigerian government in coordinating and harmonizing energy policy for households.

1.2. Study Objectives

All the sectors around the world are currently witnessing an upsurge in energy demand with the residential sector being the most significant consumer of energy in developing nations (Çelik andOktay, 2019; Zou and Luo, 2019). Despite the increase in the energy demand, individuals in developing countries continue to be energy poor with Nigeria being one of the energy poorest nations around the globe notwithstanding its long-standing tag as the giant of Africa. The energy consumption of the household could be engendered by a lot of factors and this study beams its spotlight on the spatial and temporal analysis of energy consumption by Nigerian households.

1.3. Research Questions

- Does the level of deprivation in energy consumption in Nigeria differ across the regions and at different times?
- What are the determinants of energy deprivation and energy choices in Nigeria?
- What are the factors that drive the intensity of energy consumption by Nigerian households?

1.4. Geographic Study Area and Context

This study is conducted for Nigeria. Nigeria has a landmass of about 923,768 km² with a population density of 212.04 individuals per km². It is located in West Africa with latitude and longitude of 9.0820° N and 8.6753° E respectively. Nigeria shares a border with Niger, Chad, Cameroon and Benin Republic in the north, northeast, east and west respectively.

According to the United Nations Population Fund (2019), Nigeria has an estimated population of about 201 million people.

Figure 1.1: Nigeria's map
Source: Google Map (2018).

Nigeria is comprised of 36 states and Abuja - the Federal Capital Territory (FCT), which is the seat of governance. The states including the FCT are structured into six regions, namely, South-South, East, West and North East, West and South (see Figure 1.1). Amongst them, the South East has the least states (five states) with other regions having six or more states.

The country is a multilingual and multi-ethnic with about 250 and 500 ethnic groups and indigenous languages respectively (Ogunwale, 2013). The most populous among the ethnic groups include Yoruba, Hausa-Fulani, Igbo among others. Nigeria is known for its cultural, ethnic and religious diversity. The Nigerian population is divided into adherents of Islam (47%), Christianity (34%) and African Traditional Religion (ATR) (18%). About 1% of the population are believed to be adherent of other world religious movements. While ATR fairly spreads across the country, Hausa-Fulanis are mostly Muslims while the Igbos is predominantly Christians. The Yorubas are largely divided between the two major religious movements in the country (Islam and Christianity). Nigeria is classified as a lower-middle-income economy. With a GDP of about US$397.27 billion, Nigeria is Africa's biggest economy. However, Nigerian per capita income of $2,222 places it as 82nd in the world (World Bank, 2018). As a frontier economy, Nigeria has flourishing entertainment, financial service and communication sectors. Although it has continued to make an accelerated effort towards economic diversification, crude oil remains the major source of revenue and foreign exchange earning with annual returns amounting to over 80% of total revenue (Dimnwobi et al, 2018). Nonetheless, Nigeria produces about 2.7% of the world oil supply, while the oil sector contributes only 9% of the nation's GDP. Nigeria has expanding urban population amounting to 50.34% of its total population. The rural population largely engages in agriculture with over 85% of its agricultural enterprise being operated as subsistence ventures (Lin and Ankrah, 2018).

While some structural changes such as enhanced trade relations and flows, growth in foreign direct inflows, power sector reforms, support of energy efficiency agendas and fuel subsidies removal have occurred in the nation, they have been insufficient to guarantee the achievement of energy security in the economy (Oyedepo, 2012; Adom 2015; Adom and Adams 2018). Nigeria is rich in both in traditional and modern energy resources such as firewood, charcoal, animal waste, liquified petroleum gas as well as hydrocarbon. Additionally, the country is blessed with RE resources like wind, solar, etc. However, energy conversion technologies in Nigeria is relatively poor and hence, supply of modern energy is largely below the global threshold. Regrettably, energy sector problems in the nation, specifically the electricity sector, put grave developmental obstacles on the nation. Incidences of firm crashes and job losses resulting from frequent power outages continue to weaken the country (Oyedepo, 2012; Adom 2015; Adom and Adams 2018), hence the energy demand-supply gap reiterates the need to encourage sustainable energy use (Oyedepo, 2012).

1.5. Thesis Structure

The first and present chapter provides an overview of energy consumption. The second chapter contains the relevant literature. Specifically, the chapter presents the conceptual literature; related theories, overview of the electricity sector in Nigeria, prominent energy policies that have introduced over time in the country as well as the justification of the study. Chapter three presents the theoretical model, data, and sources of data among others while chapter four presents and explain the findings from the analysis. The final chapter provides the policy recommendations that address the findings from the study as well as presents some ideas for future studies.

CHAPTER TWO

LITERATURE REVIEW

2.0. Introduction

This chapter provides the related literature on the subject of study. The chapter began with the discussion of the major concept of the study which is energy consumption. The subsequent section provides an explication of the various theories that explain energy consumption. It is then followed with stylized facts on overview of electricity generation as well as various energy policy climates in Nigeria. Also, the chapter contains a review of prior related studies conducted on the subject matter with the summary of the literature rounding off this chapter.

2.1. Conceptual Literature

Energy is a critical driver of all economies around the globe (Keho, 2016). It is the foundation of all economies that drives socio-economic activities such as transportation, health, communication, agriculture, economic growth, food security, education among others (Lin and Atsagli, 2016; Ikpe and Torriti, 2018). The key concepts of this study are household energy consumption as well as energy deprivation. The first paragraph provided the concept of energy consumption while the last paragraph defined energy deprivation. However, there are various types of energy, but our major focus is on electricity which is a major energy utilized all over the world to fulfil diverse purposes. With this in mind and according to Danlamiet al (2015), the energy consumption of the household refers to the total energy amount utilized for domestic activities. The proportion of energy household uses differs extensively depending on the nation's living standards, residential types, age among others. Climate change is majorly caused by energy consumption and as such energy consumption changes and their composition can have a major impact on whether the objective of climate change mitigation is achievable (Adom 2015; Adom and Adams 2018).

Numerous economic and social variables influence energy consumption. The huge population increase, speed in technological uptake, urbanization, and the anticipated substantial rise in GDP can lead to a substantial rise in energy consumption, especially in developing countries

(Özcan et al., 2013). Around the globe, specifically in developing nations, the household consumes the most energy generated (Kayode, 2016; Shi et al., 2019).
However, their energy consumption is dependent on their daily behaviours which include the types of appliances utilized and end-use efficiency. To adequately lower the consumption of energy by household, energy-saving behaviour has always been touted. Energy-saving behaviours refer to the household's routine practices to lower the total energy it utilizes (Trotta, 2018). It is often split into two parts: the first part deals with the decreasing energy consumed by applying various forms of curtailment practices (for instance reducing the frequency of using air conditioners, switching off appliances when is not being utilized, turning off lights that are not being utilized and not needlessly leaving household appliances on standby mode among other pro-environmental behaviour) while the second part focuses on purchasing energy-efficient appliances and replacing inefficient appliances with efficient ones (for instance purchasing energy-saving bulbs and checking the energy rating before purchase).

Several scholars have made a modest attempt towards conceptualizing energy poverty. For instance, according to Li et al (2014), energy poverty is conceptualized as the inability to access cleaner energy services. A situation where a household can hardly meet the minimum energy required to guarantee its basic needs is referred to as energy poverty (Foster et al., 2000). Pachauri and Spreng (2011), stated that a combination of complex variables like the absence of income and physical accessibility of certain energy sorts as well as high costs connected with energy usage causes energy poverty. Some other scholars(Parajuli, 2011; Pereira et al., 2011; Ozughalu and Ogwumike, 2018 recognize an individual or household as energy poor if they are incapable of covering their fundamental energy costs to have light, prepare food and maintain a sufficiently warm home. Robic et al. (2012) on the other hand, avers that energy poverty arises if an individual or a household's energy expenditure (excluding transport fuels) is more than ten percent of their disposable income. Additionally, the multidimensional energy poverty measu re which extends energy consumption and access as being multidimensional is commonly use d (Sher et al., 2014).

2.2. Theories on Energy Consumption Behaviour

Over time, several theories have been developed to explicate energy utilization behaviour. An elaboration of the major theories which includes energy ladder theory, energy stacking model, macro-micro model, utility maximization theory as well as value belief norm theory and theory of planned behaviour is presented in this section. These theories are relevant in explaining the household's energy consumptions decisions. Amongst these theories, this study adopted the energy stacking model. The decision to adopt this model is premised on the following: First energy stacking is a phenomenon that is prevalent in Nigeria. Secondly, the model captures the complex nature of energy consumption choices across all stages of development of an economy. Further justifications of the choice of this theory for this study are elaborated in the theoretical framework (see section 3.2).

2.2.1. Energy Ladder Theory

This model is usually the first theory that comes to mind in an energy-related discussion. This theory has been generally utilized in explicating the energy consumption of households in developing nations. The theory describes a method in which households, as they witness improvements in their income, departs from the consumption of non-clean fuels like biomass to initially utilizing intermediate fuels such as coal or kerosene and finally settling for sustainable fuels like electricity or gas (Heltberg, 2005; Lay et al. 2013). Also, the model acts as an expansion of the standard income effect of consumer economic model that describes how inferior goods are exchanged for basic goods as well as luxury goods by consumers as they witness improvements in their income (Link et al., 2012). According to this theory, the energy ladder is climbed slowly by households (See Figure 2.1). Usually, they start by consuming traditional fuels, moving through commercial fuels and ending with electricity (Martins, 2005). As development intensifies, a country's real income per capita, expertise and the use and recognition of technology advancement improve considerably; making such a country change from consuming traditional fuel to modern fuel (Ogwumike and Ozughalu, 2012). The model entails that underdevelopment is strongly correlated with energy poverty while as development level improves; energy poverty reduction is anticipated (Ozughalu and Ogwumike, 2018).

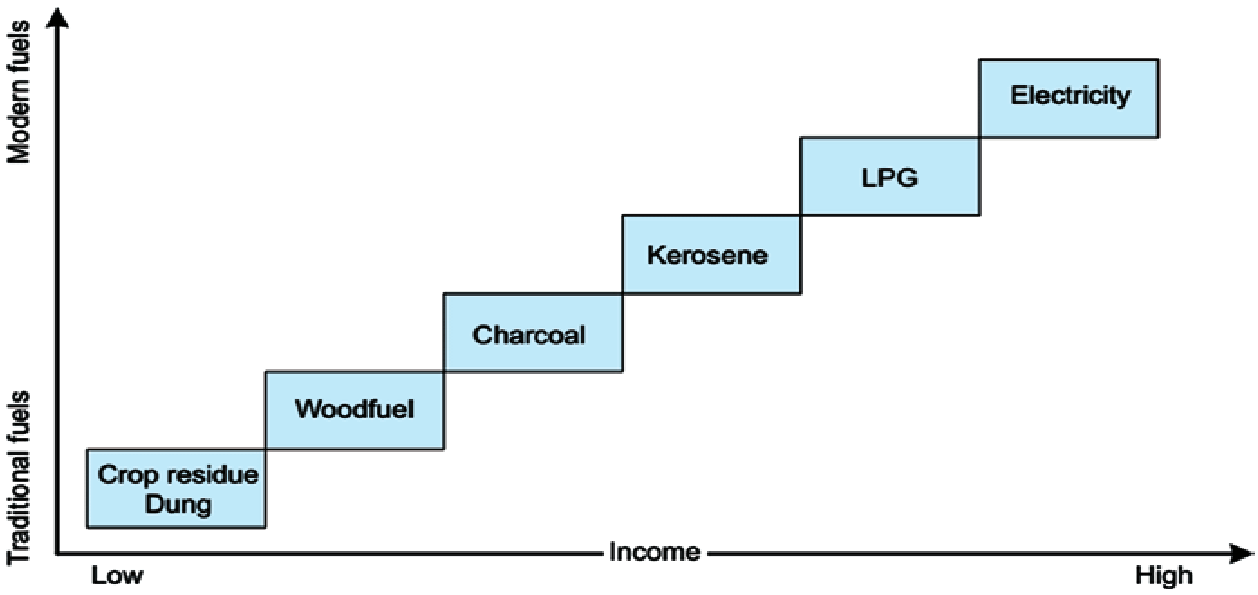


Figure 2.1: Energy ladder hypothesis

Source: Holdren and Smith (2000).

As shown in Figure 2.1, there are three stages in the energy ladder model. The stages are as follows:

- Firstly, the general dependence on biomass like dung, wood and charcoal. This stage is usually dominated by the consumption of traditional and non-clean fuels
- The second stage consists of the utilization of transition fuels, for instance, swapping to fuels like kerosene. This stage entails the consumption of intermediate fuels.
- The final stage involves the adoption and consumption of clean and sustainable fuels like electricity and other sustainable energy sources (Heltberg 2004).

Figure 2.1 further highlights the nexus between the kind of energy consumed and the income level of that specific household. At the top of the ladder is electricity which is very sustainable while at the bottom end of the ladder contains crop wastes, dung and fuelwood which is very unsustainable and harmful to mankind. There is a notion in the literature that the energy ladder model (ELM) could function on both the micro and macro levels of the economy. At the micro-level, households with lower developmental and income levels appear to dwell at the low-end of the energy ladder and utilize fuel that is poor, inexpensive and readily accessible locally but usually unclean and inefficient (Kayode, 2016). Contrarily, on the macro level, energy use enhances with an economic development which is usually associated with more dependence on sustainable fuels. Also, evidence from multi-nation assessment shows a strong relationship between sustainable energy utilization and economic growth, indicating that as a nation advances through its process of industrialization, its dependence on sustainable energy improves and the significance of non-clean fuels diminishes (Van der Kroon et al., 2013).

2.2.2. Energy stacking model

The energy ladder model was criticized by Masera et al (2000) over its inability to sufficiently explain the dynamics of household's energy utilization and as a result, the energy stacking model (ESM) which captures the complex nature of energy consumption choices across the country's level of developments was introduced in energy literature. Energy or fuel stacking refers to numerous patterns of fuel use, a situation where a mixture of fuels are chosen by the households from both the upper and lower energy ladder levels. In this case, contemporary fuels could only be partial rather than perfect unclean fuels substitutes. Recent experiences have revealed that with improvement in incomes, developing nation's households do not transit to more advanced sources of energy rather they mix both lower and higher sources of energy (Ogwumike et al., 2014). As income improves, rather than households going up the energy ladder, they select diverse sources of energy based on their current preferences, necessities, and budgets (Mekonnen and Kohlin, 2009). Energy stacking model states that energy consumption choices are driven by multiple factors, rather than, unidimensional factor. ESM emphasizes that energy-switching outcome is rather interconnected than being a simple or disconnected step. In other words, after adopting modern energy sources, households would still retain the traditional energy sources (see Figure 2.2) that is households do not completely switch after adopting cleaner fuels and this model is very prevalent in developing countries.

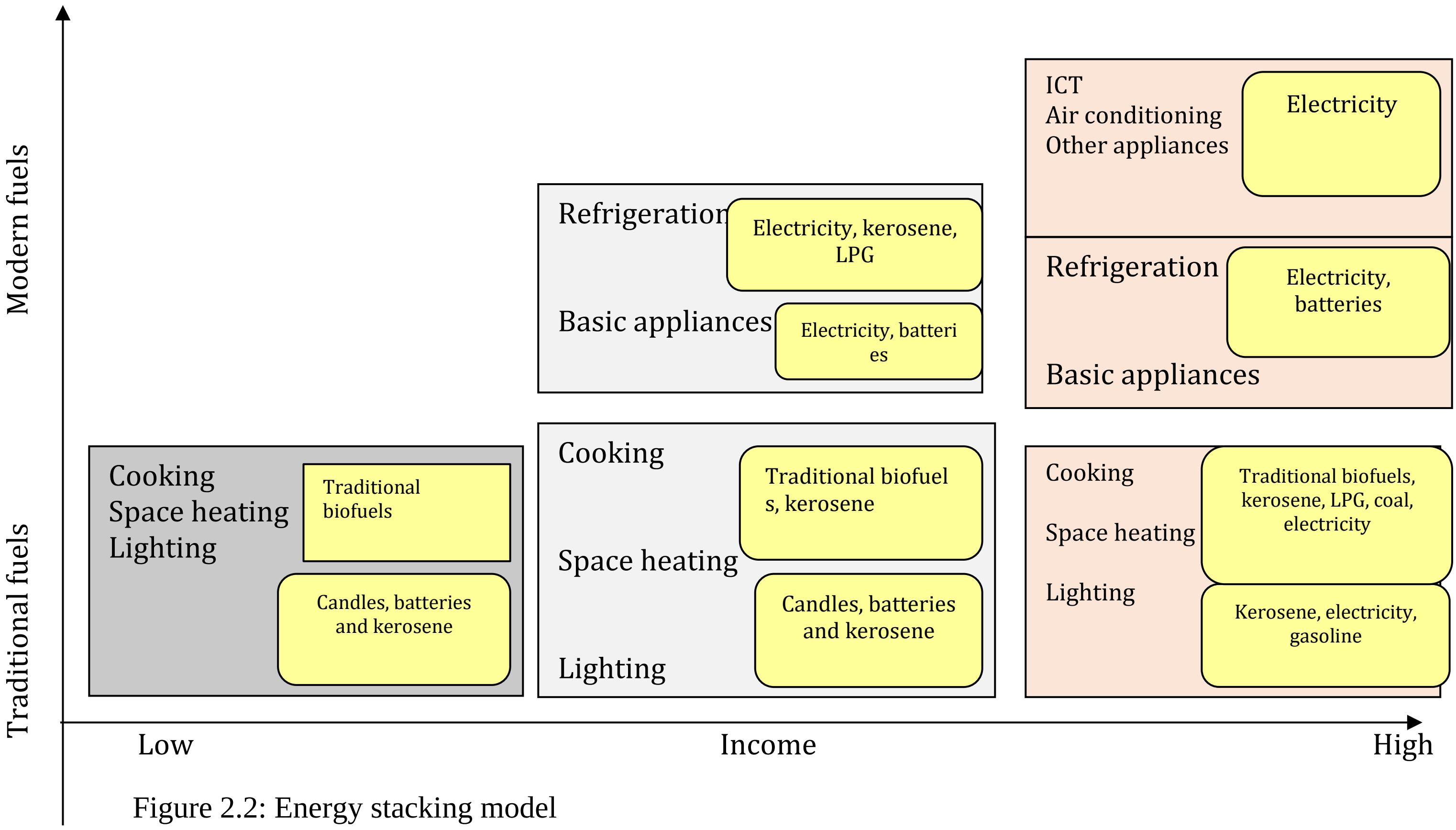


Figure 2.2: Energy stacking model

Source: IEA (2002).

Different rationales exist for using multiple fuels especially in developing nations where this model is prevalent but the major reason for this behaviour is insurance. The supply of contemporary energy in developing nations is unreliable and as such stacking provides insurance against such failures. In a bid to boost their chances of getting energy supply, households in most cases use various fuel sorts, in other instances; the decision depends on different social and cultural variables (Pachauri and Spreng, 2004). For instance, Nigerian households that utilize solar energy for lighting also retain the services of grid and electricity from their private generators, the use of kerosene powered lantern for lighting while in a similar manners households that adopted electric stove for cooking also do not discard their kerosene cooker, dungs and firewoods. This is to say that several traditional energy sources are still being utilized by elite households in Nigeria. In some instances, there is a saying in the country which opines that food cooked with firewood (traditional energy sources) is more delicious to food prepared with electric stove (modern energy sources).

2.2.3. Macro-Micro Model

Household energy consumption behaviour can also be explained with the macro-micro model of Dholakia et al (1983). A household's energy use can be seen as the consequence of a sequence of nesting and interlocking decisions that range from the individual and prompt act of switching off undesirable lights among others. The main characteristic of these "nested decisions" is that macro choices define and delimit micro choice scope. Dholakia et al (1983) note that household energy consumption is modelled not only as the consequence of choosing between behavioural options, but these alternatives creation is also seen as the social choice process outcome. Hence, energy consumption must be viewed in the framework of a wider pattern of usage that is determined socially.

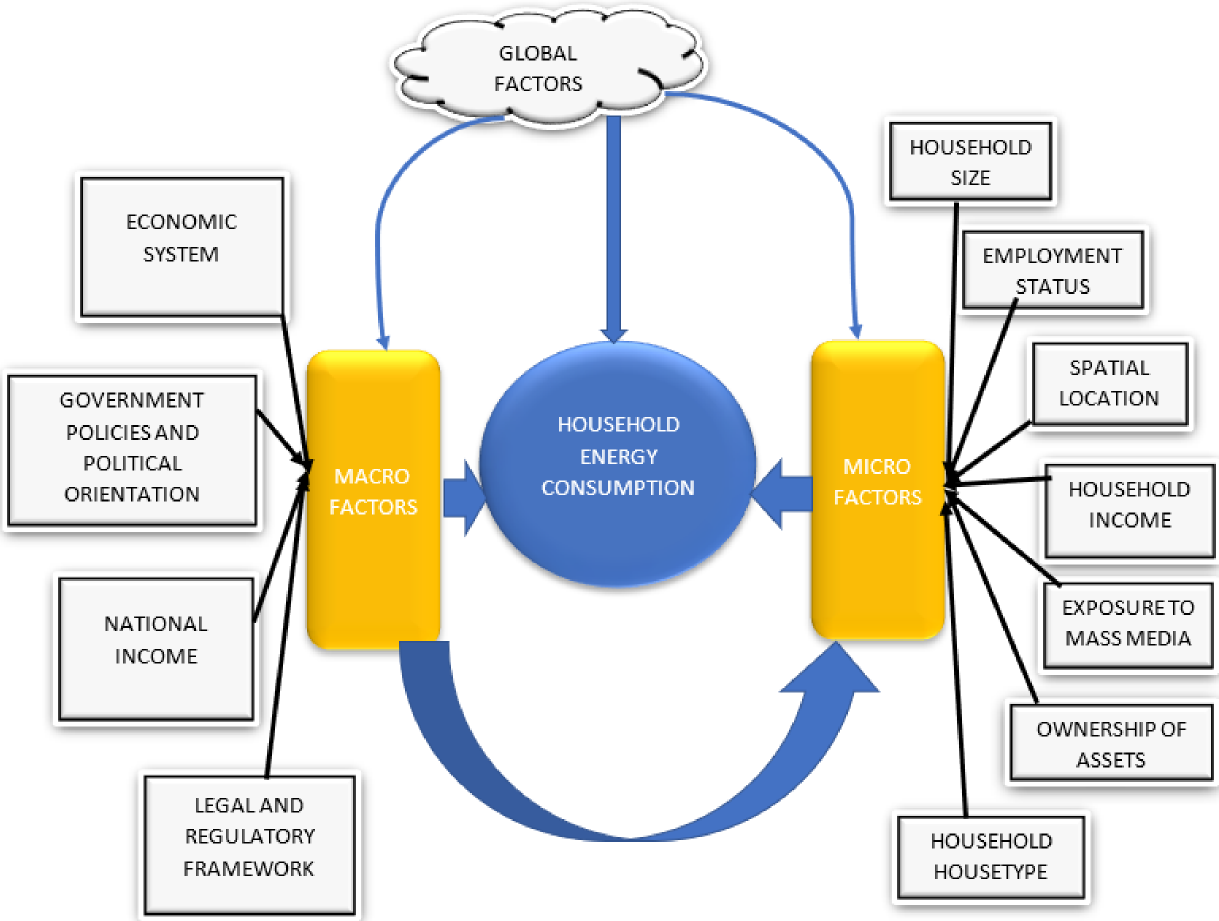


Figure 2.3: Schematic model explaining the macro-micro model
Source: Authors sketch.

The macro-micro model of energy consumption holds that the energy consumption choices made by households could be affected by both individual factors (micro) and socio-political factors (macro) (see Figure 2.3). The individual choices are usually delimited by the macro choices. For example, the overall energy investment may be determined by government policies, political orientations, and national income. The total endowment of national energy may differ among countries and will, no doubt, limit the maximum amount of energy available for household consumption. On the other hand, the quantity of the available energy consumed by each household may be contingent on several demographic and social factors. The variables that may have influence on household energy consumption often include city orientation (whether rural or urban), size and income of the household, sex of household head, education exposure of households, employment status of households, household house type, ownership of assets, exposure to mass media among others.

2.2.4. Rational Choice or Utility Maximization Model

In economics, the microeconomic model of consumer decision assumes that an individual is faced with making utility-maximizing decisions which are often subject to their budget limits. Usually, consumer's choices are contingent on the choice that provides better utility as against the ones with lesser utility. Regarding energy consumption, this model presumes that households have predilection among many sorts of energy sources and subject to their budget constraints; they always make decisions to select the energy type that provides the best utility in light of their budget. According toAlfred Marshall, one of the founders of neoclassical economics, utility is viewed to be related to want or desire. Desires cannot be directly appraised but can be measured indirectly through external phenomena to which they arise and that in such situations, the major concern of economics is the price the individual is ready to pay to satisfy or fulfil his want (Marshall, 1920). Utility is usually regarded as a substitute for personal gain, welfare or the best outcome alternative (Kahneman et al, 1999). The model is in line with the linear model where the role of information is very significant. Information produces knowledge while knowledge, in turn, forms attitudes and some specific behaviour is generally influenced by attitudes (Karatasou et al., 2013). Figure 2.4 shows the various factors that affect the consumption of energy in an economic model. As stated earlier, these factors are hinged on the individual's rational choices

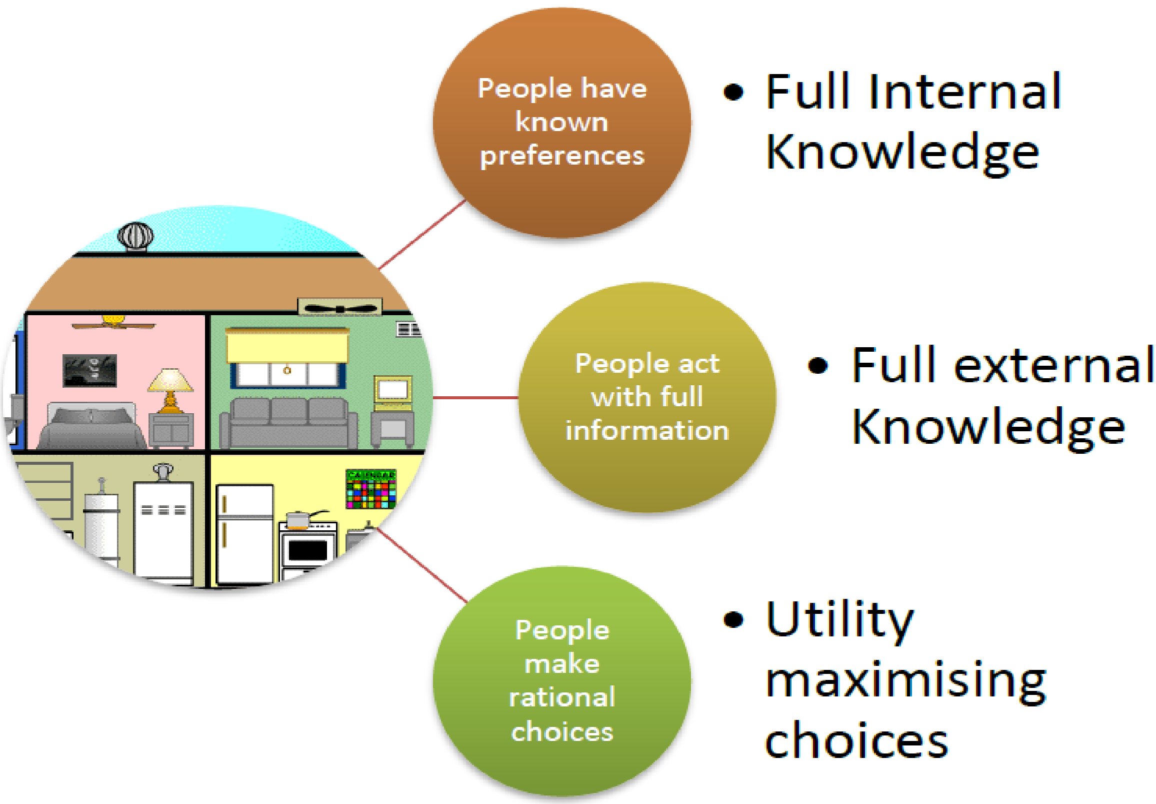


Figure 2.4: Factors influencing energy use in an economic model

Source: Bernard (2017)

In this model, energy utilization is related to households or individual's preference for commodities and such preferences could be contingent on various factors. For instance, households' selection of a specific energy source and energy poverty level of households is hinged on certain socio-economic attributes like age as well as the gender of the household head, residential area, family size and household's percentage of aged people and females (Alem et al., 2013).

2.2.5. Theory of Planned Behaviour (TPB)

This theory proposed by Azjen (1991) assumes that behaviours of human being are hinged on the intention of the individuals to execute or perform specific behaviours (Hansson et al., 2012). The theory uses some psychological ideas like perceived behavioural control, attitudes and subjective norms to describe the behaviour of human beings (Ajzen and Madden, 1986; Armitage and Connor, 2001). Attitude refers to the extent of negative or positive acceptance, perceived behavioural control denotes the recognized self-capacity to act effectively in a particular way and the subjective norm is the human viewpoint that arises as a result of social pressures in order or not to carry out a particular behaviour. In this theory, people freely control their behaviours and the utilization of energy is amongst this behaviour. Figure 2.5 shows how the psychological constructs of TPB influences an individual's behaviour

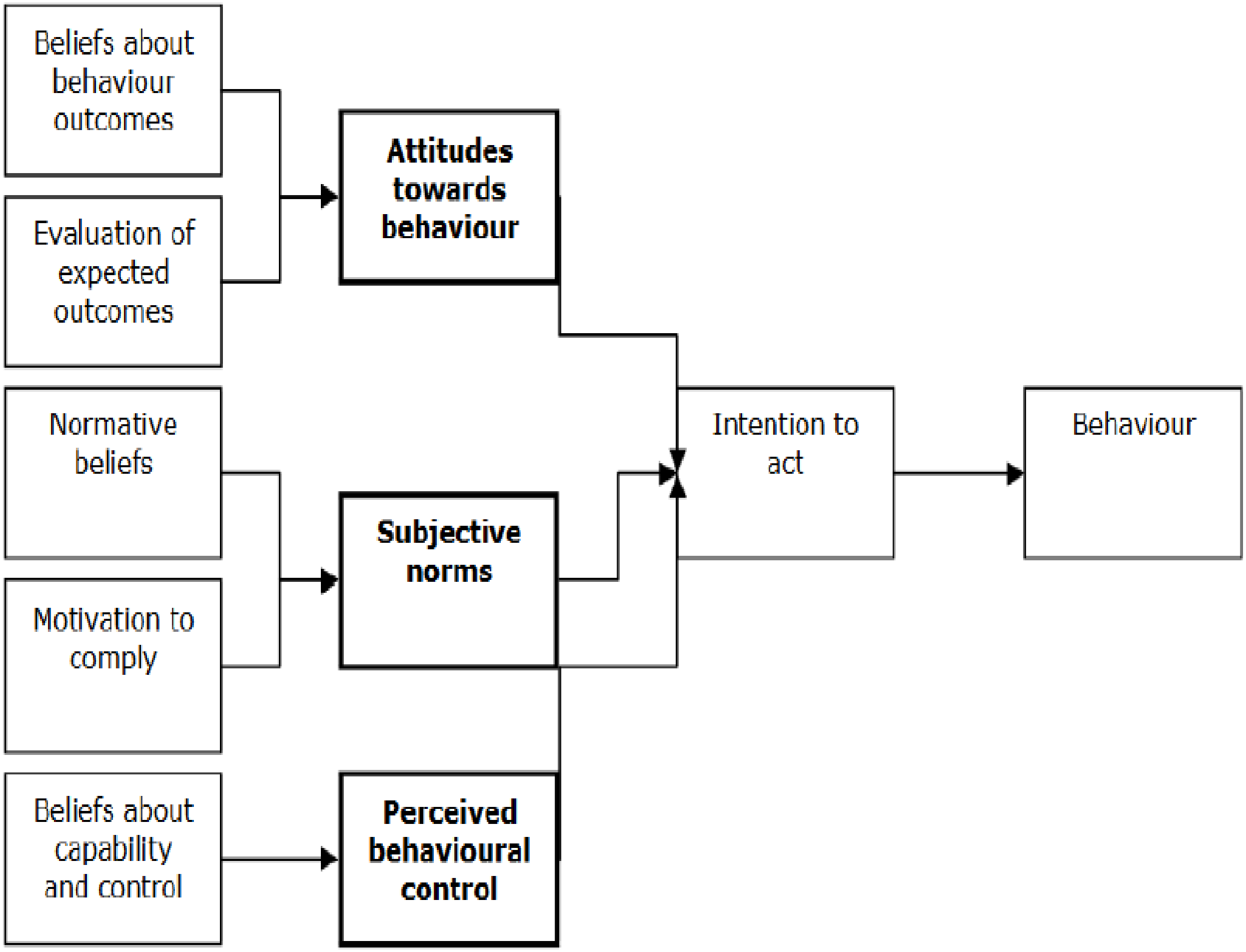


Figure 2.5: Schematic model explaining TPB
Source: Morris et al. (2012).

TPB has been largely utilized in research evaluating pro-environmental actions. To illustrate how TPB describes pro-environmental energy consumption, this scenario is presented. Let assume, for instance, an electricity consumer wants to substitute fossil fuels electricity to sustainable electricity, the acquisition decision of this sustainable electricity is recognized by the TPB constituent. For instance, the attitude could be triggered from the positive ideas the individual has regarding sustainable energy. Also, it may be as a result of the individual's decision to lower carbon emissions, assisting the development of renewable energy development, enhance public health as well as contributing to a greener society among others. Contrarily, subjective norms could be explicated in connection to the peer pressures such as the individual may be like to be seen as someone who encourages sustainability, persuasion to utilize sustainable electricity when the whole environs have embraced sustainable sources of energy. Lastly, perceived behavioural control in the illustration is an individual's own conviction in his group to be able to formulate sustainable sources of energy, the capacity to embrace sustainable electricity and regulate the individual's support to global warming.

2.2.6. Value Belief Norm theory

This theory which developed from theoretical studies of values and norm-activation methods was pioneered by Stern et al (1999) and assumes a casual group of variables influences individual behaviour. These variables include personal norms, values, and awareness of consequences beliefs, new ecological paradigm and attribution of self-beliefs responsibility. Figure 2.6 provides a pictoral illustration of the value belief norm (VBN) theory.

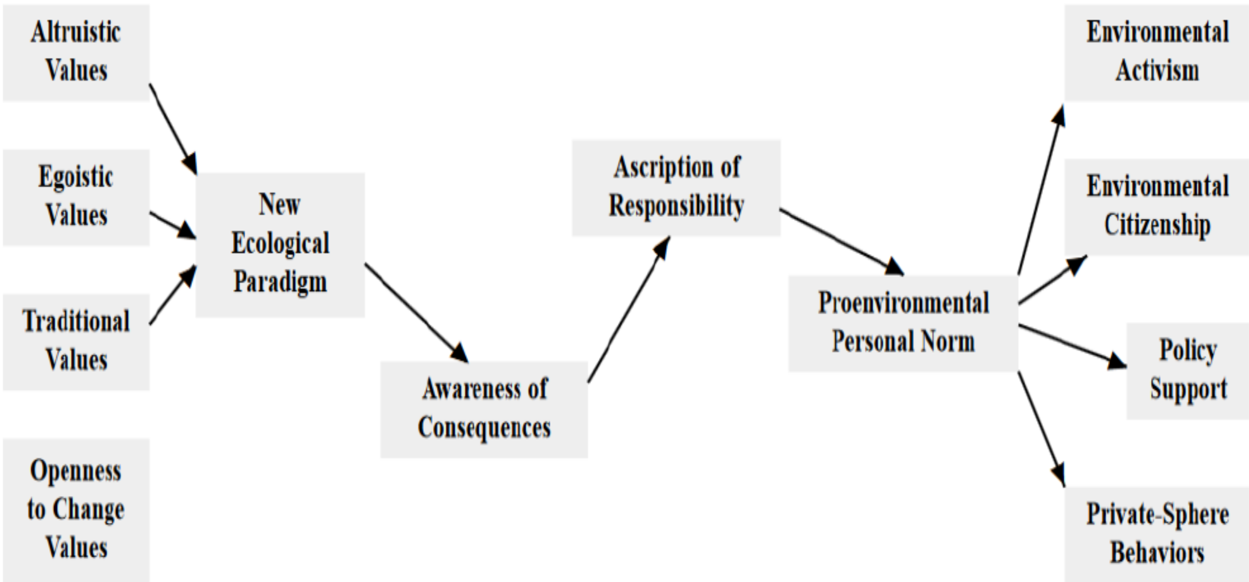


Figure 2.6: Casual associations of VBN theory
Source: Stern et al. (1999).

According to Schwartz (1973, 1977), this theory proposes that behaviours that are pro-environment occurs as a result of moral personal norms the individuals hold concerning such behaviours. However, the personal environmental values of the individual are critical determinants of the environment-friendly actions which usually shift to a three-group of basic ideas. First, the principles an individual holds influence the new ecological paradigm (NEP) which is referred to as a belief that the various actions of humans have considerable harmful impacts on a delicate biosphere (Dunlap et al, 1992). Second, the casual sequence shifts from a steady constituent of beliefs and traits to a further concentrated idea of the interaction on the human and environment, then it moves to risks to cherished items and responsibility to act. Lastly, the sense of moral responsibility is triggered, and it develops a tendency to perform a behaviour that is pro-environment.

To illustrate this theory in the context of energy consumption, this scenario is presented. Imagine a situation where household members in a developing country are being tasked to lower the consumption of electricity in their home. In this scenario a pro-environmental action involves turning off lights that are not being utilized, using household appliances that are more energy-efficient, and unplugging appliances when they are no longer in use, purchasing appliances that have decent energy rating, not needlessly leaving household appliances on standby mode and using energy efficiently among others. In this scenario, personal environmental values are the major determinants of these actions which could include conserving energy, interest on the planet, and reduction of energy costs. Beliefs involve response to issues like global warming among others while in this context the norms can be the logic of environmental-friendly actions inclusion in individual roles. Without doubts, these would improve the energy conservation and energy consciousness of the household's members.

2.3. Nigeria's energy landscape

2.3.1. Brief Overview of Nigeria's Electricity Sector

Nigeria's maiden attempt towards electricity generation started in the eighteen century when the country established its pioneer power plant in Marina area of Lagos State, South-Western region of the country in 1896 (Sambo 2008). In 1929, during the colonial period, the country founded the Nigerian Electricity Supply Company which happens to be the first utility company in the nation. The country witnessed additional advancements and to manage the electricity she generates triggered the creation of Electricity Corporation of Nigeria (ECN) in 1950, just ten years before her independence. Furthermore, after the country's independence, numerous activities were witnessed in the electricity sector (Dimnwobi et al., 2017; United Capital, 2017). For instance, two years after her independence, the Nigerian Dams Authority (NDA) was formed to supervise hydropower stations establishment as well as management. However, the roles of NDA and ECN were distinct. The NDA was mainly responsible for electricity generation in the country while the ECN was charged with the task of selling and distributing electricity in Nigeria. The year 1973 heralded the fusion of the ECN and the NDA to form National Electric Power Authority (NEPA) which is currently defunct. The reason for this merger is owing to the need to give the responsibilities of electricity generation as well as distribution to a sole entity for proper accountability and enhanced performance (Monyei et al., 2017).

The fusion of these functions into one body (NEPA) made them to function as a monopoly and they were constantly unable to live up to expectations (Ugwoke et al., 2020). It became very evident that despite NEPA's exclusive rights and the country's energy endowments, there were no considerable steady and constant enhancements in the country's electricity sector during this time (Monyei et al., 2017). As a result of these and to address these obvious concerns led to the formation of National Electric Power Policy (NEPP) in 2001 which signified the reform that happened in the sector. At this stage, it was obvious that the sector was beyond the scope of public sector financing because of other sectors that require the government's attention. Because of this, the restructuring drive for the sector went through several models with the involvement of private sector to push the efficiency and capacity featuring as the key theme and the ratification of Electric Power Sector Reform Act (EPSRA) in 2005 assisted in achieving these objectives (Monyei et al., 2017; United Capital 2017). Likewise in 2005, NEPA, which was later baptized the Power Holding Company of Nigeria (PHCN) was split into one transmission company, six generations companies and eleven distribution companies. The transmission company controls electricity transmission in Nigeria, the six generating companies and other independent producers of power sells power to the distribution companies who in turn is responsible for the electricity supply in the particular region they are assigned (Maduekwe, 2011; Dimnwobi et al., 2017). To ensure a seamless operation, Nigeria Electricity Regulatory Commission (NERC) was created in the same year asthe independent regulator. The year 2010 witnessed the establishment of the Roadmap for Power Sector Reform which was later revised in 2013.

2.3.2. A Brief Review of Energy Policies in Nigeria

Globally, policymakers come up with policies (sometimes sector-specific while in other times general policies) to drive the economy and stimulate economic development. In the case of the energy sector, a detailed energy policy is critical in guiding a nation in its quest towards efficiently utilizing its available energy resources. It should be noted that while the presence of energy policy is very essential, however, it does not necessarily ensure that the energy resources of a nation are well managed (Shaaban and Petinrin, 2014). Nigerian governments overtime has rolled out various programmes and policies to drive energy sector developments. A detailed discussion of these policies is documented by Nigerian Energy Support Programme (NESP, 2015) and some of these notable policies are presented in Table 2.1. In this section, discussing all the energy policies is not within the scope of this study, for concision and precision, we briefly discussed three policies (National Energy Policy (NEP), National Renewable Energy and Energy Efficiency Policy (NREEEP) and Vision 20:2020) that are time-based, notable and all-encompassing.

Table 2.1: Energy Policies in Nigeria

S/N	**Policy**	**Year Introduced**
1	National Energy Policy	2003
2	National Power Sector Reform Act	2005
3	Renewable Energy Master Plan	2005 and updated in 2012
4	Renewable Electricity Action Programme	2006
5	Vision 20:2020	2009
6	National Renewable Energy and Energy Efficiency Policy	2015

Source: Authors Compilation (2020).

Before 2003, the country has no comprehensive policies on energy to drive the sector. What was obtainable at the time was a different policy documents for the diverse energy sub-sectors that the county is blessed with. The NEP was introduced in 2003 to provide a roadmap for an enhanced energy future in the country (Ajayi and Ajayi, 2013). This policy assisted in the unbundling of the PHCN, authorizing and distribution of power plants and entities respectively, encouraging private sector involvement in the electricity sector and establishing a conducive setting for the expansion of an electricity market that is competitive (Enongene et al., 2019). The year 2009 witnessed the introduction of Vision 20:2020. This vision aims at a general transformation of Nigeria’s economy by the year 2020, by placing Nigeria among the top biggest 20 economies in the globe. The vision acknowledged the significant role of energy in its actualization. It recognized the importance of incorporating renewable energy (RE) sources in the Nigeria’s energy supply mix to solve the energy challenges ravaging the nation. Particularly, the vision suggested different strategies and measures to stimulate the seamless incorporation of electricity generated through RE sources (NESP, 2015).

Subsequent policies emerged as depicted in Table 2.1 and the most notable amongst them is NREEEP, approved in May 2015 outlines the measures and policies for encouraging RE and energy efficiency (EE) in the country. The policy aims to raise awareness of policymakers on the social, economic and political capability of RE by advocating the development of a suitable approach to exploit the potentials derivable from the RE in a bid to make value additions to the recent reforms in the country's electricity sector (NESP, 2015; Omoju et al., 2019). The policy observed that previous energy policies in the country are not comprehensive and unable to stimulate the development of the sector and hence proposes for the incorporation of RE and EE that will be used an instrument to drive development and uptake of RE technologies and efficient utilization of energy in the country. The NREEEP could be viewed as a comprehensive policy that strengthens other energy policies and programs in Nigeria (NESP, 2015).

2.3.3. Overview of Nigeria's Household Energy Consumption

Despite the uneven development around the globe, the residential sector has continued to maintain its position as a significant energy consumer around the world (Çelik andOktay, 2019; Shi et al., 2019). With respect to Nigeria, the residential sector consumes the bulk of electricity in the country (see Figure 2.6) with the energy demand from the sector emanating from both rural and urban regions. Although there are no statistics (at least to the best of my knowledge) that shows the difference in the demand between city orientations (that is the difference between rural and urban setting), one expects the urban region to have a higher energy demand due to some reasons. First, electricity infrastructure in Nigeria is poor (Dimnwobi et al., 2016; Nwokoye et al., 2017), hence priorities are given to urban dwellers in setting up electricity infrastructures. Secondly, owing to exposure to city lifestyles and increased opportunities for income-generating activities in the cities, they are likely to have more appliances than their counterparts in the rural regions and this enhances energy consumption. In recent times, an expansion in population, enhanced standard of living, and of course improvements in per capita gross domestic product have intensified the demand for electricity of the country's household sector with the sector's energy mix consisting of traditional solid biomass (charcoal and fuelwood), kerosene, electricity and liquefied petroleum gas (LPG) (Dioha, 2018).

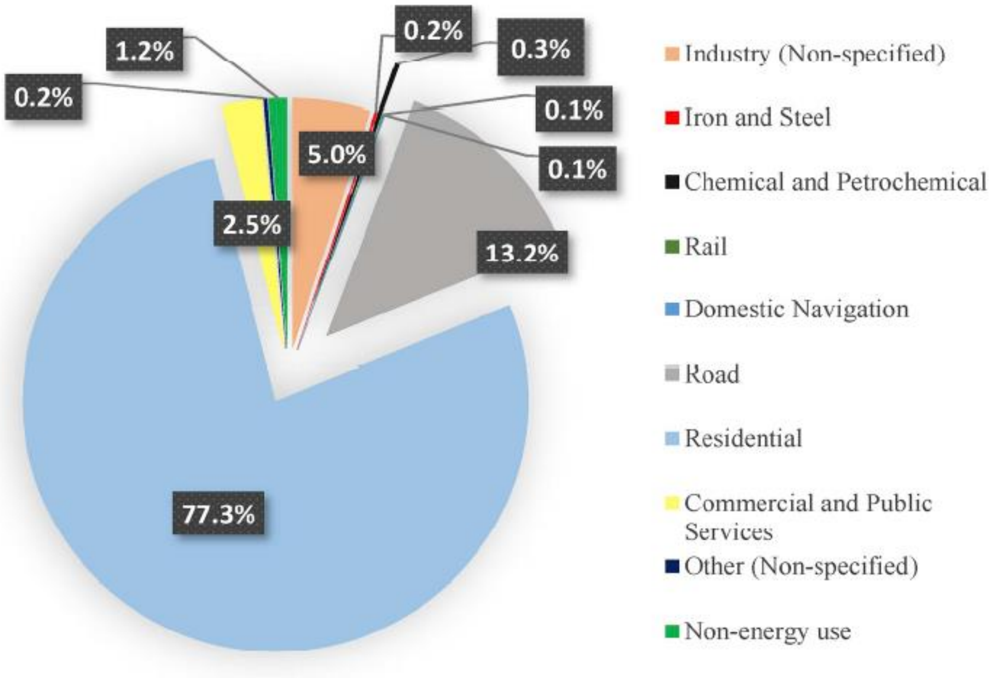


Figure 2.7: Sectoral energy consumption in Nigeria
Source: IEA (2016b).

Households utilize energy to fulfil various domestic activities like lighting, cooking, heating and to adequately operate appliances such as fans, refrigerators, televisions, air conditioners among others (Ibitoye, 2013). According to IEA (2017), 74 million Nigerians are not electrified particularly those residents in rural regions because of deficiency in electricity infrastructures. Similarly, access to modern cooking in the country is even lower. IEA (2016a) observed that the majority of the country's population (115 million) depends on traditional energy sources for their domestic activities with few households depending on sustainable energy sources. Owing to disparities in income and energy access, Nigerian households depend on diverse energy sources for their domestic activities (Dioha and Kumar, 2020). For instance, charcoal, dungs, fuelwood, kerosene and to a lesser extent electricity are utilized for cooking in most Nigerian households (NBS, 2014). The utilization of fuelwood is very prevalent in the rural region of the country (Ibitoye, 2013). Fuelwood is commonly gathered from forests in the rural parts of the nation while in the urban regions, they are obtained from vendors who make them available at a cheaper price in comparison to other fuels like LPG and kerosene that are utilized in cooking. The increasing reliance on fuelwood for cooking has intensified forest depletion in the country and has damaged the natural ecosystems (Dioha and Kumar, 2020). Besides, the health implications arising from the utilization of fuelwood is substantial. For instance, according to WHO (2017), the phenomenon accounts for over 79,000 deaths in Nigeria annually.

2.4. Literature Review (Prior Studies)

Consistent with the utility maximization model, consumers make decisions among various energy alternatives in order to maximize their utility. Consumers, in this case, refer to households which is the study major interest. Generally, households have a lot of complex alternatives and they try to make rational decisions when faced with different alternatives because most households, especially in developing countries, are budget-constrained which affects their daily decisions. However, for precision and concision, the review is performed by concentrating on literature related to the study three research questions (prevalence of energy deprivation, determinants of energy choices and determinants of intensity of energy consumption) using nationwide cross-sectional datasets or nationally-representative household datasets. The justification for reviewing only studies that adopt nationally-representative household datasets is predicated on the following reasons. First, nationwide datasets represents adequately a country's features. Second, the study employed these datasets for Nigeria because the country's regional levels differ significantly and focusing solely on a particular region will not tell the true story. Third, since these datasets best captures the country's important features among other things, the study ascertained the prevailing arguments in literature in order to adequately identify the gaps in the literature and to situate this study accordingly.

The review of empirical literature is therefore thematized along the study's three research questions. The review started by presenting studies on prevalence of energy poverty, followed by studies that focused on determinants of energy choices and then concluded by reviewing studies on intensity of energy consumption.

2.4.1. Prevalence of Energy Deprivation

The prevalence of energy deprivation could occur along regional groupings, wealth classes (example, low-income class, middle-income class and upper-income class), age categorizations, gender divisions, or even ethnicity. A key observation from the literature shows that studies report the prevalence of energy poverty along spatial groupings (e.g. rural and urban) and regional groupings. One of the major findings from the literature (especially African studies) reveals that energy poverty affects those residing in rural districts more than their counterparts in the cities. This could be because, in most African countries, energy infrastructure is inadequate and, in most cases, urban centres are given priority. Secondly, the exposure of city life and more opportunities in income-generating activities could make them obtain modern fuels relative to traditional fuels.

For Nigeria, Sanusi and Owoyele (2016) utilize the 2013 National Demographic and Health Survey to examine the household's energy poverty in Nigeria. Expectedly, the findings show a high energy poverty incidence in Nigeria with the Southern states experiencing more energy wellbeing than their Northern counterparts. Ogwumike and Ozughalu (2016) adopted the 2004 Nigeria Living Standards Survey and conclude that, energy poverty afflicts the majority of the nation's inhabitants and the incident is very pervasive in Nigeria's rural regions. Similarly, Ozughalu and Ogwumike (2018) utilize Harmonised Nigeria Living Standard Survey of 2010 and found that, severe energy poverty affects the majority of the country's populace and rural and Northern regions are more energy poor. A similar result was reported by Apere and Karimo (2014) using the same data sets. Unlike the prior studies for Nigeria reported above, Edoumiekumo et al, (2013) utilize the same data but focused solely on the South-South region of the country and they report that, the six states in the region are energy poor. Among the state in the region, the phenomenon is more severe in Cross River state. Similarly, Edoumiekumo and Karimo (2014) focused solely on a state in the South-South region of Nigeria and reports that energy poverty incidence in the state is high with rural areas experiencing more energy poverty relative to their urban counterparts. The study also found no considerable disparity in energy poverty of male-headed households and female-headed households.

These findings in Nigeria could be contingent of these justifications. First, the level of development of six regions (North East, West and Central as well South East, West and Central) in Nigeria differs significantly. Unlike the southern region, the northern region is less developed and as such, it is unsurprising that they have a high energy poverty incidence. In the aspect of poverty, they are the regional poverty headquarters of Nigeria. In the case of spatial grouping (rural and urban), modern fuels are expensive particularly for households in rural regions and they have relatively low cash flow, and this could explain the dominance of energy poverty in the rural areas.

There are some other studies on this phenomenon in Africa. For instance, Bersisa (2016) employed the Ethiopian Socioeconomic Survey of 2011 and 2014 and found that there is the severity of energy poverty in Ethiopia with the rural region and those residing in small towns being the worst victims. Employing data from four waves of the nationwide repeated survey from 2008 to 2014, Israel-Akinbo et al (2018) evaluated the prevalence of multidimensional energy poverty among South Africa's poor households. Expectedly they concluded that relative to urban households, low-income rural households suffer significantly from energy deprivation. Crentsil et al (2019) employed two Ghana household-level survey data and found that while multidimensional energy poverty level has substantially decreased in Ghana, the incidence is still high. Along the gender, the study reported that relative to their male counterparts, households headed by females' experiences the phenomenon more. Furthermore, the study established that the incidence is higher for elderly heads (over 60 years of age) and rural residents. Along regional divide, these regions (Upper West, Northern Upper East, Volta, Brong-Ahafo and Eastern regions) were confirmed to be the worst victims. Likewise in Ghana, Adusah-Poku and Takeuchi (2019) concurs with the above findings on the significant reduction of the country's energy poverty in the country. In terms of spatial locations, the study revealed that energy poverty has reduced considerably in all the regions, but the phenomenon is still very pronounced in Upper East and Upper West regions. Additionally, the study further reported that rural regions are more energy-poor relative to their counterparts in the urban areas.

Evidence on this issue is also obtainable in Asia. Drawing from Pakistan's household-level survey data, Awan et al (2013) concludes that 54.6% of Pakistan households are energy poor and the rural residents are the worst victims. Unlike the previous study that focused on energy poverty form the national level, Sher et al (2014), use the same data and looked at regional level energy poverty incidence in Pakistan. They found that the incidence of energy poverty ranged between 47% and 69% across the four regions of Pakistan studied. Specifically, they established that indoor pollution is the biggest contributor to energy poverty headcount followed by cooking fuel. Likewise, Sadath and Acharya (2017) use the 2012 India's survey to evaluate energy poverty and their findings indicated energy poverty prevalence in India. Additionally, the study confirmed that the worst casualties of energy poverty are rural residents, as well as these social factions (Adivasis and Dalits). In a comparable study in the Philippines, Mendoza et al (2019) conclude that energy poverty is significantly reduced in the country. Comparing the regions, the study further established that while Luzon (excluding Bicol and MIMAROPA) suffers a low rate of energy poverty, ARMM and Region IX is the country's energy-poorest zone.

2.4.2. Determinants of Energy Choices

In literature, the determinants of energy consumption are of considerable research interest. Existing studies, however, differ in terms of data employed, variables considered and other likely predictors but most of these studies pinpoint spatial location, demographic features, dwelling attributes, socioeconomic features amongst other characteristics. Socio-economic and socio-demographic factors are often cited in energy literature as being one of the most influential variables that affects household energy consumption (Rahut et al, 2016a; Çelik and Oktay, 2019). For instance, gender is one of the variables that could be dominant in explaining household energy consumption. However, the place of gender in describing energy consumption of households could be contingent on the societal perceptions of women.

The literature reveals two opposing views regarding the effect of gender in household energy consumption. On one hand, and as found in Nigeria, Ogwumike et al (2014) use Nigeria's Living Standard Survey of 2004 and confirm that relative to households headed by females, male-headed households are likely to utilize modern energy sources. This finding is predicated on the fact that in Nigeria, men engage in more economic activities in comparison to their female counterparts and as such, they have more resources than female-headed households. Additionally, the finding above is unsurprising because of the prevalence of patriarchy in the country and as such, household's major decisions lie in the purview of men as household heads as all the ethnic groups in Nigeria expect women to be very submissive to men and majority of women's decisions are shaped by men. The Nigerian society reflects a lot of cultural norms and beliefs which are discriminatory and biased against the physical and social well-being of women (Ohia and Nzewi, 2016). Contrary to the findings reported previously, some studies (see Farsi et al., 2007; Rahut et al., 2014; Rahut et al., 2016a; Rahut et al., 2016b, Rahut et al., 2017; Zhang and Hassen, 2017) stresses that female-headed households are more probable to consume cleaner energy against their male counterparts. A possible rationale for this findings is contingent on the fact that in most families, women are the one responsible for cooking, this exposes them to fetching of firewoods especially those residing in developing countries and valuable time that would have been used in other productive engagement would be lost, hence they will prefer cleaner sustainable energy sources that save more time and is more environmentally friendly.

Another vital predictor of a household's energy consumption is the household's wealth or income. It is worth noting that most studies on this phenomenon pinpoints income as one of the crucial energy consumption determinants. Usually, the purchasing power of a household is increased when income improves and as such the household will have the resources to purchase or utilize sustainable energy sources which are even more convenient and more environmentally friendly. Thus, income increase makes household to shift from traditional to contemporary energy sources. Unsurprisingly, Özcan et al (2013) utilize Turkish household survey and they find monthly household income affect energy choices significantly. Many other studies (Karimu, 2015; Mensah and Adu, 2015; Makonese et al., 2017) reports that an increase in income levels makes households to consume sustainable energy. On the other hand, Farsi et al (2007) and Damette et al (2018) conclude that households with low-income are more inclined to utilize traditional energy sources. Expectedly and drawing from the 2013 Demographic and Health Survey, Buba et al, (2017) shows that Nigerian households are more likely to utilize modern energy sources as their income improves. Although this study contributed significantly to Nigerian literature, their findings might significantly differ from this present study.

The educational level of the household is a crucial variable that significantly influences household's energy consumption. There are various ways in which education can affect household energy sources. First and expectedly, education improves income and exposes an individual to the consumption of sustainable energy while poverty could be connected to the utilization of traditional energy sources. Second, income enhances knowledge and consequently household's preferences. In Nigeria, Ogwumike et al (2014) and Ifegbesan et al (2016) confirms that the educational attainment of the household head strengthens household's position in choosing modern energy sources. Likewise, Mwaura et al (2014) and Paudel et al (2018) report similar results using data from Uganda and Afghanistan respectively. These findings show that through education, individuals decision making are improved and they are more aware of the grave consequences of using traditional energy sources which poses a serious health and environmental problems and thus they are more probable to adopt modern energy sources. In China, Zou and Luo (2019) depended on a Tobit estimation of the 2015 Chinese General Social Survey and found that educational attainment of the household head has a positive significant link with modern energy consumption. Similar results were reported by Zhang et al (2020) using China Urban Household Survey.

The importance of household heads' age in describing the fuel choice of a household is highlighted in the literature although empirical evidence in this regard differs significantly. Generally, one would assume that older household heads would utilize dirty fuels instead of sustainable fuels, but this assumption is refuted in previous studies. Earlier studies (Nesbakken 2001 and Farsi et al 2007 for Norwegian and Indian households respectively) in this regard provided evidence that older headed household are more probable to utilize modern fuels. Likewise, Özcan et al. (2013) and Çelik and Oktay (2019) found that in Turkey that older headed household are more probable to utilize cleaner fuels. In a study in Afghanistan by Paudel et al (2018) found that having an aged household head enhances the probability of clean fuel adoption. A similar outcome was found in China by Zou and Luo (2019) who reported that an increase in age of the household head is positively linked with sustainable fuels preference.

The justification for the above findings may be predicated on the following. First, as an individual advances in age, more experience is gained on the diverse sources of energy and they tend to be increasingly concerned about preserving the environment. Secondly, the issue of life cycle effects could be vital in explaining this phenomenon; that is, younger headed household may be financially constrained to utilize modern fuels while their older counterparts could afford the resources which they have acquired over time to purchase modern fuels. On the other side of the divide, Rahut et al. (2014) conclude that older headed households are expected to favour dirty fuels than modern fuels. Similarly, Mensah and Adu (2015) established that older headed households are unlikely to use modern fuels. The justification of their result may not be farfetched. First older folks are very conservative and over the years they have become acquainted with dirty fuels and changing this behaviour may not be easy. Secondly, in some countries, sustainable energy infrastructure is still at the infancy stage and the awareness level of the older people about these modern fuels and the several gains derivable from their utilization may be lacking.

Household size is another debated variable in the literature that can provide important insights on the uptake of diverse fuel sources. Because of this, some studies have investigated this phenomenon. For instance, Ouedraogo (2006); Farsi et al (2007); Rao and Reddy (2007); Pandey and Chaubal (2011); Özcan et al. (2013); Rahut et al (2014); Mensah and Adu (2015) and confirmed the significant effect of increase in household size and uptake of dirty fuels. A likely explanation for the above finding is that poorer households are often characterized with larger households and as such have competing demands for several household needs begging for urgent attention, they may opt to sacrifice modern energy sources to adequately cater for other needs which may be more pressing. Additionally, the high cost of purchasing modern fuels could act as a hindrance. On the other hand, Zou and Luo (2019) refuted the above findings by indicating that an increase in the household's size triggers them to adopt cleaner fuels.

The energy utilization choices of a household could be contingent on spatial locations which are often divided into regional level and across rural and urban areas. In the case of Nigeria, the country is divided into six regions while still maintaining the conventional rural and urban divisions. Insights from energy literature have revealed that spatial locations strongly explicate the pattern of energy consumption of households (Belaïd et al., 2019). Kasanen and Lakshmanan (1989) observed that previously, studies normally neglect spatial locations in their model and this neglect could have implications on these studies owing to the key role spatial differences from both the demand and supply side could have on the energy utilization of the households. While the demand side contains household's spatial disparities, the supply side includes the availability of the kind of fuels the household needs, climatic and environmental circumstances which could have an implication on the prices of energy. In Nigeria, the level of economic development across the regions is significantly distinct. As stated earlier, the country has six regions (North East, West and Central as well South East, West and Central). Unlike the northern region, the southern part of the country is more developed while the northern region has more population and high poverty incidence. This could be contingent on the fact that the region produces as many children as they wish and do not pay adequate attention to education. The region is also adjudged to have a high population of out of school children and the constant insurgency that has ravaged the region over the years particularly in the North East is not helping matters.

Additionally, the incidence of poverty and underdevelopment is more prevalent in rural districts of the nation (Dauda, 2016). With the descriptions of the difference in regional level developments in the country and since it is very obvious that that the various regions in Nigeria possess distinct structural base and economic status, it will not be out of place to expect significant disparities in the fuel choices of Nigerian households. A study in Nigeria by Ifegbesan et al (2016) relying on 2013 Demographic and Health Survey (DHS) and multinomial logistic regression confirmed that the use of dirty fuel was more prevalent by households in the northern regions of Nigeria. The reason for these findings may not be far from the justifications earlier presented. Other studies from other countries have also found that a strong nexus between regional variation and the choice of fuel household utilize. For instance, Braun (2010) in a study in Germany established that in comparison to other regions, households residing in Eastern Germany have more propensities to use modern energy. Likewise, Laureti and Secondi (2012) concurs with the above findings in Italy by reporting that households in Northern and Central Italy utilize modern energy than their counterparts in other regions. Also, in the United States, Tso and Guan (2014) conclude that owing to climatic and geographical disparities between the regions, there is considerable disparity in household use of energy. Çelik and Oktay (2019) arrived at a similar conclusion by indicating that resident of the Turkish Black Sea region are unlikely to utilize modern fuels because of the region superior level of forestation and accessibility to firewood.

Furthermore, residing in either rural or urban areas could have implications on household energy choice. The energy choice of household in rural and urban areas could be different. Modern fuels are expensive particularly for households in developing nations and households in rural regions have relatively low cash flow which could deepen their likelihood to utilize traditional fuels. In an earlier study in Turkey, Özcan et al (2013) found households in urban areas enhance the likelihood of modern fuel selection. In Nigeria, Ifegbesan et al (2016) reported that households residing in urban areas are more likely to utilize modern fuel sources. Mensah and Adu (2015) employed Ghana's two nationally repeated surveys and acknowledge that residence in urban areas is a fundamental variable that influences the decision to utilize sustainable fuels. Similarly, Rahut et al, (2017) employed 2007 Timor-Leste nationwide survey data and the result indicates that urban households are unlikely to consume and rely on traditional fuels and more probable to consume cleaner energy. Employing the 2015 Afghanistan's Demographic and Household Survey, Paudel et al (2018) revealed that residing in urban districts positively affects modern fuel selections. Some other studies conducted by Rahut et al (2014) for Bhutan and Acharya and Marhold (2018) for Nepal reported that households in urban areas have a more chance of to utilize cleaner energy than their rural counterparts.

2.4.3. Evidence on Determinants of Intensity of Energy Consumption

The previous section presented the predictors of household energy choices. However, it is pertinent to know the degree these households rely on a specific energy source differs and that is why this section is essential. The intensity of energy consumption refers to the dependency of households on different energy sources. Households could rely on multiple kinds of fuels. They can rely on traditional fuels, modern fuels depending on their income and preferences and in some cases, they can combine both the non-clean fuel sources and modern fuel choices. This combination gave birth to the notion of energy stacking. In this section, the study reviews focus on determinants of intensity of energy consumption. Relative to the study's other research questions which have been presented above, the survey of the literature showed the intensity of energy use has not enjoyed considerable attention particularly studies utilizing nationally representative micro-data (to the best of my knowledge), thus this section presents the few evidence of this phenomenon in this section.

Using the three rounds of Bhutan micro-level data, Rahut et al (2016a) evaluate the factors that likely affect household consumption intensity. The study applied a multinomial Tobit model and reported that richer households and households with higher educational exposure are more reliant on modern fuel sources. Also, households with members that are grown-ups and households headed by females are more probable to rely on fuelwood and LPG.

Furthermore, the study revealed that households with electricity access relies more on candles, electricity and gas while using firewood and kerosene as substitutes. Likewise, when markets are farther for households, they tend to be reliant on kerosene and firewood while consuming less of candles, electricity and gas. Owing to inadequate income, it is unsurprising that rural residents tend to depend mostly on firewood perhaps because it is inexpensive and accessible. Similarly, Rahut et al, (2017) employ 2007 Timor-Leste nationwide survey data and the result from the Tobit model indicate that households head with higher educational attainment consumes more of clean energy while using kerosene as a substitute. Additionally, households with higher income level relies more on clean energy while their poorer counterparts consumes more of kerosene. Also, households in rural locations are more probable to utilize dirty and transitional fuel while relying less on clean energy. Similarly, as household expands in size, the consumption of electricity and fuelwood increases while relying less on transitional fuels. With regards to gender, fuelwood is more likely to be consumed by households headed by females while using kerosene as a substitute. In terms of spatial locations, rural residents significantly rely more on kerosene relative to their urban residents.

Finally, Mbaka et al (2019) applied Kenya household micro-level data to investigate the household consumption intensity. They found that relative to their urban counterparts, households residing in rural areas consume a higher quantity of dirty fuels sources. Similarly, they reported that heads of households that are educated consumes more of modern energy while relying less on transitional fuel like kerosene. Also, the study revealed that when households witnesses improvements in their income, it will trigger them to consume more of clean energy while consuming less portion of dirty and transitional fuels (woodfuel, charcoal and kerosene). In terms of gender, the study revealed that households headed by females consume more of non-clean energy relative to their male counterparts.

2.5. Summary of Literature

Numerous theories in energy-related literature explain energy consumption. This study discussed five theories explaining the energy consumption of households and the conclusions drawn from each of the theories were explored. The first theory reviewed is the energy ladder model which opines that households will move towards the utilization of cleaner energy as they witness improvements in their income. The model argues that enhancements in energy use of the household are contingent on household income improvements. The energy ladder model was criticized for been narrow and oversimplified and thus energy stacking model was introduced in energy literature. Energy stacking model states that energy consumption choices are driven by multiple factors, rather than, unidimensional factor. The model argues that households after adopting modern energy sources still retain the traditional energy sources.

Furthermore, the energy consumption of the household can be explained using the macro-micro model which holds that households energy consumption choices could be influenced by the combination of micro and macro variables. Furthermore, the rational choice model which was drawn from neo-classical economics argues that households are confronted with making utility-maximizing decisions which are often subject to their budget limits that are households choice are made by computing the benefits of diverse options and selecting the best decision that will guarantee their anticipated net benefits. However, the inability of these theories to adequately explain the effects of habits, moral behaviours and social norms motivated researchers to introduce value belief norm and planned behaviour theory. The theory of planned behaviour suggests that subjective norms, attitudes and perceived behavioural control jointly influence the behaviours of an individual. Lastly, the value belief norm avers that the beliefs and values an individual holds influences the behaviour of energy consumption. These theories have been extensively applied in related studies both in developed and developing economies (see Abrahamse and Steg, 2009; Abrahamse and Steg, 2011; Chen and Knight, 2014; Ishak et al., 2015; Chen et al., 2017; Guo et al., 2017; Bernard, 2017; Dimnwobi et al., 2018; Shi et al., 2019) among others. While these models are very capable of explaining the energy consumption of households, it is however impossible for this study to adopt all these theories simultaneously, hence the study adopted the energy stacking model to guide the study. The model is considered apt for this study because it is a phenomenon that is prevalent in Nigeria and it captures the complex nature of energy consumption choices across all stages of development of an economy. On the other hand, the review of the literature also shows that studies (Özcan et al., 2013; Ogwumike et al., 2014; Karimu, 2015; Mensah and Adu, 2015; Makonese et al, 2017; Zhang and Hassen, 2017 among others) have tried to identify the factors that shapes energy consumption around the globe. Some of these studies found diverse outcomes which could be contingent but not limited to the nature of data the studies employed, stages of the nation development, energy infrastructure as well as the country's economy size.

This study becomes paramount to literature in five aspects. First, to my knowledge, no energy study has been conducted in Nigeria utilizing a comprehensive nationwide-representative household dataset from a two-time phase (General Household Survey 2016 and 2019) covering a large number of households in Nigeria. This allows the study to estimate energy consumption deprivation for Nigeria over the two-time periods. Second, the study analysed these at the national, regional as well as rural/urban area in Nigeria. This is vital because the various regions in Nigeria have a different structural base and economic status and their energy consumption differs. Studies that focus on the differential regional or rural/urban determinants using multiple household surveys in a specific study are rare in the Nigerian literature and this study adds value to the literature in this regard. Third, this study employed the appropriate econometric model to estimate the key drivers of Nigeria's household energy consumption/deprivation, energy consumption intensity as well as investigate deprivations in energy consumption in Nigeria. A multivariate logistic regression method is apt to pinpoint the determinants and intensity of consumption while the multidimensional energy deprivation index is utilized in estimating the incidence of deprivation as well as the severity of deprivation. Fourth, the study incorporated energy deprivation variables that previous studies did not consider. Fifth, to my knowledge, there are limited studies on energy consumption intensity using household datasets in literature, thus, this study contributes to the scanty literature in that regard. Most previous studies only focus on the factors influencing household energy use behaviour without ascertaining the degree of reliance of these households on a specific energy sources, thus it is pertinent to know that the determinants of energy choices and the consumed proportion could be influenced by diverse factors. In view of these, this study complements the few studies (Rahut et al, 2016a; Rahut et al., 2017; Mbaka et al, 2019) in literature in this regard.

To ensure universal access and meet the anticipated future energy demand in Nigeria, it is fundamental to consider the variables shaping the nation's energy consumption, any observable regional or spatial patterns as well as the impediments to electricity access for which household energy consumption is critical. Therefore, understanding households' consumption behaviour in Nigeria is crucial not only to practitioners, scholars but also to makers of policy intended at supporting an efficient and sustainable energy use through various policy schemes, measures, and programs. Also, understanding energy consumption in Nigeria's households will help provide an enhanced description and perception of the nature of domestic energy consumption along with an initiative for sound energy policy development. The findings from the study will assist the Nigerian government in coordinating and harmonizing energy policy for households.

2.6. Summary

The aim of reviewing the literature in this chapter was to ascertain the amount of studies that has been conducted on energy consumption around the globe. The various reforms, as well as policies in the Nigerian electricity sector, were presented. Reviewing the literature assisted the researcher to determine the research objectives and research questions, conceptualize the terminology the study utilized as well demonstrate why conducting this study is significant. This chapter develops the basis for the subsequent chapter (chapter three) which contains the methodology employed by the study to achieve its objectives.

CHAPTER THREE

METHODOLOGY

3.1. Introduction

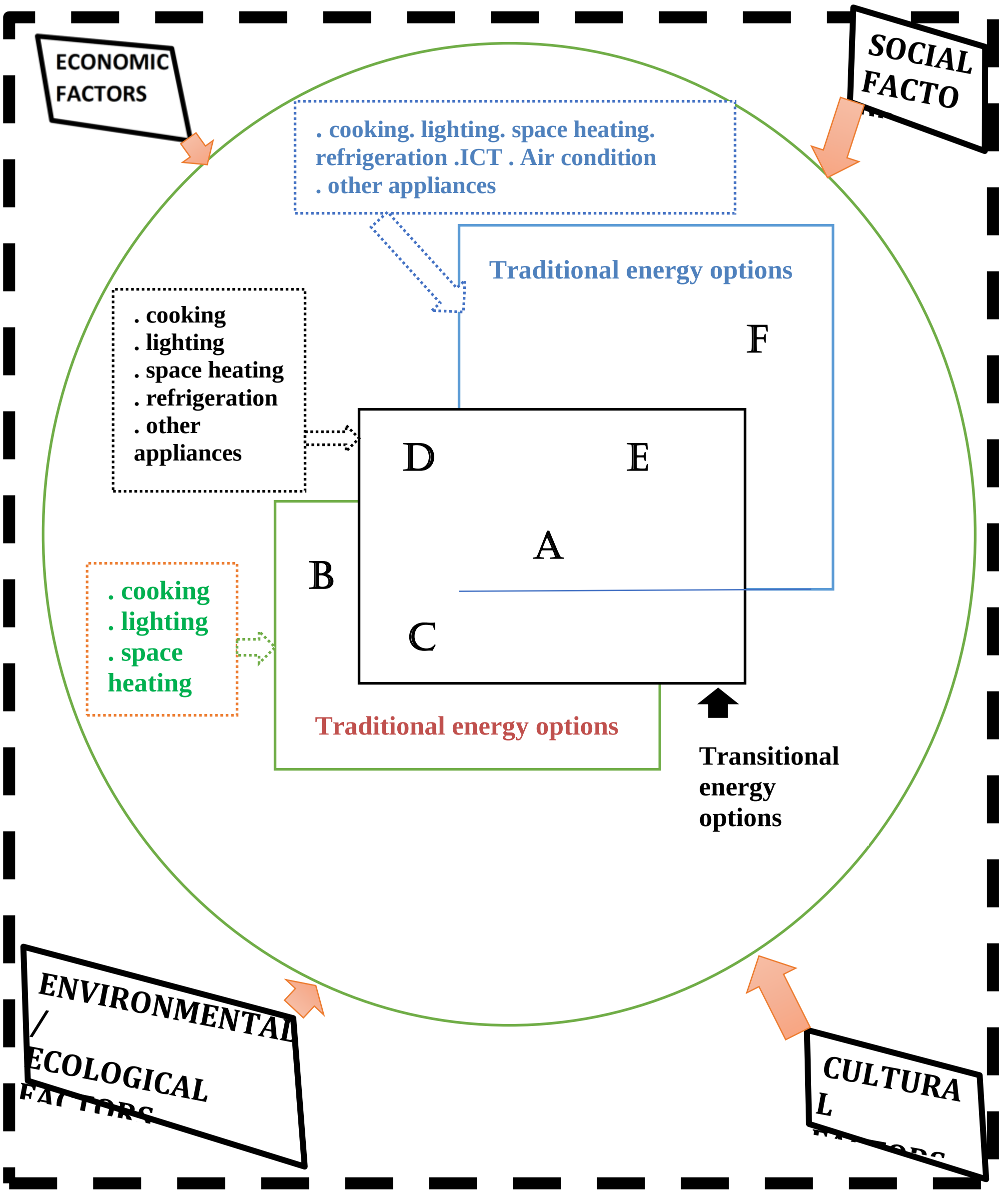
The preceding chapter contains the relevant literature on the subject of study. This chapter put forward the relevant models for analyses of the data based on relevant theoretical framework. Also, the sources from which the data was obtained was discussed as well as ethical issues

3.2. Theoretical Framework

The theoretical framework is anchored on energy stacking model (ESM). Admittedly, energy ladder model (ELM) which proposes that households, in similar manner as the utility maximizing consumer in neoclassical frameworks, transits from traditional energy options to modern or supplicated energy options as their income rises, has enjoyed a greater patronage in Nigerian energy study (see Sonibare and Akeredolu, 2006; Babatunde and Shuaibu, 2009; Gujba, Mulugetta and Azapagic, 2015). However, as noted by van der Kroon et al (2013) and Cheng and Urpelainen (2014), ELM has been under severe criticism for being empirically inconsistent. Cheng and Urpelainen (2014) observes that the assumption of ELM that energy transition follows a linear progression implies that transition to modern or sophisticated energy options is tantamount to abandonment of the traditional or lower level energy options. This prediction has been refuted by researchers for not reflecting empirical reality (Masera et al 2000; Alem et al., 2016; Nerini et al, 2017). Similarly, Hosier (2004) also criticized ELM for been narrow and oversimplified: the dynamics of energy consumption choices may not be captured by a univariate determinant model. In this regard, ESM, which captures the complex nature of energy consumption choices across all stages of development of an economy, is considered more apt.

Energy stacking model states that energy consumption choices are driven by multiple factors, rather than, unidimensional factor. According to Cheng and Urpelainen (2014), the determinants of energy consumption choices could range from economic (including household income) to cultural, social and environmental factors. In other words, household energy consumption choices that results in energy-switching could be influenced by complex and multiple factors. In the same vein, ESM also emphasizes that energy-switching outcome is rather intertwined or interconnected rather than being a simple or disconnected step. In other words, after adopting modern energy sources, households would still retain the traditional energy sources. Since energy options or sources are imperfect substitutes for each other, households would often utilize certain energy options for certain tasks depending on household need, energy preferences and household budget (see Pachauri and Spreng, 2003; Heltberg, 2004).

Suppose there are three stages of changes in energy technology, namely, traditional stage, transitional stage and modern stage. Each stage defines the kind of energy options that are consumed in such stages. The three stages are captured in Figure 3.1. During the first stage, called the traditional stage, the need for energy consumption includes cooking, lighting and space heating. The energy options available for household consumption include animal waste, agricultural waste, firewood, charcoal and other primitive energy sources. In the transition stage, more energy sources such as coal and kerosene are added to household energy choices. ESM holds that households may stack the transitional energy sources to the traditional energy sources rather than switch from traditional to transitional energy options in a discontinuous manner. Notice that at the transitional stage, more energy needs (especially for using basic appliances such as refrigerator) emerged. Similarly, more energy carriers or options (including kerosene, biofuel and electricity from grid or generator) emerged. In the modern stage, other energy carriers including liquidified petroleum gas (LPG) and solar energy would be added to the energy baskets of the households. While some very wealthy households may switch completely to the new energy options, most households, or the representative household would stack the new energy option to the existing sources.



A: Any of the Identifiable Energy Options
B: Animal Waste, Agricultural Waste
C: Firewood, Charcoal, Coal
D: Kerosene, Paraffin
E: Biofuel, electricity from grid, Electricity from Generator
F: Liquidified Petroleum Gas (LPG), Electricity from Solar

Figure 3.1: Energy Stacking Model

Source: Authors Sketch.

Energy stacking, which is most applicable to developing economies, could be driven by several factors. One of such factors is insurance. In developing countries, supply of modern energy is, more often than not, erratic. Stacking the modern carriers to the earlier carriers will provide insurance against supply failures that characterize the modern energy options in developing countries. For example, most households that adopted the use of solar energy for lighting also retain the use of electricity from grid, the use of electricity from generator, the use of battery torchlight or even the use of kerosene lantern. In the same manner, most households that adopted the use of electric stove for cooking also retain the use of kerosene stove, charcoal cooker and firewood as alternative options. Although most households may stack more than one energy carriers, the intensity of energy option use may vary among the households.

Also, energy stacking behaviour could be induced by vagaries of energy prices. To mitigate such inherent fluctuation in the price of modern energy, earlier energy carriers could be stacked to (instead of being replaced by) the modern carriers. In periods of price upsurges, the less expensive energy carriers or energy carriers with relatively stable prices may be preferred. In addition, Elias and Victor (2005) observed that high cost of acquiring modern energy (e.g. solar technologies) may induce energy stacking behaviour. For example, household may afford a small capacity solar technology that may be dedicated to providing lighting; while using kerosene stove for cooking.

Intuitively, energy stacking model suggests that household energy consumption choices could be hierarchical in an overlapping manner. In the same vein, it suggests that household stacking behaviour may vary in different context of household energy consumption decisions. One of the major concerns of researchers is to predict the stacking behaviour of an average household. According to Choumert et al (2019), the stacking behaviour could be predicted or captured using share stacking, directional stacking, simple stacking and stacking index. The simplest approach to conceptualizing energy stacking behaviour of households is the simple stacking method, which defines the stacking score as:

$$S_i = (0,1,\ldots N) \qquad 3.1$$

Where S_i is the number of different energy options purchased or consumed by the household.

Equation 3.1 shows that simple stacking only accounts for the types of energy options purchased/consumed by households. Although S_i indicates the direction of energy stacking, its shortcoming is that it fails to capture the extent of stacking behaviour. For example, simple stacking approach to capturing stacking behaviour will hardly differentiate between households that buy firewood and coal from households that purchase LPG and solar energy carriers: both households will be assigned the same stacking score. Alternatively, one can use directional stacking to differentiate the energy options being stacked based on the quantity or nature of energy that the energy carrier offers. In other words, the degree of energy stacking for each energy option may be ascertained. For example, suppose electricity (E) and Gas (G) is in the energy baskets defined by S_i, the directional stacking will be specified as:

$$D_i = \frac{\sum (E_i + G_i)}{S_i} \quad 3.2$$

Equation 3.2 presupposes that E and G are given at no cost such that household are only constrained by the quantity of each energy option that is available. However, this scenario is not always the case. Households are also constrained by its budgets. To capture the relativity of household budget to its stacking behaviour, Equation 3.2 is rewritten as follows:

$$SS_i = \frac{\sum (Y_i^E + Y_i^G)}{EY_i} \quad 3.3$$

Where SSi is the stacking share of electricity and gas expenditure as a ratio of total energy spending; Y_i^E is household expenditure on electricity. Y_i^G is the household expenditure on gas and EY_i is the total energy spending for the period.

Equation 3.3 indicates that households may alter their energy consumption by modifying their budget on any given energy option. In this context, the dependency of a household on any energy option could be ascertained. One shortcoming of Equation 3.3 is that it does not equally account for quantitative usage. For example, energy option with the highest share of expenditure may not necessarily be the one that is most stacked. This is because some energy sources are characterized by huge sunk per unit. Thus, to simultaneously account for both the quantity of energy options purchased or consumed and the share of energy spending allocated to each energy option, energy stacking index, ESI_i could be obtained. ESI_i could be expressed as:

$$ESI_i = SS_i \sum_{n=1}^{N} \frac{1}{N} Q_{ik} \quad 3.4$$

Where Q captures the quantity of a particular energy option that is purchased by an i^{th} household and N is the number of energy options. Essentially, ESI_i, weights the quantity of energy option purchased by the share of energy expenditure.

3.3. Empirical Model

The major thrust of this research is to ascertain the prevalence and determinants of energy consumption in Nigeria. To achieve these goals, we shall set up the empirical strategy as discussed in section 3.3.1, 3.3.2 and 3.3.3.

3.3.1. Prevalence of Energy Deprivation in Nigeria

To ascertain the prevalence of energy deprivation in Nigeria, we propose to use multidimensional energy deprivation index (MEDI). Our empirical strategy follows the approach utilized by Nussbaumer et al (2011) in their study of energy poverty. MEDI is an extension of Akire-Foster (AF) multidimensional poverty index (Alkire and Foster, 2011; Alkire et al, 2015). Although multidimensional energy deprivation may be estimated using other approaches such as composite indices approach, statistical approach, dashboard approach, the axiomatic approach among others (Layte et al. 2001; Tsui 2002; Atkinson 2003; Chiappero-Martinetti, 2006), Alkire-Foster (AF) approach to multi-dimensional deprivation is adjudged to be a superior methodology since it draws jointly the counting and axiomatic approaches distinctly while building upon understanding from several other methodologies. The AF method is a flexible technique for measuring deprivation (Angulo, 2016) and it can integrate different indicators and dimensions to create measures specific to particular contexts.

Particularly, Nussbaumer et al (2011) note that multidimensional approach to energy deprivation has numerous advantages over others. First, by focusing on energy services, MEDI is computed using information that is related to energy deprivation rather than use, such variables as energy usage which is presumed to be correlated. Second, the methodology used for estimating MEDI fulfils the dimensional monotonicity condition. Monotonicity condition requires that aggregate deprivation index falls if there is a reduction in deprivation such that at least one deprivation is removed from among the energy deprived. Put differently, if a person or household becomes deprived in additional dimension or indicator of energy deprivation, the MEDI increases to reflect such changes. Similarly, MEDI captures the number of energy deprived household (that is, the incidence of energy deprivation) as well as the intensity of energy deprivation among such households. Again, methodology used for estimating MEDI allows for decomposability. This implies that the energy deprivation index could be decomposed to reflect the prevalence or incidence in sub-divisions of the population such as geopolitical zones (example, South-South, East, West and North East, West and South zones), wealth classes (example, low income class, middle income class and upper income class), age categorizations, gender divisions, or even ethnicity (Igbo, Hausa, Yoruba, etc. in the case of Nigeria).

To construct the MEDI, we proceed as follows. Suppose there are ***n*** number of households in Nigeria whose energy consumption are evaluated by ***d*** indicators. Suppose the energy consumption of household ***i*** in indicator ***j*** is denoted as $\Pi_{ij} \epsilon R$ for all $i = 1, \ldots n$ and $j = 1, \ldots, d$. To collectively assess the energy consumption of the i^{th} household in all the indicators, a relative weight, w_j, is assigned to each indicator such that $0 < w_j < 1$ and $\sum_{j=1}^{d} w_j = 1$. Notice that the weight assigned to each indicator of deprivation is relative to other indicators of deprivation. The weight assigned to each indicator indicates the relative effect which being deprived or not being deprived has on the deprivation score of the household on identification and on energy deprived households on deprivation. Similarly, the weight also has impact on the removal or addition of a particular deprivation on the MEDI. According to Alkire et al (2015), weights assigned to indicators create comparability among the indicators of deprivation that are used in constructing the MEDI. In addition, since deprivation values are summarized in dichotomous variables (0 = deprived, 1= not deprived), weights help to evaluate different levels and degrees of deprivations in a single variable. In other words, the dichotomous nature of the indicators warrants that the only possible tradeoffs across deprivations take the value of the relative weights.

The total number of energy deprived is given as:

$$q = \sum_{i=1}^{n} w_j \theta_k (y, z) \qquad 3.5$$

Where q is the summation of energy deprived households identified using dual cut-off procedure indicated as $\theta_k(y_i; z)$ and $y_i = (y_{i1}, \ldots y_{ij}, \ldots y_{id})$ denotes the profile of i^{th} household energy consumption in all the d indicators. Following Nussbaumer et al (2011) and Alkire and Robles (2015), a household is classified as being energy deprived based on two cut-off procedures. Identification of the energy deprived follows dual cut-off procedure. In one-dimensional case, the identification of the energy deprived is straightforward: all persons with achievements below a given threshold are considered deprived. In multidimensional case, the identification of the energy deprived is rather more complex. It involves definition of a threshold (minimum achievement level below which a household is considered deprived) for each dimension. In other words, when a household's achievement (that is, energy consumption) is below the cut-off or minimum threshold, the household is considered deprived in that particular dimension. This is the first cut-off and it is called identification cut off. But that is not all that is required to consider a household as being energy deprived. The second cut-off, known as deprivation cut-off, involves setting a threshold of deprivation across the dimensions. While identification cut-off identifies deprivation in each dimension, deprivation cut-off identifies the deprived as one whose achievement is below the minimum threshold across all the dimensions. This implies that one may be deprived in one dimension but may not be considered to be multidimensionally energy deprived.

The first deprivation cut-off for indicator *j* is denoted as *z*, such that vector *z* summarizes the deprivation cut-off. Suppose the energy consumption or achievement of *n* households in *d* indicators is denoted as matrix *X* with *n* x *d* dimension. The i^{th}household is considered deprived in a j^{th} indicator if $x_{ij}<z_{ij}$, otherwise the i^{th}household is not considered deprived. Then we can assign deprivation status score g_{ij}= 1 and g_{ij} = 0 for the deprived and non-deprived respectively.

The second deprivation cutoff is denoted as *k*. *k* represents the number of deprivations a household must have before it is considered to be energy deprived. As noted by Alkire et al (2015), the second cutoff can use the union or intersection approach. In union approach, a household is considered energy deprived if it is deprived in at least one dimension. In this case, the value of *k* = 1. Contrarily, intersection method categorizes a household as being energy deprived only if one is deprived in all the indicators (that is, when *k* = *d*). In this study, we define the value of k to lie within the range $0 < k \leq 1$. Overall score c_i would be computed for each household such that:

$$c_i = \sum_{j=1}^{d} w_j g_{ij} \qquad 0 \leq c_i \leq 1 \qquad 3.6$$

Based on this cut off, a household is categorized as energy deprived if $c_i \geq k$, otherwise, it is considered to be non-deprived in the consumption of energy.

Now, suppose the headcount ratio of the energy deprived households is represented as D such that D defines the ratio of the households that are deprived. H indicates the incidence of energy deprivation in among the Nigerian households. Mathematically, H is computed as:

$$D = \frac{q}{n} \text{ and } 0<D<1 \qquad 3.7$$

Where q is as stated in Equation 3.5 and n is the total headcount of all households in the country (we assume that the representative households covered in the General Household Survey is representative of the population of households in the country).

The use of headcount ratio as the measure of multidimensional deprivation has come under serious attack. As observed by Bourguignon and Chakravarty (2003), it is a partial index of deprivation. It violates the dimensional monotonicity property: the ratio remains unchanged should a deprived household become deprived in a new dimension or in an aspect in which he was not deprived previously. It also violates the decomposability property. To mitigate these drawbacks, D is adjusted. D is adjusted by multiplying it with the intensity or breath of multidimensional deprivation (I). Deprivation intensity refers to mean deprivation score across the households. Suppose the deprivation score $c_i(k)$ denotes the share of deprivation experienced by an i^{th} energy deprived household. The intensity of deprivation (I) is defined as:

$$I = \sum_{i=1}^{n} \frac{c_i(k)}{q} \qquad 3.8$$

Thus, the adjusted headcount deprivation ratio (M_0) is given as:

$$M_0(X;z) = D \text{ X } I = \frac{1}{n}\sum_{i=1}^{n} c_i(k) = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} w_j g_{ij} \qquad 3.9$$

$M_0(X;z)$ is called the multidimensional energy deprivation index (MEDI). Since I is sensitive to changes in depravity, MEDI is also sensitive to changes in the state of deprivation. MEPI also exhibits both dimensional monotonicity and decomposability properties.

In addition, the M_0 can be decomposed into subgroups such as spatial groupings (eg rural and urban) and regional groupings (eg geopolitical zones: South-South, East, West and North East, West and South). Subgroup decomposition enhances the understanding of the depravity and deprivation dynamics of the component units that make up the population. Suppose the population share (τ^{φ}) and subgroup achievement matrix (X^{φ}) are given or obtainable for subgroup, φ, M_0could be redefined as:

$$M_0(X) = \sum_{i=1}^{m} (\tau^{\varphi}) M_0(X^{\varphi}) \qquad 3.10$$

Notice that Equation 3.10 is additive. This implies that one can compute the contribution of each subgroup ($\mathbb{Q}_{\varphi}^{0}$) to the overall M_0 such that:

$$\mathbb{Q}_{\varphi}^{0} = \tau^{\varphi} \frac{M_0(X^{\varphi})}{M_0(X)} \qquad 3.11$$

MEDI identifies energy deprivation as a condition of multiple deprivations. We adopt three-dimension of energy use or consumption; namely, cooking, lighting, appliances (see Table 3.1). The indicator of cooking dimension is "use of modern cooking fuel". Similarly, the indicator of lighting dimension is "has access to electricity". The appliance dimension has three indicators, namely, ownership of household service appliance, ownership of entertainment/educational appliance, and ownership of communication device. Equal weights, 0.333, were assigned to each dimension.

Table 3.1: Dimension, Indicators and cut-off rules for MEPI

Dimension	**Indicators**	**Variable**	**Weight**	**Deprivation cutoff (Deprived if …)**
Cooking	Use of modern cooking fuel	Types of cooking fuel	0.333	Household utilize any cooking fuel aside electricity, natural gas, LPG or biogas
Lighting	Access to electricity	Has access to electricity	0.333	FALSE
Appliances	Ownership of household service appliance	Has a fridge/washing machine/electric grinder/air conditioner etc	0.111	FALSE
	Ownership of entertainment/education appliances	Has radio/television/decoder	0.111	FALSE
	Ownership of communication device	Has hand phone/landline	0.112	FALSE

Dimension	Indicators	Variable	Weight	Deprivation cutoff (Deprived if …)
		phone		

Source: Adapted from Nussbaumer*et al*. (2011). The researcher however adjusted for dimensions, indicators and weight assignment.

3.3.2. Determinants of Energy Deprivation and Choices in Nigeria

There are several sources of energy that may be available to the household. This implies that an average household may be faced with choice problem: which energy source to utilize or consume. Again, the nature of these choices may elicit mutually inclusive behavior such that household energy choices may be correlated. This suggests that to capture the determinants of such variety and mutually inclusive household energy choice, a multivariate discrete choice model will me more apt. We therefore adopt multivariate probit model for estimating the determinants of energy choices in Nigeria. Multivariate probit model, unlike the binary model, simultaneously evaluates energy choices of the households by considering all the energy sources in an individual-specific basis. We identify four energy sources, namely, electricity, natural gas, fuelwood and biomass. These energy sources are considered the dependent variables. The independent variables are observed covariates which include household characteristics, ownership of wealth, income sources, supply of labour, ethnicity, religion, region, etc.

Following Chib and Greenberg (1998), we specify the multivariate probit as follows. Suppose j denotes energy choices and k denotes individual households, the multivariate function for the determinants of energy choices $y_k = (y_1, \ldots, y_j), (k=1,\ldots,N)$ is specified as:

$$pr(\mathbf{y}_k / Z_k \Psi, \varepsilon) = \int_{A_J} \ldots \int_{A_1} fN(\mathbf{y}_k^* / Z_k \Psi, \varepsilon) dy_1^* \ldots dy_J^* \qquad 3.12$$

$$pr(\mathbf{y}_k / Z_k \Psi, \varepsilon) = \int 1y \in A \; fN(\mathbf{y}_k^* / Z_k \Psi, \varepsilon) dy_1^* \ldots dy_J^* \qquad 3.13$$

Where $A_k = \begin{cases} [-\infty, 0] & y_k^* = 0 \\ [0, \infty] & y_k^* = 1 \end{cases}$

And the log likelihood function is:

$$\log l = \sum_{k=1}^{N} \ln pr(\mathbf{y}_k / Z_k \Psi, \varepsilon) \qquad 3.14$$

3.3.3. Determinants of Intensity of Energy Consumption

The intensity of energy consumption indicates the dependency of households on different energy sources. The dependent variable, *z*, is generated by dividing the expenditure of each household on each energy source by total energy expenditure of the household on all energy sources. Since *z* ranges from 0 to 1, censored Tobit model would be applied to estimate the determinants of intensity of household consumption, or put differently, the dependency of household energy consumption.

Assuming a latent dependent variable that is censored at 0, the Tobit function is specified as follows:

$$z_i^* = \alpha_z^{'} x_i + \varepsilon_{zi} \tag{3.15}$$

Where z_i^* is latent dependent variable which truncates household consumption of any given energy source by indicating the level of energy consumption intensity below which a household is taken not to have consumed a given energy source. x_i, $\alpha_z^{'}$ and ε_{zi} are a vector of explanatory variables, vector of coefficients, and independently and normally distributed error term respectively. Now suppose R indicates the threshold that differentiates households that consume a specific energy source from those households that do not. From Equation 3.15, the intensity of household energy use of a specific source of energy is specified as:

$$z_i = z_i^* \text{ if } z_i^* \geq R \tag{3.16}$$

and

$$z_i = 0 \text{ if } z_i^* < R \tag{3.17}$$

Also, the probability density function for households that consume a particular energy source and the standard normal cumulative function for households that do not consume a specific energy sources are specified in Equations 3.18 and 3.19 respectively:

$$f(z_i / z_i^* \geq R) = \frac{f(z_i)}{p(z_i^* \geq R)} = \frac{\frac{1}{\sigma}\gamma\left(\frac{z_i^* - \alpha_{zi}^{'} x_i}{\sigma}\right)}{\Omega\left(\frac{\alpha_{zi}^{'} x_i}{\sigma}\right)} \tag{3.18}$$

$$p(z_i^* < R) = \Omega\left(\frac{\alpha_z^{'} x_i}{\sigma}\right) \qquad 3.19$$

Also, the log-likelihood function is specified as:

$$Logl = \sum_{z_i^* < R} \ln\left(1 - \Omega\left(\frac{\alpha_z^{'} x_i}{\sigma}\right)\right) + \sum_{z_i^* \geq R} \ln \frac{1}{\sigma} \gamma\left(\frac{z_i^* - \alpha_{zi}^{'} x_i}{\sigma}\right) \qquad 3.20$$

Notice that the Equation 3.20 is the summation of the probability functions for both households that consume a particular energy source and those that do not.

3.4. Data Sources

Essentially, this study is a quantitative research that adopts micro econometric procedures. The study utilises survey data, particularly, Nigerian General Household Survey (NGHS) data. The NGHS is conducted through a tripartite project known as Demographic and Health Survey (DHS). DHS is a USAID project implemented in collaboration with Nigerian data agency, particularly, National Bureau of Statistics (NBS) (or other national data agencies in the case of other countries), and the World Bank. This study utilises NGHS 2015/16 and NGHS 2018/2019. While both NGHS 2015/16 and NGHS 2018/2019 would be used for the estimation of multidimensional Energy Deprivation Index (MEPI), only NGHS 2018/2019 is used in the estimation of determinants of energy consumption choices and energy consumption intensity.

The NGHS is a cross-sectional survey that uses household as data unit. About 22,200 households are covered in the cross-sectional survey. The respondents were sampled using multi-stage stratified sampling procedure. In the design of the survey samples, a total of 2220 enumeration areas were selected nationwide with about 60 enumeration areas being selected from each of the 37 states in Nigeria (the Federal Capital Territory is considered as the 37th state). 10 households were selected from each of the 2220 enumeration unit making it a total of 22,200 households covered in the survey.

3.5. Overview of Ethical Issues

This study is a quantitative research that utilized secondary data gathered through a tripartite project known as Demographic and Health Survey (DHS). DHS is a USAID project implemented in collaboration with Nigerian data agency, particularly, National Bureau of Statistics (NBS) (or other national data agencies in the case of other countries), and the

World Bank DHS Program (2019). The unit of data collection was the households. However, the households were coded in a manner that the households are not identifiable, and the codes are not known to the researcher and there is no intention by the researcher to apply for access to the codes (DHS Program, 2019). In other words, ethical issues involving informed consent are not required (Norwegian National Research Ethics Committees - NNREC, 2014). The data required in this research are accessible from www.DHSprogram.com. However, it is required that a researcher who proposes to utilize such data registers with USAID DHS Program (DHS Program, 2019). The researcher obliged the registration requirement for data access. As traditional in research, it is required that the data sources are appropriately cited (DHS Program, 2019). Thus, this requirement is compiled in this research.

3.5.1. Risks for Participants

A participant scheduled to participate in research may be exposed to possible risks, and such risks refer to the likelihood of harm like loss of confidentiality etc., occurring to the participant as a result of his/her involvement in the research process (NNREC, 2016). Following this, a researcher is required to minimize, if not eliminate, possible risks exposures to the participants (NNREC, 2016). For example, the identities of participants who participated in a research process would never be released to any third party without the express permission of the person or participant (NNREC, 2016).

Since the proposed research required for this thesis does not involve engaging identifiable participants, there are no identifiable risks to the participants. There are no identifiable participants in this research. The data to be used have been collected by data agencies in a way that subjects are not identifiable. Thus, there are no potential risks envisaged in this study. According to the DHS Program (2019), due diligence was observed to ensure that there are no potential risks to the participants in the course of collecting the original data.

3.5.2. Risks for Yourself

There are no identifiable risks of harm to the researcher in carrying out this research. The data to be used have presumably passed data quality assessment by the data agency and also presumed that the data agency complied with ethical considerations required for a survey study DHS Program (2019). All sources of secondary data to be used shall be appropriately cited.

3.5.3. Informed Consent

Informed consent enables a researcher to respect the autonomy and rights of subjects to participate in research, it involves informing the subject (expected to participate in a research process) of the study's purpose, the procedure to be utilized in the study, the rights of the subjects (in participating in the research) as well as the potential risks and benefits of participating in research by the subject (NNREC, 2016, p. 13-14). Therefore, in this study, no identifiable person(s) is (are) expected to participate in the research. The study utilizes secondary data (general household surveys that are documented by data agencies), and the survey data uses code to represent households in which the identities of the households are not revealed in the survey data (DHS Program, 2019). Thus, signing of the informed consent form by subjects will not be required since there is (are) no identifiable subject(s) to sign the form(s) (NNREC, 2016).

3.5.4. Internet Research

Internet research is a research method that involves the compilation of information from the web or the internet (Felzmann, 2013). Unlike the traditional research method, internet research can be used to conduct research that involves research subjects that are geographically dispersed, for example, internet research on customer satisfaction for a product can be done using respondents from every continent of the world where such a product is sold, without incurring any distance-related costs (Felzmann, 2013). The techniques of internet research available to a researcher include online-based focused group discussion, online key-informant interview, online-based survey, online text analysis, and online social network analysis (Felzmann, 2013). This study is, essentially, not internet research. It rather involves the analysis of household surveys carried out in Nigeria among Nigerian households. In carrying out the survey, the physical locations of the households were mapped out and sampled using standard sampling procedures, and the selected households were visited with a questionnaire in which responses were elicited from them (DHS Program, 2019). The responses obtained were documented by the USAID Demographic and Health Survey (DHS) and the survey was a tripartite project of the USAID, National Bureau of Statistics (NBS) and World Bank (DHS Program, 2019). These survey data were obtained from the USAID Demographic and Health Survey (DHS). However, in other to obtain such survey data from www.DHSprogram.com, a researcher is required to register with USAID Demographic and Health Survey (DHS) because such registration is required to access the survey data from www.DHSprogram.com (DHS Program, 2019). Thus, this requirement was complied with.

3.5.5. Personal Data Protection

Technically, personal data refers to any data or piece of information that relates to an identifiable or identified individual or natural person (NNREC, 2016). An individual or a natural person is said to be identifiable if he or she may be identified using a specific or known location, name, identification code or any other special attribute that relates specifically to a known subject or person (NNREC, 2016). In Nigeria, the 1999 constitution of the Federal Republic of Nigeria amended in 2011, (Section 37) requires the protection of citizens privacy, their correspondence, homes, as well as telephone and telegraphic communications (FRN, 1999, n.p.n). Thus, we are committed to protecting personal data in the course of this study.

The main data to be used in this study is household survey data obtainable from www.DHSprogram.com. The survey data use unidentifiable code to represent households and is impossible for a researcher or any other user of such information to match the codes with the real natural person or household units (DHS Program, 2019). DHS interviews and surveys are carried out as privately as possible and, in the event, that two members of a household are interviewed, they are interviewed independently such that the responses of one respondent are not known to another (DHS Program, 2019). The respondents are also represented with codes that provide information about the location, local government area and the state of the respondent. However, the code does not indicate any personal characteristics through which the individual respondent could be identified (DHS Program, 2019).
Although individual code identifiers indicate unique enumeration areas (EAs) for each respondent during the data collection process, the questionnaire data sheet that contains these specific code identifiers is destroyed and the enumeration areas and household numbers are reassigned randomly (DHS Program, 2019).

As noted earlier, this study utilizes DHS data collected and documented by the DHS program. DHS is household survey data obtained through a joint survey conducted by USAID, National Bureau of Statistics (NBS) and World Bank (DHS Program, 2019). The data set is impersonal and does not indicate any identifiable person(s). The data to be utilized do not require one to obtain any special legal permission (DHS Program, 2019I). However, they shall be downloaded from www.DHSprogram.com after being duly registered. The registration process requires one to sign up to abide by privacy and confidentiality regulations of the DHS and the country (DHS Program, 2019). They are published as open access documents and, it is required that the material be appropriately cited when used for any purpose. This requirement is strictly complied with for this study. The use of secondary data that is obtained with appropriate permission is allowable by the GDPR and thus, it does not also violate national regulations implemented by the Norwegian Centre for Research Data. Besides, it does not contravene any known law in Nigeria.

Empirical research also requires that informed consent be obtained from the participants before enrolling them in research (NNREC, 2016). Informed consent refers to the deliberate agreement by subjects or respondents to partake in research involving an interview, focus group discussion, questionnaire survey, experimental research as well as any other form of research that requires subjects or respondents to partake in any way (NNREC, 2016). The Norwegian Centre for Research Data and other research regulations provides that informed consent must be obtained from subjects or respondents before involving or engaging them in research (ibid., n.p.n). To the extent that this study does not engage identifiable natural persons directly or indirectly, there is no legal or moral demand on us to obtain informed consent for this study. However, according to the DHS Program (2019), informed consent was duly obtained before collecting the DHS data.

DHS Program (2019) specifically asserts that an informed consent statement was read to the respondents who are allowed to accept or reject to partake. DHS Program chose to read the informed consent to the participants to ensure that even the illiterate households exercise their right to participate or not to participate in the research. If children or adolescents are to participate in the survey, parents or guardians were required to provide their consent or otherwise before such children or adolescents are allowed to participate in the survey (DHS Program, 2019). As noted by DHS Program (2019), the informed consent statements read to the participants have the following details: the aim of the interview, interview likely risks to the participant, potential benefits of the interview to the participant, the duration of the interview and the interview procedure. The informed consent statement also clearly states that involvement or partaking in the survey is deliberate and partakers may decline to participate if they so wish (DHS Program, 2019). It also provides that after participants have enrolled for the interview, they can also opt-out or terminate their participation in the survey or interview. DHS Program (2019) also added that the informed consent also emphasizes that information supplied by or relating to the participant shall be strictly confidential.

3.6. Summary

The methodology employed to achieve the objectives of the study were presented. It discusses the theoretical framework, empirical model, data sources as well as the ethical considerations. The next chapter will proceed to analyze and present the study's findings.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION OF FINDINGS

4.1. Introduction

In this chapter, the survey data from Nigerian Household Survey (2016, 2019) is applied to analyze the dynamics of energy consumption in Nigeria. The analysis is an attempt to provide answers to the research questions through quantitative evidence obtained from the data. First, a descriptive analysis of the underlying patterns of energy deprivation is undertaken. This is followed by several estimations aimed at providing answers to the research questions. Finally, the findings from the estimations are discussed to provide further understanding of the behavioural patterns, theoretical underpinnings and empirical findings in other climes.

4.2. Descriptive Statistics

Energy is one of the most essential household utilities in most countries. It is mostly required for lighting and cooking. There are different sources of fuel that could provide energy for cooking. These include kerosene, liquidified petroleum gas (LPG) also known as cooking gas, firewood and charcoal. Others include electricity, biomass, grass and palm kernel husks. As shown on Table 4.1(a), the proportion of household that use kerosene in Nigeria in 2019 is 21.3%. The distribution, however, differ across urban and rural residences. For example, the use of kerosene is more predominant in urban areas than rural areas. On average, about 41.7% of urban households use kerosene while it is being used by only 21% of rural households. Similarly, the spread of kerosene usage across the various geopolitical zones indicates that it is used more in southern Nigerian than northern Nigeria. For example, the proportion of households that use kerosene in North Central, North East and North West is 14%, 1.3% and 5.6% respectively.

Table 4.1(a): Proportion of Households that utilize various cooking fuel sources

	Kerosene			LPG/Cooking Gas		
	2016	2019	Percentage change	2016	2019	Percentage change
North Central	13.3	14	5.3%	5.5	6.7	21.8%
North East	4.7	1.3	-72.3%	1.9	0.3	-84.2%
North West	7.1	5.6	-21.1%	3.2	2.4	-25.0%
South East	33.4	37.9	13.5%	4.2	6	42.9%
South-South	27.3	31.6	15.8%	12.6	17.9	42.1%
South West	34.2	35.6	4.1%	22.2	25.7	15.8%
Urban	39.1	41.7	6.6%	18.5	23.6	27.6%
Rural	10.2	12	17.6%	3.9	4.1	5.1%
National	20.2	21.3	5.4%	8.1	10.2	25.9%

Source: Computed by the researcher using NGHS (2016, 2019).

On the other hand, Table 4.1(a) shows that the usage of kerosene by southern Nigerian household in 2019 is highest in South East Nigeria with about 37.9% of the households in that zone. In the South West and South-South zone, about 35.6% and 31.6% of households used kerosene in 2019. The distribution of the usage of kerosene across the geopolitical zones shows that on average the usage of kerosene was five times higher in the Southern Nigeria than Northern Nigeria. The consumption of LPG in 2019 is also higher in Southern Nigeria than in Northern Nigeria. For example, the proportion of households that consume LPG in North Central, North East and North West are 6.7%, 0.3% and 2.4% respectively while that of South East, South South and South West are 4.2%, 12.6% and 22.2% respectively. However, in 2016, the proportion of households that consume LPG in North Central, North East, North West, South East, South South and South West are 5.5%, 1.9%, 3.2%, 4.2%, 12.6% and 22.2% respectively. In the same vein, the consumption of LPG in urban residence is 23.6% and 18.5% of households in 2019 and 2016 respectively. However, in rural areas, the consumption of LPG in 2019 and 2016 is 4.1% and 3.9% of households. In other words, the consumption of LPG in the urban area is approximately six times higher that of rural areas. Also, on national average, the consumption of LPG is only about 10.2% in 2019 and

8.1% in 2016. Although, this represents an improvement of about 25.9% between 2019 and 2016

Table 4.1(b): Proportion of Households that utilize various cooking fuel sources

	Charcoal/Coal			**Wood**			**Others**		
	2016	2019	Percentage change	2016	2019	Percentage change	2016	2019	Percentage change
North Central	8.8	9	2.3%	75.8	74.6	-1.6%	3.8	2.7	-28.9%
North East	12.1	11.6	-4.1%	93.4	95.7	2.5%	2.6	3.4	30.8%
North West	5.6	6	7.1%	82.5	89.2	8.1%	7.1	8	12.7%
South East	1.1	0.8	-27.3%	58.4	55.8	-4.5%	2.4	1.9	-20.8%
South-South	0.4	0.1	-75.0%	56.7	50.8	-10.4%	4.4	3.4	-22.7%
South West	3.2	2.7	-15.6%	38.6	35.9	-7.0%	3.5	3	-14.3%
Urban	9.5	9.1	-4.2%	36.6	31.7	-13.4%	3.2	3.3	3.1%
Rural	1.8	2.6	44.4%	85.4	82.3	-3.6%	4.1	4.4	7.3%
National	5.2	4.7	-9.6%	68	66.5	-2.2%	4.5	4.1	-8.9%

Source: Computed by the researcher using NGHS (2016, 2019).

Contrarily, the consumption of wood is higher in Northern Nigeria than Southern Nigeria. In 2019, about 93.4% and 89.2% of the households in North East and North West respectively consume firewood. The data trend also shows that the consumption of firewood declined marginally in the North Central in much the same way as in Southern Nigeria. However, in North East and North West, the consumption of firewood increased by 2.5% and 8.1% respectively. The consumption of firewood however declined from 36.6% of urban households to 31.7% and 85.4% of rural households to 82.3%. Also, the national average declined from 68% to 66.5%. The pattern of consumption of charcoal did not change significantly between 2019 and 2016 in the North. However, in southern Nigeria, there is significant decline in the consumption of charcoal. Other household fuels consumed for cooking include electricity, biomass among others.

The changes in the usage of kerosene between 2019 and 2016 indicate that there is decline of 72.3% and 21.1% respectively for North East and North West. However, there is increased usage in North Central (5.3%), South East (13.5%), South-South (15.8%) and South West (4.1%). In the same vein, the consumption of firewood increased in the North but decreased in the South. Again, the consumption of LPG also declined in North East and North West by 84.2% and 25.0% respectively. In other zones, there is increase in the consumption of LPG. Premised on the theory of energy ladder, the poorer households consume lower energy sources such as firewood while the richer households go for modern sources such as LPG.

As shown on Figure 4.1, there is no substantial change in the consumption of cooking fuel in 2019 and 2016. For example, the proportion of households that consume kerosene increased by 5.4% between 2016 and 2019. Similarly, the proportion of households that consume firewood and charcoal decline by only 9.6% and 2.2% between 2016 and 2019. However, for LPG, the consumption increased by about one-fourth between 2016 and 2019.

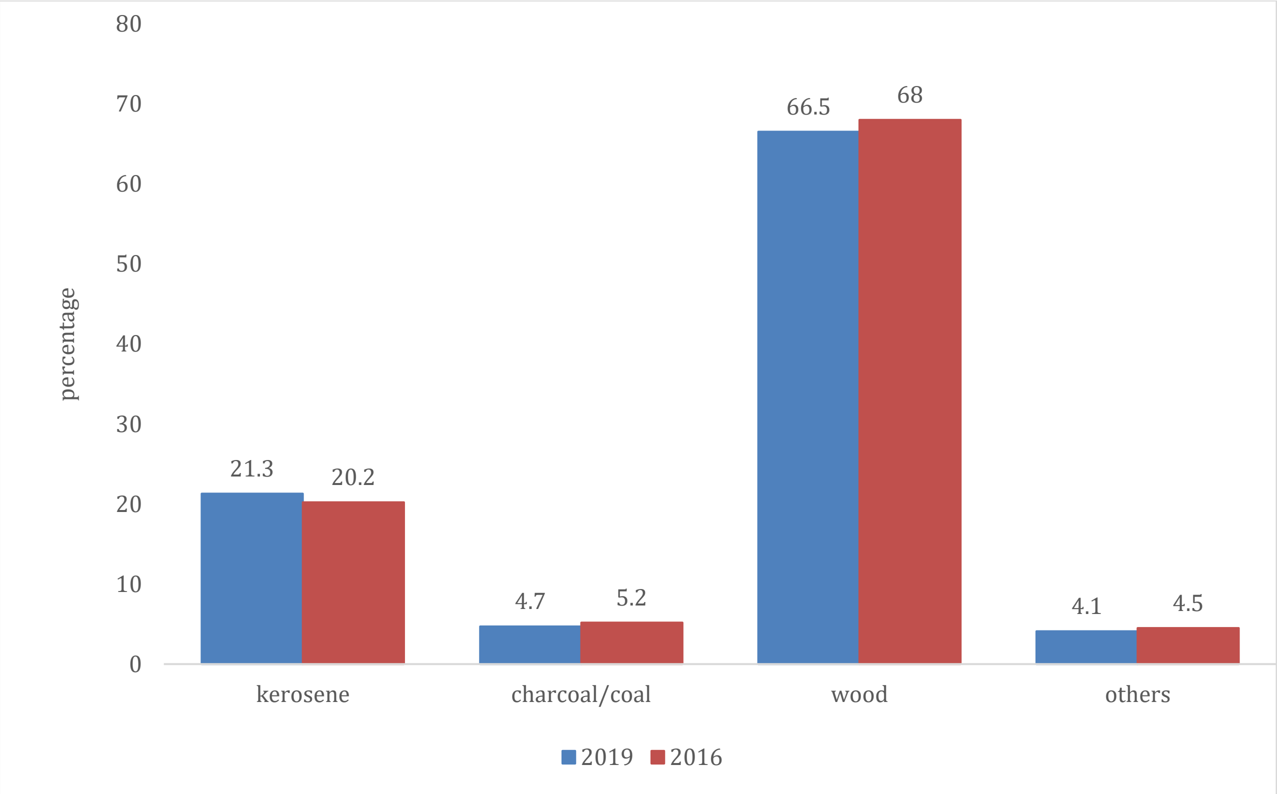


Figure 4.1 Cooking Fuel Consumption in 2019 and 2016
Source: Graphed by the researcher using NGHS (2016, 2019).

Another critical utilization of household energy is for lighting or electricity. The sources of electricity covered in both 2019 and 2016 survey include national grid (usually called PHCN or NEPA in Nigeria), generator, lantern and solar energy. The national grid which has the ability to generate 11 MW of electricity via its 23 power generating plants is said to be underutilized. As shown on Table 4.2 (a), the national average for the consumption of electricity through the supply chain of national grid is only 6.6 hours and 4.9 hours per week respectively. Also, in urban residence, about 7 hours of electricity per week was supplied by national grid in 2019 and 5.9 hours per week in 2016. The spread of national grid electricity is not substantially different across the various geopolitical zones in Nigeria. For example, in 2019, the distribution of national grid electricity per household is 7 hours per week for North Central, 7.5 hours per week for North East, 6.8 hours per week for North West, 4.4 hours per week for South East, 6.4 hours per week for South-South, and 8 hours per week for South West. The status of national grid consumption shows that there is positive increase in the consumption of national grid electricity across all the geopolitical zones in Nigeria.

In the same vein, the utilization of generator increased in Southern Nigeria but decreased in Northern Nigeria. For example, it decreased from 7.2 hours per week, 9.3 hours per week and 5.2 hours per week in North Central, North East, and North West to 5.7 hours per week, 8.8 hours per week and 5.2 hours per week respectively. The highest improvement in the utilization of generator for lighting (which is 30.2%) was recorded in South-South Nigeria.

Table 4.2(a): Sources of Electricity and Lighting: Hours of electricity per week

	National grid			**Generator**		
	2016	2019	% change	2016	2019	% change
North Central	6.3	7	11.1%	7.2	5.7	-20.8%
North East	4.6	7.5	63.0%	9.3	8.8	-5.4%
North West	4.3	6.8	58.1%	6.5	5.2	-20.0%
South East	3.7	4.4	18.9%	4.2	4.3	2.4%
South-South	4.2	6.4	52.4%	6.3	8.2	30.2%
South West	6.5	8	23.1%	2.6	2.8	7.7%
urban	5.9	7	18.6%	4.1	4.3	4.9%
Rural	4	6.2	55.0%	6.2	7	12.9%
National	4.9	6.6	34.7%	6.1	6.3	3.3%

Source: Computed by the researcher using NGHS (2016, 2019).

The consumption of solar energy for lighting is generally low in all the geopolitical zones. The week utilization in 2019 was 3.2 hours, 0.7 hours, 1.2 hours, 2.3 hours, 2.2 hours and 4.2 hours for North Central, North East, North West, South East, South-South and South West respectively. In the northern region, only North Central zone recorded increase in solar usage between 2019 and 2016. North East and North West recorded decline in solar usage by about 50% and 20% respectively. However, all geopolitical zones in the southern regions (South

East, South-South and South West) recorded increase in the usage of solar energy between 2019 and 2016.

Table 4.2b also shows that lantern and rechargeable torch are being used more intensively for lighting than national grid, solar and generator. Although the use of lantern decline from 11.2 hours per week, 7.5 hours per week , 13.3 hours per week, and 27.7 hours per week to 9.4 hours per week, 6.7 hours per week, 12..5 hours per week and 24 hours per week between 2016 and 2019 in North Central, South East, South-South and South West respectively, it however increased from 8.3 hours per week to 10.4 hours per week and 12.4 hours per week to 14.9 hours per week between 2016 and 2019 in North East and North West respectively. The highest change between periods occurred in the North East where utilization rose by 25.3% between 2016 and 2019.

Table 4.2(b): Sources of Electricity and Lighting

	Lantern*			**Solar**		
	2016	2019	% Change	2016	2019	% Change
North Central	11.2	9.4	-16.1%	2.3	3.2	39.1%
North East	8.3	10.4	25.3%	1.4	0.7	-50.0%
North West	12.4	14.9	20.2%	1.5	1.2	-20.0%
South East	7.5	6.7	-10.7%	1.8	2.3	27.8%
South-South	13.3	12.5	-6.0%	1.6	2.2	37.5%
South West	27.7	24	-13.4%	4.2	4.6	9.5%
Urban	5.6	4.9	-12.5%	3.1	3.2	3.2%
Rural	11.4	10.9	-4.4%	1.1	1.4	27.3%
National	13.4	9.8	-26.9%	2	2.1	5.0%

Source: Computed by the researcher using NGHS (2016, 2019).

**Lantern here includes kerosene-powered lantern, Battery-Powered lantern and Rechargeable lantern*

Overall, there is decline in the average number of hours that households use lantern in both urban and rural residences. Urban household diminished the use of lantern from 5.6 hours per week in 2016 to 4.9 hours per week in 2019. This represents about 12.5% decline. In the same vein, rural households reduced the use of lantern from 11.4 hours per week in 2016 to 10.9 hours per week in 2019. The change in the use of lantern in the rural area is rather marginal (Only 4.4%). The national average, however, shows that there is approximately 27% decline in the utilization of lantern between 2016 and 2019. To be precise, weekly usage of lantern for lighting declined from 13.4 hours in 2016 to 9.8 hours in 2019. Figure 4.2

shows that there is no substantial variation in the energy consumption for lighting between 2016 and 2019 except in the case of lantern.

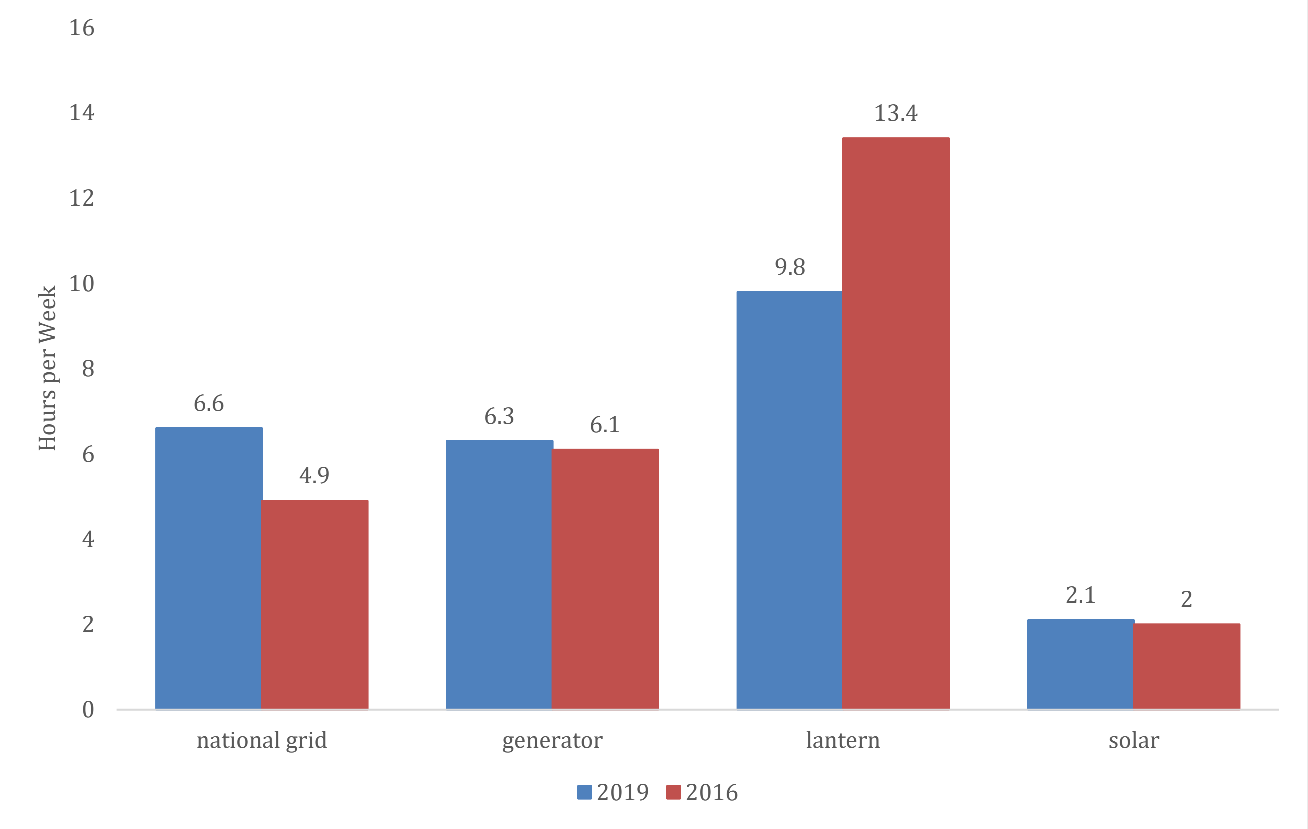


Figure 4.2: Energy consumption for lighting in 2016 and 2019.
Source: Graphed by the researcher using NGHS (2016, 2019).

Figure 4.3 reveals that there is no substantial variation in the weekly expenditure on energy in Nigeria between 2016 and 2019. In 2016, weekly expenditure on LPG was ₦2,678 (or $8.81). In other words, the annual expenditure on LPG in 2016 was ₦139,256 ($458.08). In 2019, the annual expenditure was ₦144,872 ($473.44). Given that the per capita income in Nigeria in 2019 was $2,222, it implies that an average Nigerian spent 21% of annual income on LPG. In the same vein, expenditure on generator fuel was extremely high in 2019 with total expenditure amounting to ₦159,484 ($521.19) which amounts to 23.46% of per capita income. Expenditure on charcoal increased by 28.1% between 2016 and 2019.Similarly, expenditure on generator fuel per household also increased by 29% between 2016 and 2019. The increase in expenditure on generator fuel could be as a result of hike in the price of gasoline by 67% between 2016 and 2019. Although there are increases in expenditure on LPG and national grid electricity per household between 2016 and 2019, the percentage changes are not substantial. For example, household expenditure on LPG increased marginally by 4% while that of national grid electricity increased by 18%. On the other hand, household weekly expenditure on wood and kerosene declined from ₦1,208 ($3.97) and ₦1,101 ($3.33) in 2016 to ₦1,012 ($3.32) and ₦969 ($3.19) in 2019 respectively.

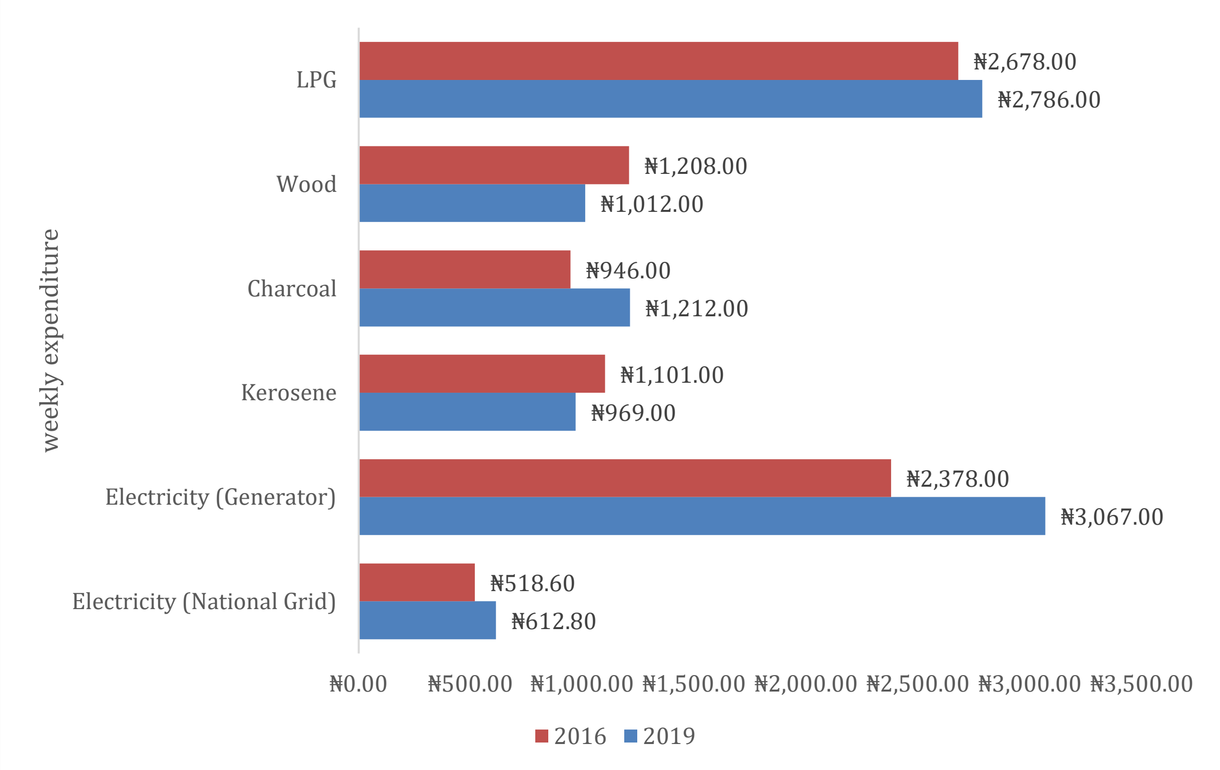


Figure 4.3: Weekly expenditure on energy in 2016 and 2019
Source: Graphed by the researcher using NGHS (2016, 2019).

One of the major constraints to electricity consumption is epileptic supply from the national grid. Table 4.3 shows that a typical household experiences about 5.9 blackouts (or power outages) in a week with each outage having an average duration of 11.6 hours. In others, a total of 68.44 hours of blackout is experienced per week. The frequency of blackout is even higher in rural areas with average of 8.3 blackouts with average of 13.7 hours per week. This implies that rural areas lose total of 113.71 hours of lighting per week due to black out. Similarly, urban areas experience average of 62.72 hours of black out weekly. Total duration of blackout per week is highest in South-South zone with about 107.25 hours.

Table 4.3: Summary of Weekly Blackout in 2019 in Nigeria

	No blackout per week	Duration of each blackout (hours)	Total duration of blackout per week (hours)
North Central	5.8	9.3	53.94
North East	6.9	5.3	36.57
North West	6.1	14.4	87.84
South East	5.1	10.6	54.06
South South	6.5	16.5	107.25
South West	5.7	9.5	54.15
Urban	6.4	9.8	62.72
Rural	8.3	13.7	113.71
National	5.9	11.6	68.44

Source: computed by the researcher using NGHS (2016, 2019).

Figure 4.4 is the summary of the sources of firewood as indicated in the 2019 GHS. The sources of firewood include unfarmed area of community (36%), own woodlot (29%), community woodlot (25%) and forest reserves (10%). The high use of unfarmed area of community as a major source of firewood is an indication of threat of deforestation.

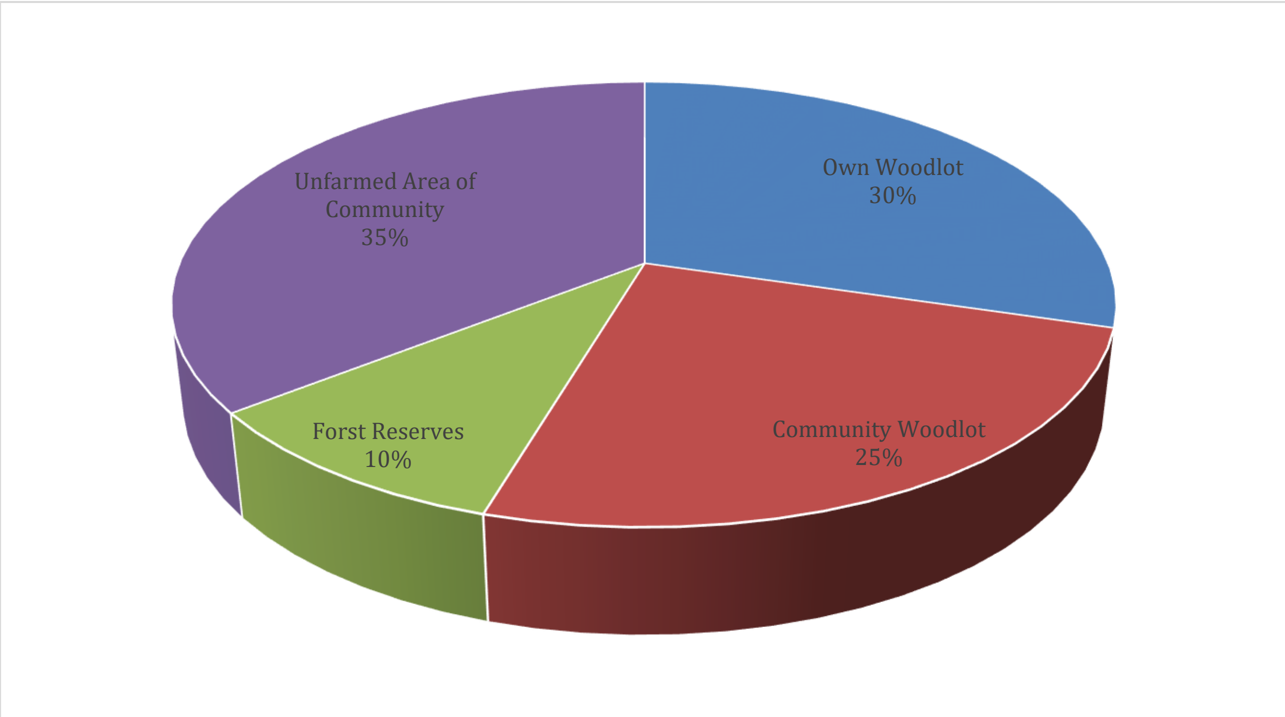


Figure 4.4: Sources of firewood
Source: Graphed by the researcher using NGHS (2019).

4.3. Prevalence of Energy Deprivation in Nigeria

To ascertain the prevalence of energy deprivation in Nigeria, multidimensional energy deprivation index (MEDI) was computed following Nussbaumer et al (2011). We set k = 0.33. The national level and spatial residential level results are as depicted in Table 4.4. The results show that the population’s proportion that is multidimensionally deprived in 2016 was 75.19%. The national intensity of deprivation in 2016 was 62.3%. This indicates that, on average, 75% of the population was deprived in 62% of modern household energy needs. In 2019, the headcount of the multidimensionally energy deprived persons slightly increased to 75.99%. The intensity of energy deprivation in 2019 was 75.74%. This suggests that an average Nigerian is deprived in 75.4% of the weighted indicators. Put differently, in 2019, about 76% of the population was deprived in approximately four out of the five indicators. On the other hand, energy deprivation is worse in the rural areas than urban areas. The proportion of the population that was energy deprived in urban Nigeria in 2016 was 56.60%. However, in rural Nigeria, the proportion of the population that was energy deprived was 92.9%. In 2019, the result also shows that 57.21% of the urban population was deprived in 66.25% of the indicators. Although the proportion of the deprived in urban Nigeria in 2019 is higher than that of 2016, the MEDI of 2016 is higher than that of 2019. That is because; the intensity of deprivation was more severe in 2016 than in 2019.Similarly, the intensity of deprivation is higher in rural areas than urban areas. The energy deprived persons in the rural area are deprived in 78.20% of the indicators or four out of five indicators in 2016 and 77.54% of the indicators in 2019.

Table 4.4: Multidimensional Energy Deprivation Index (MEDI)

	MEDI	Proportion of the population that are deprived	Intensity of deprivation
		2016	
Urban	0.388	56.60%	68.50%
Rural	0.726	92.90%	78.20%
National	0.468	75.19%	62.30%
		2019	
Urban	0.379	57.21%	66.25%
Rural	0.728	93.89%	77.54%
National	0.576	75.99%	75.74%

Source: Computed by the researcher using NGHS (2016, 2019).

Figure 4.5 shows the population's proportion that is deprived in the various indicators in Nigeria and in rural and urban centres in 2016. At the national level, 72% of the Nigerians are deprived in modern cooking energy. Cooking energy is the indicator with the highest proportion of deprived persons. This is closely followed by lighting with 66% of the population being deprived. Similarly, 57%, 55% and 42% of Nigerians are deprived in ownership of entertainment/education devices, household service appliances and communications respectively. These devices and appliances are energy dependent to function and may not be acquired if there is no access to such energy.

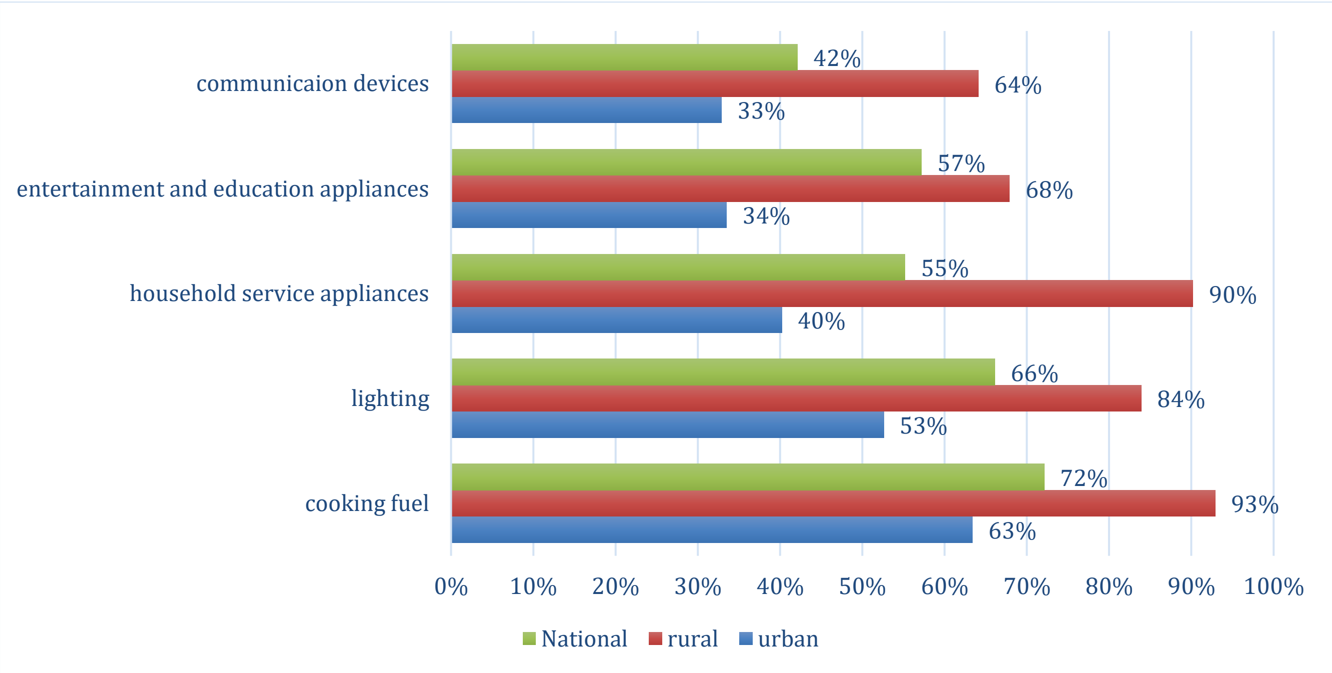


Figure 4.5: Energy Deprivation Headcount based on the indicators in 2016
Source: Computed by the researcher using NGHS (2016).

In the case of rural dwellers, 93% of the population is deprived in modern cooking appliances. Another 84% of the rural population lack access to electricity for lighting. Similarly, 90% and 68% of the rural population lack ownership of energy-dependent household service and entertainment/education appliances. Also, 64% of the rural population is also deprived in ownership of energy-dependent communication devices. This suggests that the level of energy deprivation in rural Nigeria is very high. Similarly, the proportion of urban households that are deprived in cooking fuel and lighting/electricity are 63% and 53% respectively. Others include household service appliance (40%), entertainment and educational appliance (34%) and communication appliance (33%).

The distribution of headcount ratio or the population's proportion that are deprived in the indicators did not change substantially in 2019 (see Figure 4.6). For national incidence, cooking energy tops the chart. About 71.30% of the population is deprived in cooking fuel while 62.70%, 54.20%, 56.60% and 35.40% of the population are deprived in lighting/electricity, ownership of household service appliances, ownership of entertainment/educational appliances and ownership of communication devices respectively.

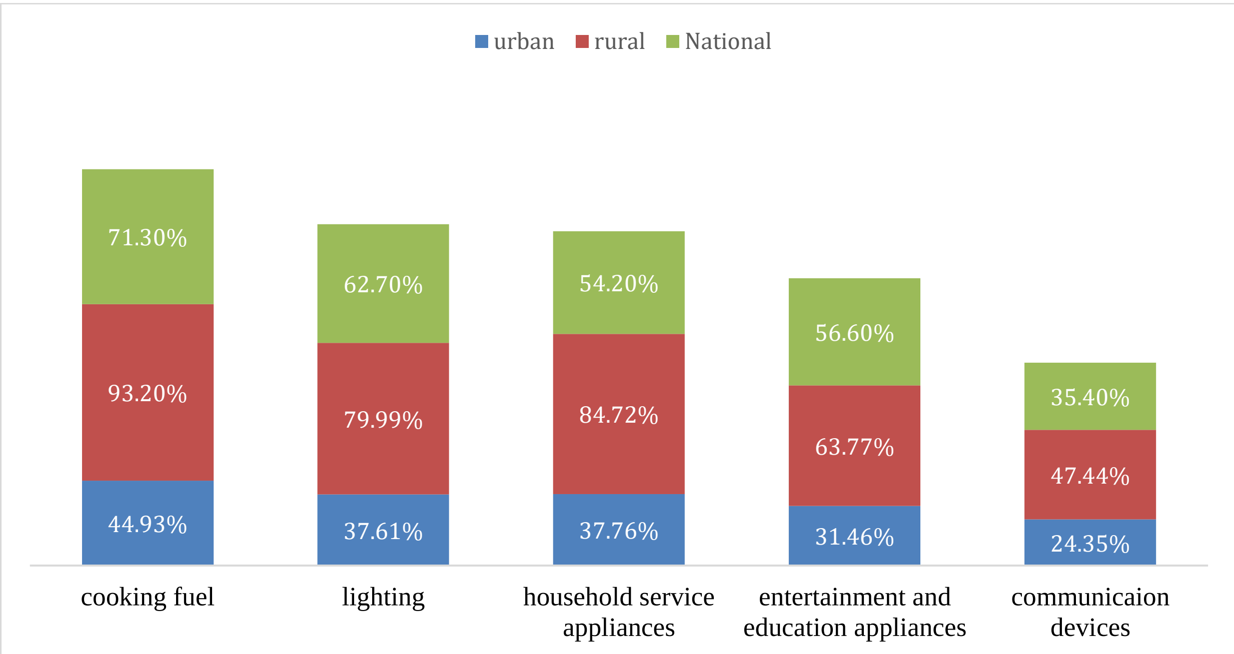


Figure 4.6 Energy deprivation headcount based on indicators in 2019

Source: Computed by the researcher using NGHS (2019).

Also, while 93.20% of rural households were deprived in cooking fuel, only 44.93% of urban population is deprived. Similarly, proportion of the population that was deprived in lighting was 62.70%. However, for rural and urban population, about 79.99% and 37.61% respectively were deprived. National deprivation is lowest in communication. This is also the case for urban dwellers where only 24.35% of the urban population was deprived in communication devices. The contribution of each indicator to the multidimensional energy deprivation index is shown in Figure 4.7. Cooking fuel and lighting contributes 36% each to MEDI while entertainment/educational appliances, household service appliance and communication devices contributed 11%, 10% and 7% respectively.

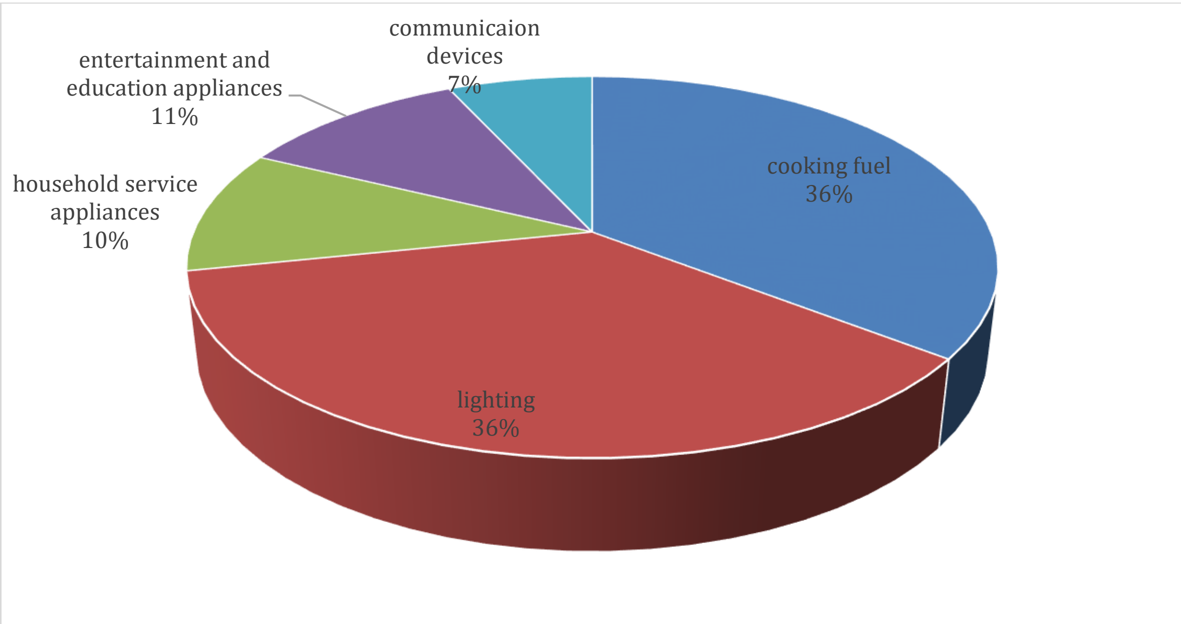


Figure 4.7: Contribution of the indicators to National MEDI in 2019

Source: Computed by the researcher using NGHS (2019).

Energy Deprivation in Northern Nigeria

The incidence of energy deprivation is more substantial in Northern Nigeria than in Southern Nigeria.

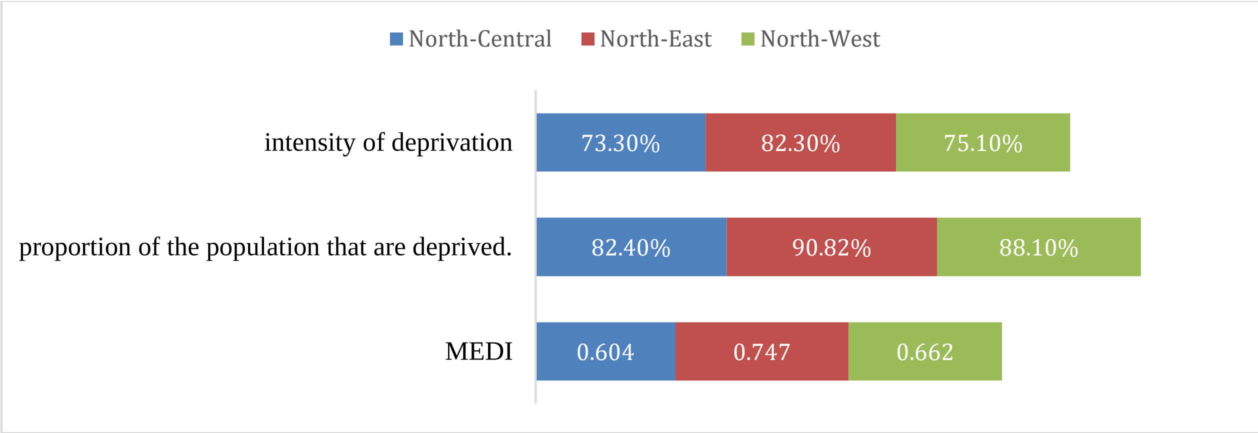


Figure 4.8: Energy Deprivation in Northern Nigeria based on NGHS (2016)
Source: Computed by the researcher using NGHS (2016).

The proportion of the energy deprived was highest in North-East. Figure 4.8 shows that 90.82% of the population of North-East was energy deprived in 2016. This is followed by North-West (88.10%) and North-Central (82.40%). The intensity of deprivation is 82.30% in North-East, 75.10% in North-West and 73.30% in North-Central. Also, MEDI is 0.604 in North-Central, 0.747 in North-East, 0.662 in North-West.

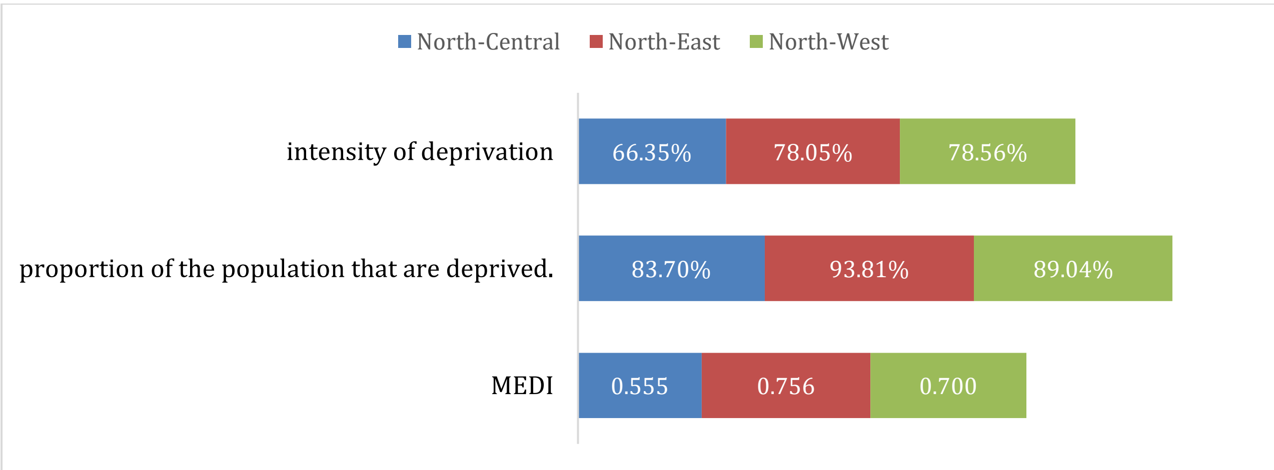


Figure 4.9: Energy deprivation in Northern Nigeria based on NGHS (2019)
Source: Computed by the researcher using NGHS (2019)

The incidence of deprivation in 2019 followed similar pattern as in 2016. The proportion of the deprived population was highest in the North East. As shown on Figure 4.9, 93.81%, 89.04% and 83.70% of the northern geopolitical zones were energy deprived in 2019. The intensity of deprivation shows that the North-East and North-West were deprived in four out of five indicators while they were deprived in three out of five indicators in North-Central.

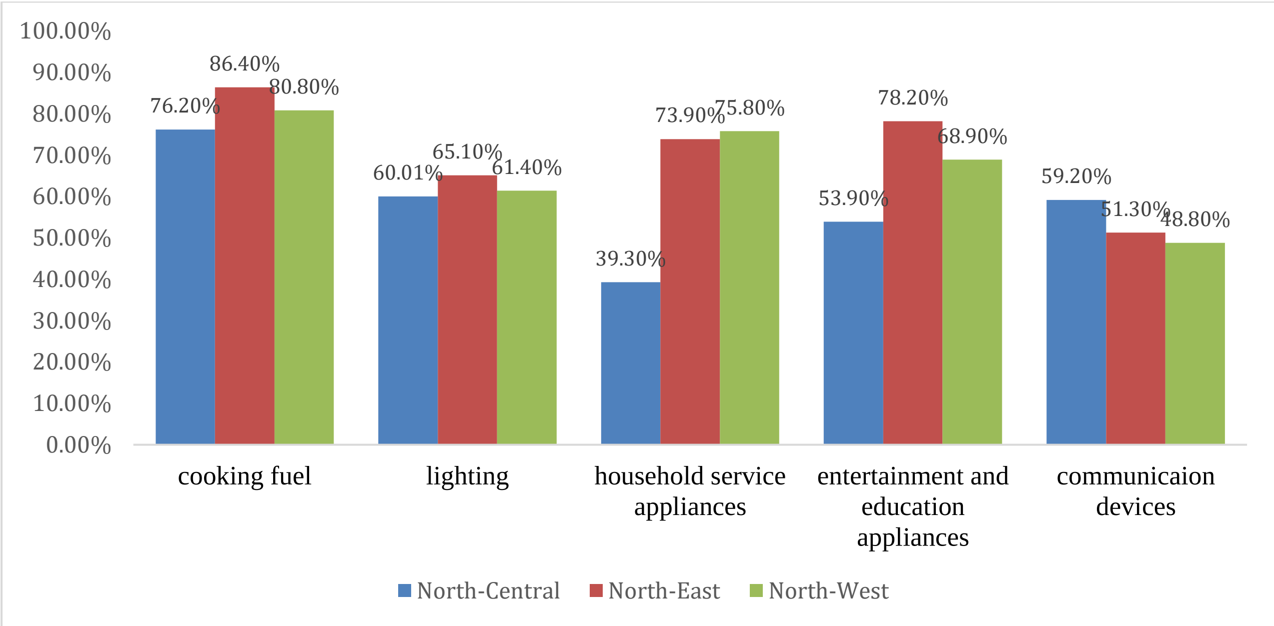


Figure 4.10: Energy deprivation headcount of each indicator

Source: Computed by the researcher using NGHS (2016).

The proportion of the population that was deprived in cooking fuel was 86.40%, 80.80% and 76.20% for North East, North-West and North Central respectively. Similarly, headcount ratio for lighting is 65.10% for North-East, 61.40% for North-West and 60.01% for North-Central. While the headcount ratio for deprivation in household service appliances was high for North-East (73.90%) and North-West (75.80%), it was relatively low (39.30%) for North-Central. It is noteworthy that energy deprivation worsened between 2016 and 2019 in North East and North West. Similarly, Figure 4.11 shows that cooking fuel contributed most to energy deprivation in all the northern zones. It contributed 39.99%, 29.45%and 38.20% in North-Central, North-West and North East respectively. Another indicator that contributed substantially to energy deprivation in Northern Nigeria is lighting with 33.69%, 30.26% and 29.70% for North-Central, North-West and North-East respectively. Deprivation in the ownership of household service appliances was highest in the North-West with a contribution of 12.84% and least in the North-Central with a contribution of 7.38%.

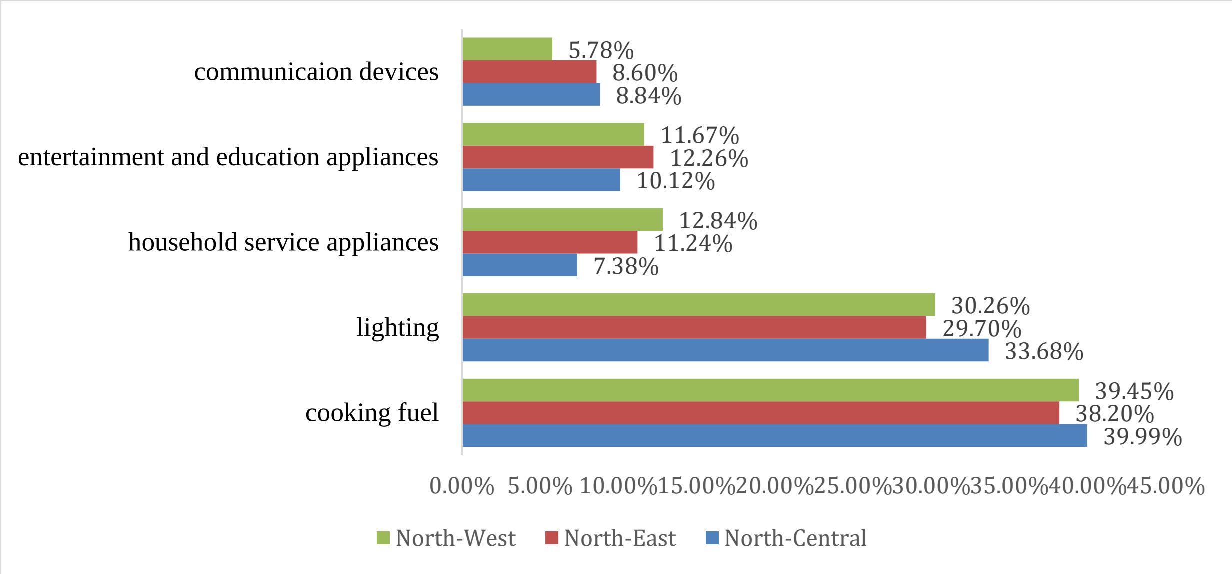


Figure 4.11: Contribution of each indicator to MEDI in 2019

Source: Computed by the researcher using NGHS (2019).

Energy Deprivation in Southern Nigeria

The southern region of Nigeria is made up South-East, South-South and South-West geopolitical zones. South-West has the lowest proportion of energy deprived population in 2019. The proportion of energy deprived population in South-West also declined from 71.92% in 2016 to 62.46% in 2019. The intensity of deprivation, however, increased between the two survey years. In 2016, South-East, however, has the lowest proportion of energy deprived persons in 2016. Energy deprivation also declined in the South-East from 70.31% in 2016 to 64% in 2019. However, intensity of deprivation increased between the two survey periods. South-South also experienced decline in energy deprivation from 79.12% in 2016 to 72.01% in 2019.

Table 4.5: Summary of MEDI, headcount ratio and intensity of deprivation in Southern Nigeria

	MEDI	Proportion of the population that are deprived	Intensity of deprivation
		2016	
South-East	0.416	70.31%	59.20%

South-South	0.492	79.12%	62.20%
South-West	0.468	71.92%	65.10%
		2019	
South-East	0.497	64.00%	77.72%
South-South	0.528	72.01%	73.34%
South-West	0.455	62.46%	72.84%

Source: Computed by the researcher using NGHS (2016, 2019).

Figure 4.12 presents each indicator's contribution to energy deprivation. Unlike Northern Nigeria, lighting contributes highest (41.52%) to energy deprivation in South-East Nigeria. Cooking fuel contributes 34.77% of energy deprivation while household service appliances, entertainment and education appliances and communication appliances contribute 8.15%, 9.41% and 6.15% respectively.

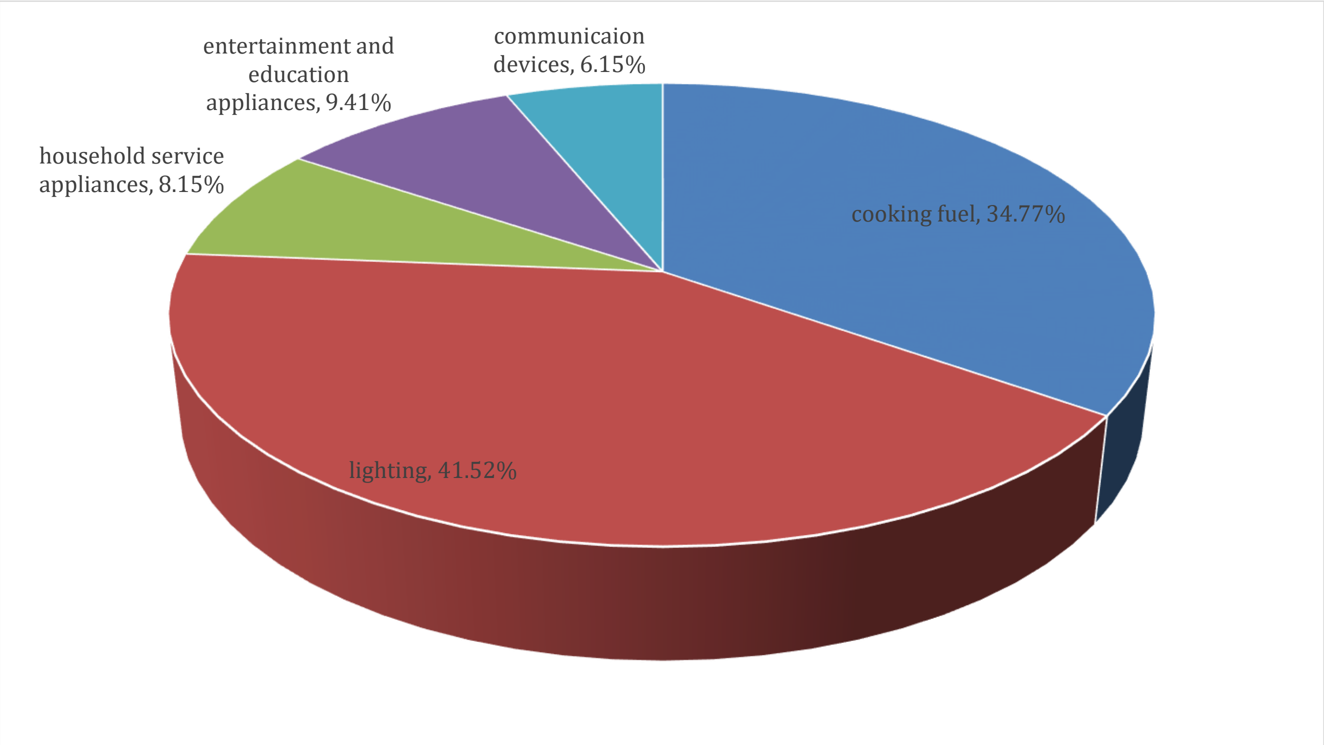


Figure 4.12: Contribution of each indicator to MEDI in south east

Source: Computed by the researcher using NGHS (2019).

Similarly, in South-South zone lighting also has the highest share of contribution to energy deprivation with a percentage share of 45%. This is closely followed by cooking fuel deprivation with a share of 31%. Others include entertainment/educational devices (10%), household services appliances (8%) and communication appliances (6%). In other words, deprivation in meeting the energy needs of using communication devices contributed only 6% of the total MEDI score in South-South Nigeria.

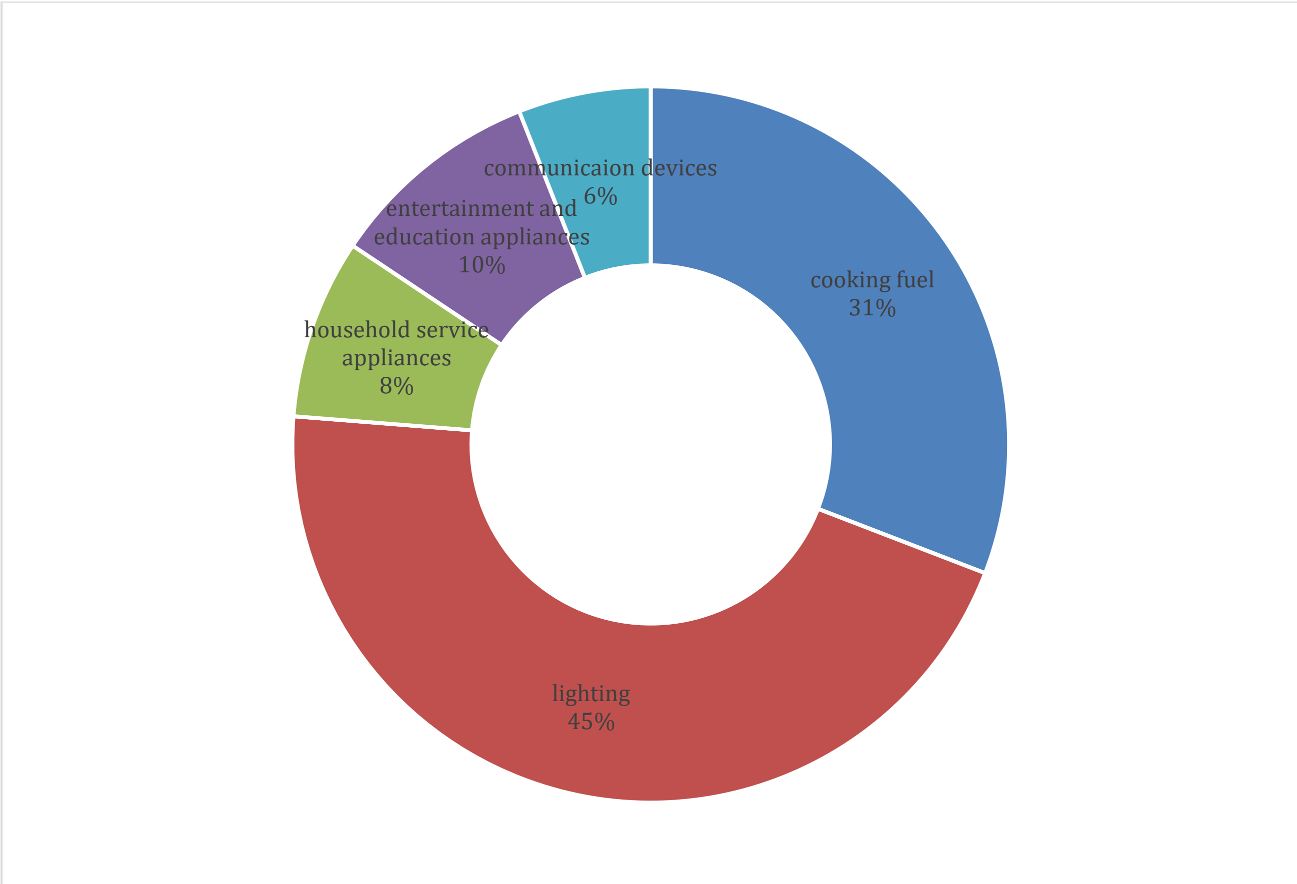


Figure 4.13: Contribution of each indicator to MEDI in South-South
Source: Computed by the researcher using NGHS (2019).

On the other hand, in South-West, lighting contributed the highest share to MEDI in 2019 with a share of 39%. Cooking fuel ranked second with a contribution share of 35%. Others are entertainment/education devices (10%), household service devices (9%) and communication devices (7%). Again, as it is applicable to South-East and South-South, deprivation in energy need for owned communication devices ranked least with only 7% contribution to MEDI score.

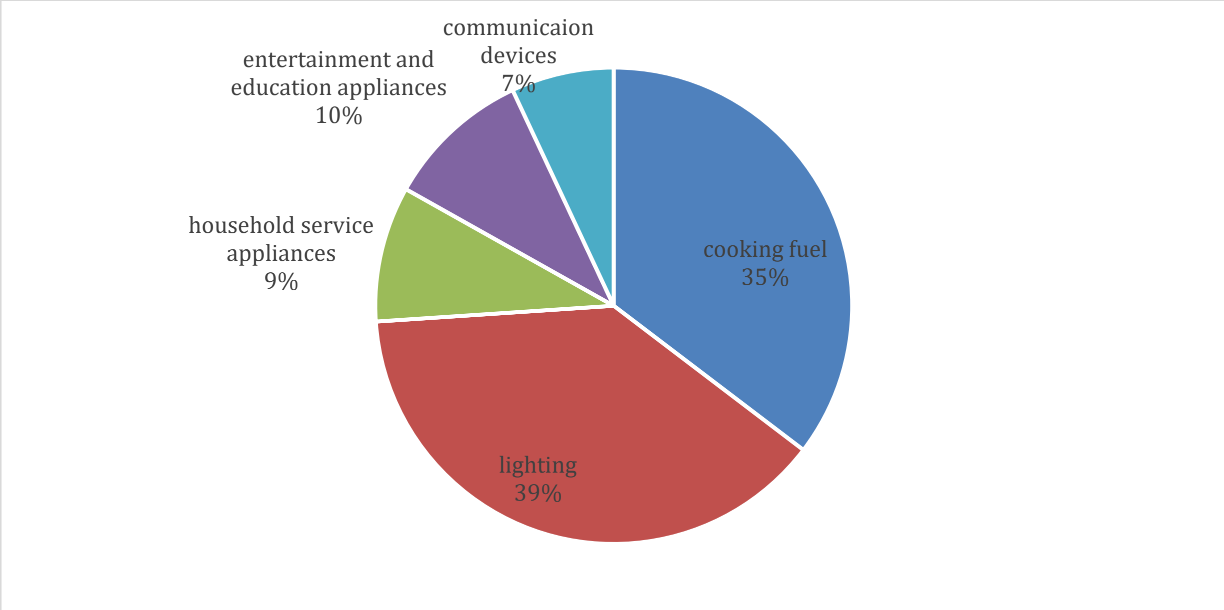


Figure 4.14: Contribution of each indicator to MEDI in South West

Source: Computed by the researcher using NGHS (2019).

On the other hand, the indicator headcount ratio of deprivation which defines the population's proportion that is deprived in a particular indicator shows that the distribution of headcount ratio varies across the three zones in the southern region.

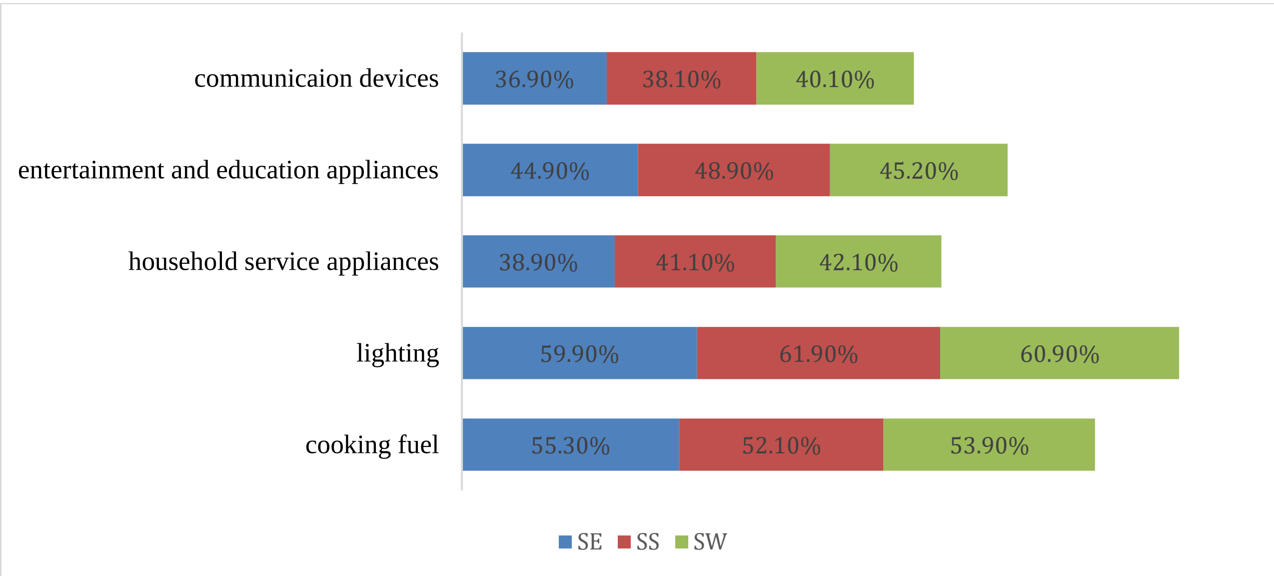


Figure 4.15: Indicator headcounts in Southern Nigeria

Source: Computed by the researcher using NGHS (2016).

In 2016, South-East has the highest headcount in cooking fuel (55.30%). Cooking fuel deprivation headcount for others include 53.90% for South-West and 52.10% for South-

South. In lighting deprivation, South-South ranked highest with headcount ratio of 61.90%. This is closely followed by South-West (60.90%) and South-East (59.90%). Howbeit, the variation is quite marginal indicating that all the zones in the South may have similar pattern of deprivation in lighting and even cooking energy. Also, in the southern region, South-West was the most deprived in ownership of household service appliances (42.10%) and communication devices (40.10%) while South-South was the most deprived in the ownership of entertainment/educat ional devices (48.90%).

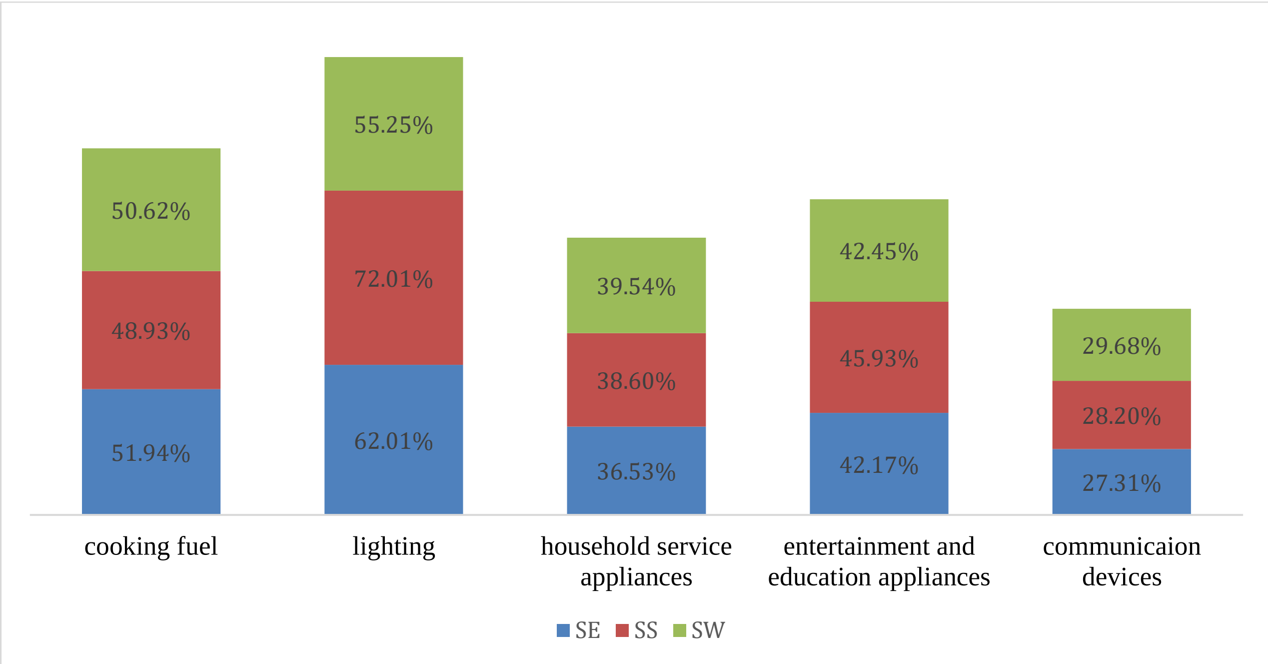


Figure 4.16: Indicator headcount in Southern Nigeria
Source: Computed by the researcher using NGHS (2019).

Similarly, in 2019, the cooking fuel deprivation headcount was highest in South-East with a headcount ratio of 51.94%. Cooking fuel deprivation headcount for other zones in the region include 50.62% for South-West and 48.93% for South-South. The deprivation headcount for lighting was, however, highest in South-South with a score of 72.01% followed by South-East (62.01%) and South-West (55.25%). Also, while South-West scored has the highest headcount ratio for deprivation in ownership of household service appliances (39.54%), South-South ranked highest in deprivation in ownership of entertainment/educational appliances (45.93%) and South-West ranked highest in deprivation in ownership of communication appliances (29.68%).

4.4. Determinants of Energy Deprivation and Energy Preferences

To ascertain the determinants of energy deprivation and energy choices/preference, a multivariate probit model was estimated using NGHS (2019). The estimates obtained are summarized and interpreted in subsequent sections.

Table 4.6: Determinants of Energy deprivation

Dependent Variable: Energy Derivation				
	Coefficient	Standard error	Marginal effect	Standard error
LOCATION				
Rural	0.079***	0.024	0.020***	0.006
Urban	-0.070***	0.014	-0.018***	0.004
DEMOGRAPHICS OF HOUSEHOLD HEAD				
Age (log)	0.107***	0.019	0.027***	0.005
Age-squared (log)	0.025	0.027	0.006	0.007
Female headed household	0.023**	0.010	0.006**	0.003
Male-headed household	-0.055**	0.026	-0.014**	0.006
No education	0.045**	0.021	0.011**	0.005
Primary school	0.078***	0.010	0.020***	0.003
Secondary education	-0.098***	0.035	-0.024***	0.009
Tertiary education	-0.071***	0.005	-0.018***	0.001
WORK STATUS OF HOUSEHOLD HEAD				
Employed	0.043***	0.014	0.011***	0.003
Unemployed	0.090***	0.020	0.023***	0.005
ASSET/WEALTH				
Landowner	-0.126***	0.013	-0.031***	0.003
Ownership of livestock asset	0.086***	0.014	0.021***	0.003
Household assets-first quantile	0.044***	0.004	0.011***	0.001
Household assets-second quintile	0.076***	0.010	0.019***	0.002
Household assets-third quantile	0.090	0.140	0.022	0.035

.	. Coefficient	. Standard error	. Marginal effect	. Standard error
Household assets-fourth quantile	-0.025***	0.004	-0.006***	0.001
Household assets-fifth	-0.078***	0.024	-0.020***	0.006

quantile				
Expenditure-food (log)	-0.017***	0.005	-0.004***	0.001
Expenditure-non-food (log)	-0.017**	0.009	-0.004**	0.002
		OTHER FACTORS		
Access to internet	-0.051***	0.006	-0.013***	0.001
Medical expenditure (log)	0.039***	0.009	0.010***	0.002
Job loss	0.194***	0.031	0.048***	0.008
Business failure	0.110***	0.012	0.027***	0.003
Energy Price	0.013**	0.006	0.003**	0.002
Insecurity (kidnapping/banditry)	0.082**	0.036	0.021**	0.009
Access to loans	-0.066***	0.007	-0.016***	0.002
Safety net	-0.099***	0.021	-0.025***	0.005
High interest rate	0.052***	0.016	0.013***	0.004
Fixed Effect				
Geopolitical Zones	Yes			
Energy options	Yes			
Obs	22,200			
%predicted	81.03%			
Pseud. R	0.20			
LR (X^2)-2781.10 (0.0001)				

Source: Estimated by the researcher using NGHS (2019).

The result obtained as shown on Table 4.6, indicates that the coefficient for rural residence and urban residence are 0.079 and -0.070 respectively. This suggests that rural residency has tendency of increasing the chances of being energy deprived in Nigeria, while urban residency has a significant probability of reducing the tendency of being energy deprived in Nigeria. The marginal effects for rural and urban residency are 0.020 and 0.018 respectively. This suggests that a slight change in residency can change energy deprivation by approximately two percentage point in both rural and urban residency. Another important factor that affects energy deprivation is demographic attributes of the household head. The result obtained shows that age, gender and educational achievements of the head of household are significant determinants of energy deprivation in Nigeria. The coefficient of age is 0.107 with standard error of 0.019; the marginal effect of 0.027 suggests that one-unit increase in age could aggravate energy deprivation by 2.7 percentage point. This suggests that the aged are more likely to be energy deprived than the young household heads. The result also shows that female household heads are more likely to be energy deprived than male-headed households. The coefficients for “no education”, “primary education”, “secondary education” and “tertiary education” are 0.045, 0.078, -0.098 and -0.071 respectively. All educational variables are significant. The result obtained suggests that the more educated households are less likely to energy deprived than the lowly educated households.

The result also shows that the coefficient of employed and unemployed household-headship are 0.043 and 0.070 respectively, both coefficients are significant and positive. The marginal effect, however, shows that the tendency of experiencing increased deprivation is higher for the unemployed (2.3%) than the employed (1.1%). However, both employed and unemployed have the tendency of experiencing energy deprivation. Another factor that determines energy deprivation is the wealth and asset ownership status of the households. The coefficient for land and livestock ownership is- 0.126 and 0.086 respectively with marginal effects of -0.031 and 0.021 respectively. This suggests that while being a landowner reduces the tendency of being deprived in multiple indicators, being a livestock owner rather increases the tendency of being energy deprived. This may not be unconnected with the fact that most livestock owners are Fulanis who stay in local areas and are more akin to primitive sources of energy than modern energy sources. Also, tendency to be energy deprived decreases with ownership of household assets and expenditure on food and non-food items. Put differently, the wealthy households are less likely to be energy deprived in multiple indicators. Other factors that influence energy deprivation include access to internet (-0.051), medical expenditure (-0.039), job loss (0.194), business failure (0.110), insecurity (0.082), access to loans (-0.066), safety net (-0.099) and interest rate (-0.052).

4.4.1. Determinants of Energy Choices/Preferences: Cooking Fuel

The household has a choice of what type of cooking fuel to use. However, making such choice could be contingent of several factors. As shown in Table 4.7, the choice of kerosene, charcoal, LPG, firewood, and electricity as cooking could be influenced by several factors.

Kerosene

The coefficient for rural and urban residence is -0.038 and 0.070 respectively with standard errors of 0.023 and 0.014 respectively. This suggests while rural dwellers have less likelihood of using kerosene, urban dwellers are more likely to use kerosene.

Table 4.7(a): Determinants of Cooking Energy Preferences

Dependent Variables	Kerosene		Charcoal	
	Coefficient	Standard error	Coefficient	Standard error
LOCATION				
Rural	-0.038*	0.023	0.054***	0.017
Urban	0.070***	0.014	-0.124***	0.020
DEMOGRAPHICS OF HOUSEHOLD HEAD				
Age	-0.079***	0.024	0.031**	0.014
Age-squared	-0.025	0.027	0.362***	0.042
Female -household head	-0.031***	0.003	0.023**	0.010
Male -household head	0.043***	0.014	-0.031***	0.004
No education	-0.090***	0.020	0.099***	0.021
Primary school	-0.078***	0.010	0.065***	0.005
Secondary education	0.098***	0.035	-0.481***	0.037
Tertiary education	0.071***	0.005	-0.051***	0.006
WORK STATUS OF HOUSEHOLD HEAD				
Employed	0.055**	0.026	-0.423***	0.101
Unemployed	-0.045**	0.021	0.031***	0.011
ASSET/WEALTH				
Landowner	0.034	-0.119	0.029	-0.096
Livestock asset	-0.041	0.004	0.486	0.550
Household assets-first quintile	-0.044***	0.004	0.606***	0.067
Household assets-second quintile	-0.076***	0.010	0.031*	0.016
Household assets-third quintile	0.090	0.140	0.031***	0.007
Household assets-fourth quintile	0.025***	0.004	-0.030***	0.011
Household assets-fifth quintile	0.017***	0.005	-0.031***	0.010
Expenditure-food	-0.002	0.001	0.030	0.028
Expenditure-nonfood	0.017	0.029	0.086	0.914
OTHER FACTORS				
Access to internet	0.076	0.055	0.030	0.203
Medical expenditure	-0.039***	0.009	0.029***	0.009
Job loss	-0.194***	0.031	0.033***	0.009

.

	Kerosene		Charcoal	
	Coefficient	Standard error	Coefficient	Standard error
Business failure	-0.110***	0.012	0.228***	0.020
Insecurity (kidnapping/banditry)	-0.078***	0.024	0.031***	0.004
Access to loans	0.066***	0.007	-0.031*	0.017
Safety net	0.082**	0.036	-0.024***	0.004
High interest rate	-0.031***	0.002	0.099***	0.021
Fixed Effect				
Geopolitical Zones	Yes			
energy options	No			
Obs	22,200			
%predicted	88.92%			
Pseud. R	0.089			
LR (X^2)-11100 (0.0001)				

Source: Estimated by the researcher using NGHS (2019).

The use of kerosene is also most likely to decline as a household head becomes older. Given that the coefficient for age-squared is not significant, we may conclude that the decline is not exponential but linear. The coefficient for male-headed and female-headed household head is 0.043 and -0.031 respectively, suggesting that the male-headed households are more likely to use kerosene than female-headed households. In the same manner, households headed by educated person are more likely to use kerosene that the ones headed by less educated persons. The coefficients for employed and unemployed are 0.055 and -0.045 with standard errors of 0.026 and 0.021 respectively.

Land ownership and livestock ownership appear not to substantially determine the use of kerosene: coefficients are not statistically significant. Wealth status using asset quintile (first and second) shows that person at the low quintile are less likely to use kerosene while persons at the fourth and fifth quintiles are more likely to use kerosene as a cooking fuel. Also, access to internet is not significant in explaining choice of kerosene usage. Coefficient for medical expenses, job loss, business failure, and insecurity are -0.039, -0.194, -0.110, and -0.078 respectively. This indicates that increase in medical expenses, incidence of job loss, incidence of business failure, and insecurity reduce the likelihood of using kerosene as a cooking fuel. However, access to loan and safety net with coefficients of 0.066 and 0.082 increases the likelihood of using electricity.

Charcoal

The coefficient for rural and urban residency in charcoal equation are 0.054 and -0.124 respectively indicating that the urban dwellers are less likely to use charcoal while rural dwellers are more likely to utilize charcoal. The tendency to use charcoal increases as household head becomes older. This increase is rather exponential as indicated by the significance of the coefficient of age-square. Similarly, female-headed household and households headed by uneducated persons are more likely to use charcoal. The coefficient for employed and unemployed are -0.423 and 0.031. The wealth factors also show that charcoal is more likely to be used by the less wealthy. Other factors that significantly affect the choice of charcoal as cooking fuel include medical expenses by households, job loss, business failure and insecurity. The coefficient of insecurity is 0.031 with standard error of 0.004. This suggests that increase in insecurity increases the tendency of households using charcoal.

Firewood

Firewood responds to the hypothesized factors in much similar way as charcoal. The coefficient for rural residency is 0.077 while the coefficient for urban residency is -0.035. Both statistics for location factors are statistically significant. This suggests that while urban residency is likely to reduce the consumption of firewood, rural residency is likely to increase it. The coefficient for age which is 0.063 is statistically significant but the coefficient of age-square, 0.084, is not significant. This suggests that the effect of age on firewood consumption may be exponential. Households headed by persons with no educational achievement and households headed by persons with maximum of primary school achievement are more likely to consume firewood than households headed by secondary and post-secondary school certificate holders. Similarly, the coefficient for employed is -0.044 with standard error of 0.007 while that of unemployed is 0.080 with standard error of 0.020. This suggests that unemployment increases the chances of using firewood. In the same vein, the coefficients for household assets ownership quintile are first quantile (0.016), second quintile (0.123), third quantile (0.020), fourth quantile (-0.042) and fifth quantile (-0.034). This suggests that persons at the top quintile are less likely to consume firewood compared to person at the bottom quintile. Job loss, business failure and insecurity also increase the tendency of consuming firewood.

LPG and Electricity

LPG, also known as cooking gas, is a modern cooking fuel. Similarly, electricity is required for powering electric cooker/stove. The response of LPG and electricity appears to be largely similar. With coefficient of -0.015 and 0.012 for rural and urban residency respectively, the result indicates that urban dwellers are more likely to consume LPG. This applies to electricity also. The coefficients for age and age-square of household head are 0.066 and 0.226 respectively for LPG. The age and age-square coefficients for electricity are 0.081 and 0.090 respectively. While the age-squared coefficient is statistically significant for LPG, it is not statistically significant for electricity. Female headship of household entered the model with negative signs for LPG and electricity.

Also, persons with low education are less likely to use both LPG and electricity. The coefficient for access to internet is 0.037 and 0.009 for LPG and electricity respectively. The coefficients for access to internet are significant for both LPG and electricity. Safety net and access to loan entered the model with coefficients of 0.051 and 0.031 for LPG and 0.012 and 0.097 for electricity. Job loss, insecurity and business failure reduces the likelihood of a household consuming LPG or electricity for cooking fuel.

Table 4.7(b): Determinants of Cooking Energy Preferences

Dependent Variable	Firewood		LPG		Electricity	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
LOCATION						
Rural	0.077***	0.014	-0.015***	0.002	-0.026***	0.002
Urban	-0.035**	0.017	0.012***	0.003	0.014***	0.002
DEMOGRAPHICS OF HOUSEHOLD HEAD						
Age	0.063***	0.022	0.066***	0.009	-0.081***	0.007
Age-squared	0.084	0.107	0.226**	0.116	0.090	0.101
Male-headed household	0.038*	0.023	0.056***	0.004	0.150***	0.011
Female-headed household	0.061***	0.008	-0.260	0.167	-0.042***	0.005
No education	0.043***	0.011	-0.023***	0.002	-0.060**	0.032
Primary school	0.016***	0.006	-0.015**	0.006	-0.011***	0.002
Secondary education	-0.027	0.142	0.032***	0.009	0.065***	0.024
Tertiary education	-0.019***	0.003	0.016***	0.003	0.040***	0.002
WORK STATUS OF HOUSEHOLD HEAD						
Employed	-0.044	0.007	0.002***	0.001	0.026***	0.003
Unemployed	0.080	0.020	-0.009***	0.001	-0.070***	0.002
		ASSET/WEALTH				
Landowner	0.035***	0.005	0.021***	0.001	0.072***	0.012
Livestock asset	0.021***	0.005	-0.033***	0.003	-0.011***	0.001
Household assets-first quantile	0.016***	0.006	-0.016***	0.001	-0.203***	0.040
Household assets-second quintile	0.123**	0.063	-0.011***	0.001	-0.303***	0.041
Household assets-third quantile	0.020***	0.004	0.020	0.021	-0.066***	0.010
Household assets-fourth quantile	-0.042***	-0.005	0.011***	0.002	0.213***	0.031
Household assets-fifth quantile	-0.034*	-0.019	0.029	0.028	0.043***	0.012
Expenditure-food	0.030	0.022	0.026***	0.011	0.016***	0.002
Expenditure non-food	0.005***	0.001	0.084	0.059	0.091***	0.007
OTHER FACTORS						
Access to internet	0.070	0.362	0.037***	0.006	0.009***	0.002
Medical expenditure	0.045***	0.022	-0.020***	0.006	-0.009***	0.004
Job loss	0.010**	0.005	-0.024***	0.005	-0.008***	0.002
Business failure	0.080***	0.015	-0.095***	0.014	-0.021***	-0.004
Insecurity (kidnapping/banditry)	0.060***	0.007	-0.055***	0.011	-0.050***	0.008
Access to loans	-0.065***	0.012	0.051***	0.008	0.012***	0.002
Safety net	0.085***	0.010	0.031***	0.007	0.097***	0.029
High interest rate	0.031***	0.002	-0.047***	0.018	0.006***	0.001
Fixed Effect						
Geopolitical Zones	Yes					
energy options	No					
Obs	22,200					
%predicted	91.76%					
Pseud. R	0.342					
LR (X^2)-39783 (0.0001)						

Source: Estimated by the researcher using NGHS (2019).

4.4.2. Determinants of Energy Choice for Electricity

Apart from the use of energy for cooking or heating, energy is also largely used for electricity. The major energy sources for electricity include national grid, generator and solar devices. As shown in Table 4.8, being in rural area reduces the propensity of a household to utilize national grid and solar devices as sources of electricity. The coefficient of rural residency for both national grid and solar devices include -0.053 (with standard error of 0.015) and -0.041 (with standard error of 0.005). This could be reflective of uneven development in Nigeria. National electrification projects are concentrated in the cities with little or no supply in most rural areas. In the same vein, the awareness of the solar alternative may be deficient in the rural areas. The coefficient for generator is rather positive for rural residency. The coefficient of 0.165 show that rural dwellers have the likelihood to use generator as alternative source of electricity. The result also indicated that being an urban dweller is associated with increasing utilization of all sources of electricity.

Similarly, all ages have the tendency of increasing the consumption of all sources of electricity, except persons above the age of 60 years. While persons above the ages of 60 years have the tendency of increasing the consumption of national grid, the consumption of generator and solar energy appears to decline with the age bracket. This may be indicative of the economic status (in the case of high cost of generator consumption) and technology adaptation behaviour (in the case of solar energy).

Table 4.8(a): Determinants of Electricity Energy Choices

	National Grid		Generator		Solar	
	Coefficient	Standard Errors	Coefficient	Standard Errors	Coefficient	Standard Errors
LOCATION						
Rural	-0.053***	0.015	0.165***	0.041	-0.048***	0.005
Urban	0.036***	0.007	0.110***	0.021	0.033***	0.004
DEMOGRAPHICS OF HOUSEHOLD HEAD						
Age (less than 25 years)	0.019**	0.008	0.097***	0.034	0.029**	0.012
Age (25 -60 years)	0.031***	0.008	0.010**	0.005	0.014***	0.003
Age (above 60 years)	0.046***	0.014	-0.116**	0.052	-0.034***	0.011
Male headed household	0.042***	0.008	0.128***	0.025	0.038***	0.006
Female headed household	0.011**	0.004	-0.031***	-0.009	-0.010***	0.002
No education	-0.032**	0.015	-0.098***	0.031	-0.029***	0.009
Primary school	0.033***	0.004	0.091	0.232	-0.030**	0.014
Secondary education	0.007***	0.002	0.020***	0.006	0.006***	0.002
Tertiary education	0.030***	0.002	0.091***	0.007	0.027***	0.003
WORK STATUS OF HOUSEHOLD HEAD						
Employed	0.018***	0.006	0.053***	0.014	0.016***	0.003
Unemployed	-0.038***	0.008	-0.117***	0.023	-0.034***	0.008
ASSET/WEALTH						
Landowner	0.034***	0.003	0.102***	0.012	0.030*	0.019
Livestock asset	-0.030***	0.004	0.090	0.214	-0.027***	0.006
Household assets-first quantile	-0.023***	0.002	-0.069***	0.008	-0.021***	0.004
Household assets-second quintile	0.045***	0.006	-0.125***	0.017	-0.041***	0.012
Household assets-third quantile	0.011	0.016	0.031**	0.016	-0.010*	0.005
Household assets-fourth quantile	0.010***	-0.001	0.029***	0.008	0.009***	0.003
Household assets-fifth quantile	0.190***	0.013	0.057***	0.022	0.017***	0.005
OTHERS						
Access to internet	0.024	0.021	0.015***	0.003	0.152***	0.013
Medical expenditure	-0.038***	-0.008	-0.117*	0.063	-0.034**	0.017
Job loss	0.171	0.828	-0.055***	0.008	-0.049***	0.010
Business failure	-0.017	0.202	-0.049***	0.009	-0.015***	0.003
Insecurity (kidnapping/banditry)	-0.005***	0.001	-0.002***	0.001	-0.014***	0.003
Access to loans	0.028***	0.003	0.084***	0.010	0.025***	0.003
Safety net	0.011***	0.003	0.040	0.039	0.146***	0.023
High interest rate	0.016	0.207	-0.127***	0.043	-0.037***	0.005
Fixed Effect						
Geopolitical Zones	Yes					
energy options	No					
Obs	22,200					

	National Grid		Generator		Solar	
	Coefficient	Standard Errors	Coefficient	Standard Errors	Coefficient	Standard Errors
%predicted	79.23%					
Pseud. R	0.224					
LR (X^2)-40981 (0.0001)						

Source: Estimated by the researcher using NGHS (2019).

The coefficients of male and female headed household consumption of national grid are 0.042 and 0.011 respectively. This indicates that although consumption of national grid is likely to increase for both covariates, the propensity for the consumption of national grid to increase for male headed household than for female headed households. In the equation of national grid, the coefficient of no education, primary education, secondary education and tertiary education include -0.032, 0.033, 0.007 and 0.030 respectively. Similarly, the coefficient of no education in generator and solar equation are -0.098 and -0.029 respectively, however, the coefficients of both secondary and tertiary education are positive in all the electricity equations. Another variable that is critical for choice of electricity energy is status of employment of the household head. In national grid, generator and solar equations, the employed household heads have the likelihood of increasing the consumption of electricity from all sources. However, the coefficients of unemployed household heads are -0.038, -0.117 and -0.034 respectively. This indicates that the unemployed have likelihood of reducing their consumption of electricity from all energy sources.

The results show that wealth quintile matter for electricity choices. In national grid, generator and solar equations, the coefficients for first quintile are -0.023, -0.069 and -0.021 respectively. However, from second to fifth quintile, the coefficients turned positive in national grid equation. In generator and solar equations, the coefficients of second quintile are -0.125 and -0.041. The coefficients of the third quintile, fourth quintile, and fifth quintile, however, turned positive in the generator equation while only the coefficient of the fourth and fifth quintile turned positive in the solar equation. This shows that the low wealth class will afford more of the national grid than generator and solar. In addition, households within the middle wealth class may afford generator, while only households above the middle wealth class are expected to afford solar energy. In the same vein, although access to internet may not influence the consumption of national grid, it could increase the consumption of solar and generator energy.

Other factors that affect choice of electricity energy include medical expenditure, job loss and business failure. The result obtained show that increases in medical expenses declines the consumption of all energy choices. The coefficients of job loss are 0.171, -0.055 and -0.049. The coefficient is, however, not significant in national grid equation. This shows that loss of job could decline the consumption of generator and solar energy for electricity but not national grid. This may not be unconnected with the post-paid system of national grid billing which allows households to pay in arrears. The coefficients of business failure also behave in similar manner as job loss. Other critical covariates include insecurity, access to loan, safety net and high interest rate. The coefficients of insecurity include -0.005, -0.002, and -0.014 respectively. This implies that insecurity reduces the consumption of all sources of energy for electricity. On the other hand, the coefficients for access to loan are significant for all equations except national grid equation. This may imply that although access to loan may not be a major factor in national grid equation, it has substantial implication for the consumption of solar energy and generator.

4.5. Intensity of Energy Use

To investigate the determinants of consumption intensity, the study employs censored Tobit model. Estimates were obtained for two energy options, namely, cooking and lighting energy. The effects of geopolitical zones are fixed in both estimations. A total of 15,056 households were utilized in the estimation. The results obtained are shown on Table 4.9.

Table 4.9: Determinants of Energy Consumption Intensity

	Lighting energy		**Cooking energy**	
	coefficient	standard error	coefficient	standard error
Household size	0.079***	0.025	0.167***	0.018
Floor space	0.138***	0.048	0.099	0.073
Income	0.165***	0.032	0.173***	0.027
Employed	0.044***	0.013	0.158***	0.018
Unemployed	-0.139***	0.045	0.072	0.048
Ownership of cooling devices	0.143***	0.020	0.165	0.218
Ownership of heating devices	-0.029	0.308	-0.172	0.119
Acquisition of new electronics/entertainment devices	0.130***	0.010	0.137	0.224
Fixed effect: Geopolitical zones	Yes		Yes	
Sigma (P-value)	0.034 (0.0001)		0.0467 (0.0001)	
Loglikelihood (P-value)	-897 (0.0001)		-1070 (0.0001)	
Obs	15056		15056	

Source: estimated by the researcher using NGHS (2019).

Table 4.9 shows that intensity of energy use can be influenced household size. The coefficients of household size in lighting and cooking energy equations are 0.079 and 0.167 respectively. This suggests that increase in household size increases intensity of energy consumption by 7.9 percentage point and 16.7 percentage points for lighting energy and cooking energy respectively. Similarly, larger floor space is associated with increase in energy intensity for both lighting and cooking energy. In addition, ownership of cooling devices increases the energy consumption intensity for lighting energy. However, the coefficient of ownership of cooling devices is not significant for cooking energy. In the same vein, the coefficients of ownership of heating devices are not statistically significant in all equations. This indicates that use of heating devices may not drive intensity of energy consumption in Nigeria. The coefficient of acquisition of new electronics/entertainment devices is 0.130 for lighting energy and it is significant at 1%. This suggests that acquisition of new electronics/entertainment devices increases the intensity of lighting energy use. However, acquisitions of new electronics/entertainment devices appear not exert significant influence on the intensity of cooking energy consumption.

4.6. Discussion of Findings

This study sought to (1) ascertain the prevalence of energy deprivation in Nigeria, (2) the determinants of energy deprivation and energy choices in Nigeria and (3) the determinants of intensity of energy consumption in Nigeria. The discussion of findings is grouped into three sub-divisions based on the research questions.

1. Prevalence of Energy deprivation in Nigeria

The results obtained from 2016 and 2019 survey indicate that

(a) The proportion of households that are energy deprived in Nigeria is about 75% based on both 2016 and 2019 survey. In addition, the multidimensional energy deprivation index is 0.468 in 2016 and 0.576 in 2019. This is similar to the findings of Ogwumike and Ozughalu (2016). Using 2004 National Living Standard Survey, Ogwumike and Ozughalu (2016) obtained energy poverty incidence of 75.5%. Ogwumike and Ozughalu (2016) did not however, obtain intensity of deprivation and MEDI. However, from our findings, intensity of deprivation in 2016 and 2019 are 62.30% and 75.74% respectively. Invariably, the MEDI increased from 0.468 in 2016 to 0.576 in 2019 due to increase intensity of deprivation in 2019.

(b) The prevalence of energy deprivation was higher in rural areas than in urban areas in Nigeria. Similarly, the intensity of energy deprivation was higher in rural area than in urban areas. Kanbur and Venables (2005) opine that about 76% of the world poor lives in rural areas. Njiru and Letema (2018) also obtained similar evidence in Kenya. Prevalence of energy deprivation in rural areas may be driven by poor earning power, dearth of information and scarcity of energy. For example, World Bank (2018) indicated that while 81.2% of urban dwellers in Nigeria have access to electricity, only 30.95% of rural Nigerians have access to electricity. In this context, access implies installation of national grid in an area. It does not reflect actual usage of electricity.

(c) Northern Nigeria is more energy deprived than Southern Nigeria. This may not be unconnected with high level of poverty, higher proportion of rural areas, low level of education and increasing rate of insecurity in the region (Ngbea and Achunike, 2014). Results obtained from estimations of determinants of energy deprivation confirm that income, insecurity and education are critical determinants of energy poverty in Nigeria.

2. Determinants of Energy Deprivation and Energy Choices

This research objective aims at ascertaining the determinants of energy deprivation and energy choices in Nigeria. The findings obtained are discussed below.

(a) Spatial location matters for energy deprivation as well as energy choices. The findings indicate that rural residency accentuates energy deprivation in Nigeria. Also, those resident in rural areas are more likely to prefer the use of traditional energy options. Nigerian rural population is estimated at 52.2% or about 104 million people (Raji et al, 2017). However, access to modern energy in rural Nigeria has remained a major concern. Rural energy deprivation could be as a result of income poverty of the residents (Damette et al, 2018) or unavailability of modern energy sources in the rural areas (Nwokoye et al 2017). In most cases, the rural dwellers rely on direct combustion of firewoods, crop residues and animal dung (biomass), and coal. These biomasses and coal are usually used on polluting stoves, which are largely inefficient. It also poses poor standard of living and environmental challenges to the rural dwellers. As noted by Ozughalu and Ogwumike (2018), the use of traditional fuel energy is associated with damage to human health, drudgery (to the rural dwellers) and increased cost of providing energy per capita (to the energy firm). The result obtained also show that there is manifest difference between the energy preferences of rural and urban dwellers. The rural dwellers prefer the usage of the affordable but inefficient traditional energy sources while urban dwellers prefer the consumption of modern energy.

(b) The age of household head is associated with energy deprivation in Nigeria. The result shows that energy deprivation worsens as the household head becomes older. Similarly, younger persons are more likely to embrace modern energy than aged persons. This result is further collaborated by findings from energy preference estimations which indicate that the older populations have the tendency of using traditional energy options while younger population are more likely to use modern energy options. This finding corroborates Rahut et al. (2014) and Mensah and Adu (2015) who opines that older citizens are associated with acute energy poverty.

Energy deprivation of the older citizens in Nigeria may not be unconnected with dearth of social safety net and social protection for the aged. Tanyi (2018) noted that Nigeria has no social security or old age care system that provides economic buffer to the aged. Although there is a pension scheme in Nigeria, it covers only about 5.1% of the old people's population. Tanyi, Pelser and Mbah (2018) also noted that only 36% of the pensionable aged people receive their pension. This implies that old age is associated with deprivation in essentials of life including modern energy options. The results obtained from energy preference estimations also show that aged people are more probable to consume traditional cooking energy options, such as firewood and charcoal than electric cooking energy and LPG than the younger population. The aged are also found to be less likely to adopt the use of solar energy. This collaborates Ramanach, Hall and Meikle (2017) finding that the use of solar energy and LPG declines with old age. This could be as a result of economic strain or inertia for adoption of new and more complicated technology.

(c) Households held by women are more vulnerable to energy deprivation. The results obtained show that households headed by women are more energy deprived than those headed by men. Nigeria practices a patriarchal family system, which naturally suggests that men are heads of households by default. However, in households where the male head (husband or father) has died, the next woman in rank (wife or mother) could assume the headship role. Also, in the case of divorce or where the man is away for a long time, especially where the woman takes custody of the children, the woman may also assume headship. In other words, such households headed by women may be economically constrained. This finding also corroborated World Bank (2019). In a survey in Uzbekistan, World Bank (2019) found that female-headed households are vulnerable to energy poverty. In most parts of Nigeria, women are not entitled to wealth inheritance. Economic constraints due to dearth of wealth and low income may accentuate energy poverty among women. World Bank (2019) also added that reduced consumption of energy among female-headed households may be reinforced by the fact that female-headed households are more likely to reduce food consumption than male-headed households. This implies that they are likely to demand less energy for cooking. Khan, and Khalid (2012) also opined that energy deprivation among women may be reinforced by the reluctance of women to borrow.

The male household heads are more likely to borrow to pay for basic needs, including energy, than women.

(d) The uneducated are more vulnerable to energy deprivation than the educated. The findings indicate that households headed by uneducated persons are more likely to experience energy deprivation than households headed by educated persons. The results also indicate the uneducated household heads are more likely to make preferences for traditional cooking energy (such as firewood and charcoal) than the educated. Similarly, the educated household heads are more likely to make preferences for LPG and solar than the uneducated. This finding suggests that education could be a panacea for energy deprivation. Inglesi-Lotz and Morales (2017) observe that education could reduce energy deprivation through increase in income. The more educated are more likely to have higher income earning potentials than the uneducated. This implies that the educated could afford modern energy. Education also increases the likelihood of accepting or adopting modern energy or modern devices that utilize modern energy options. In the same manner, the educated are more likely to have information on energy efficiency, which could help them to afford modern energy at minimal cost.

(e) Wealth is a critical factor for energy deprivation and energy preferences. The findings indicate that the wealthier households are less likely to be energy deprived. Similarly, the wealthier households are more likely to make preferences for such modern energy as LPG, solar energy, etc. Bao and Li (2020) also affirm that in the UK, wealth play critical role in household energy demand. The use of modern energy requires financial capacity to pay the bill. The wealthier households could easily make choices for modern energy because they can pay the price. This finding indicates that energy deprivation could decline with increase in household wealth.

(f) Insecurity reinforces energy deprivation among Nigerian Households. The findings indicate that rising insecurity predisposes households to energy deprivation. Nigeria has had its fair share of insecurity in the sub-Saharan Africa region. As noted by Garga (2015), insecurity in Nigeria is fuelled by Boko Haram, rural banditry, kidnapping for ransom, cattle rustling and religious-induced killings in Northern Nigeria and Niger-Delta militancy, kidnapping for ransom and farmer/herder clashes in the Southern Nigeria. Nwanegbo, Umara and Ikyase (2017) estimated the number of persons exposed to insecurity due to the activities of bandits at over 40 million Nigerians. Nwanegbo et al (2017) also added that Boko Haram insurgency affected about 35 out of 92 local governments in Borno, Yobe, Adamawa and Gombe. Garga (2015) obtained evidences that insecurity breeds poverty through deprivation. In most of the affected states, rural residents are dislodged, and economic activities stalled. These leads to energy scarcity and loss of economic power that could enable energy access.

(g) Rising medical spending among households reinforces energy deprivation. In microeconomic theory, each household is faced with budget constraints. Allocation of fund to one expense head tantamount to foregoing some other spending needs. Medical and health insurance is poorly developed in Nigeria (Audu et al., 2014). According to Etobe and Etobe (2015), only 3% of Nigerians are covered by health insurance. In other words, out of 200 million Nigerians, only 3 million persons are covered by health insurance. This suggests that increasing burden of medical expenditure accentuates energy deprivation as household shift financial commitment from energy need to medical spending.

(h) Job loss and business failure increases energy deprivation. They also increase the likelihood that households will prefer traditional energy options. However, social safety net reduces energy deprivation. The high impact of job loss and business failure on energy deprivation could be reinforced by dearth of social safety net as well as poor adoption of insurance practices in Nigeria. As noted by Nwokoye, Igbanugo and Dimnwobi (2018), there is no organized social safety net in Nigeria, including unemployment benefit. Thus, the impact of job loss on households is neither delayed nor ameliorated. Incidence of job loss and business failure, which are characteristic of capitalist economic system, accentuates energy deprivation status of households.

(i) While access to loan reduces vulnerability to energy deprivation, high interest rate exacerbates energy deprivation. Similarly, access to loan increases the likelihood that households will demand for modern energy. Contrarily, high interest rate reduces the likelihood that households will prefer modern energy options. Nigerian households and businesses are faced with twin problem of limited access to loan and high interest rate (Silong and Gadanakis, 2019). While Nigerian Enterprise Survey of 2014 indicates that only 11.4% of Nigerian businesses have access to credit facilities, Silong and Gadanakis (2019) holds that only about 2% of Nigerian households have access to formal credit. In addition, even when credits are accessible, the cost of fund is prohibitive. According to Central Bank of Nigeria directive, the lending rate in Nigeria ranges from 14.73% (prime rate) to 30.69% (maximum rate). This is in sharp contrast to 5.28%, 5.51% and 0.5% lending rates in USA, France and United Kingdom respectively. From the foregoing, the households could prefer to remain energy deprived than borrowing to finance energy spending.

(j) The findings uphold the tenets of the theoretical framework of energy stacking model. The findings indicate that while income determines energy preferences, there are some other factors that equally influence household choice of energy option. Put differently, energy preference is a multifaceted phenomenon that requires holistic approach.

3. Determinants of energy consumption intensity

Intensity of energy consumption could be determined by several factors. The result obtained indicates that the following factors are critical for explaining the intensity of energy consumption.

(a) Household size: The house of the household could be a critical factor for determining the intensity of energy consumption. The result obtained show that it explains the intensity of energy consumption for both lighting and cooking energy. Yalcintas and Kaya (2017) also obtained similar evidence that household size matters for energy consumption intensity in Hawaii. Larger household size would translate to higher demand for energy.

(b) Floor space: Floor space is found to be significant in explaining energy intensity of lighting but not cooking. As noted by Rahut, Behera, & Ali (2016b), larger floor space is tantamount to higher energy need. Thus, as floor space increases, it is expected that energy intensity of lighting energy increases. However, intensity of consumption of cooking energy may not be driven by floor space.

(c) Ownership of cooling devices increases the intensity of consumption of lighting energy. However, it does not exert significant impact of cooking energy. Cooling devices require lighting energy such as electricity by national grid, electricity by generator and solar energy. In other words, households that own cooling devices are more likely to utilize more of lighting energy.

(d) Acquisition of new electronics/entertainment devices increases the intensity of energy consumption of lighting energy but not for cooking energy. Invariably, households that acquire new electronics devices are more likely to consume more of lighting energy than cooking energy.

4.7. Summary

This chapter provided answers to the various research questions of the study as well as discussing the obtained results. The next chapter presents conclusion, recommendations and makes modest suggestion for future studies.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

In this chapter, the conclusion, recommendations as well as the suggested area for future research are presented.

5.2. Conclusion

Based on analysis of results and discussion of findings, the following conclusions are drawn.

(a) There is high prevalence of energy deprivation in Nigeria. Current evidence does not show any sign of significant improvement in the trend of energy deprivation in Nigeria between 2016 and 2019.

(b) There is a significant difference in energy deprivation across the diverse geopolitical zones in Nigeria. Energy deprivation is more widespread and intense in northern Nigeria than in Southern Nigeria. In addition, North East and North West zones appear to be the most vulnerable to energy deprivation.

(c) Rural households are more energy deprived than urban households.

(d) Energy deprivation and energy choices in Nigeria could be driven by several factors including residential location, attributes of the head of household such as education, age, wealth ownership, availability of social safety net, access to loan and lending rate, energy options, access to internet and social insurance.

(e) Intensity of energy consumption is also influenced by household size, floor size, and ownership of cooling/heating devices and acquisition of new electronics devices.

(f) Energy stalking model appears to explain household energy preference behaviour. Although energy preferences are associated with income and wealth levels of the households, there are other factors that equally drive energy choices. Energy choices also appear to be overlapping, indicating that households may not completely abandon the consumption of modern energy in preference for traditional energy. In other words, while shifting to modern energy, households may still continue to consume traditional energy in certain proportion. Thus, energy stalking model could be more appealing than energy ladder in explaining the energy choice behaviour of households.

5.3. Recommendations

The goal of empirical research is to offer practical/policy recommendations as well as recommendations in furtherance of research endeavors. Based on the findings obtained from the results, these recommendations are suggested.

5.3.1. Policy/Practical Recommendations

1. One of the major findings of this study is that rural households are more energy deprived than urban households. One of the solutions to be adopted by the Nigerian government is the establishment of microgrids. Micro grids are decentralized electricity generation systems that usually operate in synchrony with traditional utility grids. However, it can equally function in "island modes" in the case of which they operate autonomously. A microgrid holds many benefits. First, it is efficient and affordable. It could also be a veritable source of clean energy. Second, microgrid is seen by expects as the panacea for constant power outage. Third, it reduces peak loads and congestion of the grids. The successes of microgrid in nations (such as Netherland and Palau) are an eloquent testimony that it could represent a paradigm shift in Nigeria energy scarcity, especially, as it affects rural households. Shifting from centralized power generation system to a localized, decentralized or distributed generation, especially in campuses, communities, cities, council areas, makes microgrid more resilient and competitive.

2. Deregulation of power generation and ownership. There is need to overhaul the legal framework of power generation in Nigeria. Currently, Nigerian law only empowers the Federal Government to generate electricity. This makes it illegal for private investors to venture into any form of power generation. To allow for microgrid as well as mini grid, there is no to deregulate the power sector. This will enhance energy availability and efficiency. It will also enforce affordability of energy among households.

3. Regular household energy audit. This involves visits to vulnerable households aimed at providing advice and supports that will enable them to improve their condition of

energy derivation. This support function may be carried out by social or civil society organizations, health professionals and government functionaries.

4. Energy subsidy. One of the constraints to energy access is high energy prices or high expenditure on energy. To increase affordability and accessibility, direct energy subsidy to households could be introduced. Energy subsidy could be implemented in the form of social tariff which lowers the energy fees to be paid by households, or, as energy fee support which provides direct financial assists to households to pay their energy bill. This approach is bound to have direct effect on the households.

5. Tackling of insecurity problem: To reverse the rising trend of energy deprivation in Nigeria, especially in Northern Nigeria, there is need to tackle the insecurity problem. Currently households are constantly dislodged and economically strained due to rising cases of insecurity. Government should take bold step to quell the nationwide insecurity.

6. Social security and safety net: One of the findings of this study is that job loss, business failure and unemployment constitute significant drivers of energy deprivation as well as determinants of energy preferences. To reduce the effect of income loss due to loss of job and business, there is need to establish adequate social security safety nets like unemployment benefits and social insurance scheme. Currently, there is no form of unemployment benefit in Nigeria. Given the high incidence of unemployment in the economy, energy deprivation will worsen if palliatives are not provided for the unemployed.

7. Reduction of lending rate. The lending rate in Nigeria is prohibitive. This makes it difficult, if not impossible, for households to access credit to take care current energy needs. The Central Bank of Nigeria may consider reducing the lending rate to single digit rate. Also, given that access to credit is low in Nigeria, the CBN may also intensify its financial inclusion program to enhance access to credit, especially by households in rural Nigeria.

5.3.2. Recommendation for Future Research

The findings of this study raise a need for further investigations to ascertain the attitude of households towards energy efficiency and technology adoption. Energy deprivation could be reduced through the adoption of energy saving practices by households. The scope of this study does not allow for interrogation of such behaviour. Therefore, it is recommended that further research be undertaken to ascertain the attitude of households towards energy efficiency and how energy saving behaviour of households may ameliorate the severity of deprivation.

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