GEOSPATIAL ANALYSIS OF DOMESTIC ENERGY CONSUMPTION IN KADUNA STATE, NORTHWEST REGION OF NIGERIA

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GEOSPATIAL ANALYSIS OF DOMESTIC ENERGY CONSUMPTION IN KADUNA STATE, NORTHWEST REGION OF NIGERIA

by

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LIST OF ACRONYMS AND ABBREVIATIONS

ACRESAL	Agroclimatic Resilience for Environmental Sustainability and Livelihood
CBN	Central Bank of Nigeria
CSOs	Civil society organizations
CO	Carbon monoxide
CO2	Carbon dioxide
DARE	Development Association for Renewable Energy
ECN	Energy Commission of Nigeria
ESMAP	Energy Sector Management Assistance Program
EPAI	Energy Poverty Action Initiative
ELF	Energy Leap Flogging
EIA	Environmental Impact Assessment
ESM	Energy Stacking Model
FAO	Forestry and Agricultural Organization
FGN	Federal Government of Nigeria
GDP	Gross Domestic Product
GBD	Global Burden of Disease
GWR	Geographically Weighted Regression
GHGs	Greenhouse gases
GPS	Global Positioning System
HDI	Human Development Index
HAP	Household air pollution
ICEED	International Centre for Energy, Environment & Development
IDEA	Integrated Development Association
IEA	International Energy Agency
IDW	Inverse Distance Weighting
IPCC	Intergovernmental Panel on Climate Change
LARA	Local Area Resource Analysis
LGAs	Local Government Areas

LPG	Liquefied Petroleum Gas
MRA	Multiple Regression Analysis
MVP	Multivariate Probit Model
NASRDA	National Space Research Development Agency
NBS	National Bureau of Statistics
NPC	National Population Commission
NCC	Nigerian Communication Commission
NEPA	National Electric Power Authority
NREEEP	National Renewable Energy and Energy Efficiency Policy
NGOs	Non-governmental organizations
NNPC	Nigerian National Petroleum Corporation
NPC	National Population Commission
ODK	Open Data Kit
OECD	Organization for Economic Co-operation and Development
PEH	Poverty- Environmental Hypothesis
PHCN	Power Holding Company of Nigeria
PMS	Petroleum Motor Spirit
PQOL	Physical Quality of Life
REA	Rural Electrification Agency
SDGs	Sustainable Development Goals
SPA	Structural Path Analysis
SMLE	Simulated Maximum Likelihood Estimation
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN	United Nation
WEC	World Energy Council
WHO	World Health Organization
WEF	World Economic Forum
WEO	World Energy Outlook
WSSD	World Summit on Sustainable Development

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ANALISIS GEOSPATIAL PENGGUNAAN TENAGA DOMESTIK DALAM NEGERI KADUNA, WILAYAH BARAT LAUT NIGERIA

ABSTRAK

Tenaga adalah elemen penting untuk pembangunan sosioekonomi sesebuah negara. Walau bagaimanapun, banyak isi rumah di Nigeria kekurangan akses kepada sumber tenaga moden dan bergantung kepada bahan api tradisional. Ini mempunyai kesan negatif yang buruk terhadap kesihatan dan produktiviti isi rumah, dan alam sekitar. Kajian ini menganalisis secara geospatial penggunaan tenaga domestik di Negeri Kaduna. Kajian ini mempunyai lima objektif iaitu mengenal pasti corak penggunaan tenaga domestik mengikut isi rumah, menganalisis yang mempengaruhi pemilihan tenaga domestik, menganalisis corak taburan ruang dan kadar penggunaan tenaga domestik, menilai implikasi alam sekitar penggunaan tenaga domestik, dan meramalkan corak penggunaan tenaga domestik pada masa hadapan di kawasan kajian. Kajian ini menggunakan pelbagai kaedah, di mana ia menggabungkan kedua- dua pendekatan kuantitatif dan kualitatif. Tinjauan terhadap 400 isi rumah yang dipilih secara rawak dan data dikumpulkan menggunakan soal selidik ODK. Berdasarkan tinjauan isi rumah yang dijalankan, sebanysk 357 soal selidik telah dianalisis dan digunakan dalam kajian ini. Kawasan kajian adalah di Negeri Kaduna yang dibahagikan kepada zon utara, tengah dan selatan. Di samping itu, pendekatan kualitatif, melibatkan temu bual mendalam dengan dua puluh pihak berkepentingan, pemimpin masyarakat dan wanita telah dijalankan. Kaedah triangulasi digunakan untuk memastikan hasil yang diperolehi adalah sah. Kajian ini juga menggunakan teknik geospatial untuk menganalisis corak taburan ruangan dan kadar penggunaan tenaga domestik.

Berdasarkan objektif satu iaitu mengenal pasti penggunaan tenaga domestik, dapatan daripada tinjauan isi rumah menunjukkan bahawa kayu api dan arang merupakan sumber bahan api utama yang digunakan, terutamanya di kawasan luar bandar. Sebaliknya, gas adalah bahan api utama yang digunakan dalam kalangan isi rumah bandar. Bahan api digunakan adalah kombinasi dengan arang, yang muncul sebagai bahan api utama dalam kalangan isi rumah. Berdasarkan objektif dua, yang mengkaji penentu penggunaan tenaga isi rumah, menunjukkan adalah campuran faktor, iaitu umur, harga bahan api, pendapatan, saiz isi rumah, pendidikan, lokasi, mempengaruhi pilihan isi rumah kepada bahan api tertentu. Berdasarkan objektif tiga menunjukkan bahawa corak taburan spatial yang berbeza dan kadar dan sumber penggunaan tenaga adalah berbeza di dalam kawasan bandar dan luar bandar. Analisis geospatial menunjukkan penyebaran ruangan dalam wad yang berbeza dipengaruhi oleh gabungan faktor seperti ketersediaan bahan api, keadaan sosio-ekonomi, pembangunan ekonomi dan populasi di sesuatu kawasan. Tambahan pula, kadar penggunaan tenaga dalam negeri Kaduna menggambarkan tahap penggunaan tenaga yang lebih tinggi di sesuatu kawasan dan lebih rendah dalam kawasan tertentu. Analisis corak penggunaan tenaga domestik dalam kawasan bandar dan luar bandar memaparkan taburan ruangan yang berbeza bagi sumber tenaga dan corak penggunaan diperngaruhi gabungan ciri geografi, ekonomi dan demografi. Berdasarkan objektif empat, iaitu menilai implikasi penggunaan tenaga domestik dapatan menunjukkan interaksi yang kompleks antara penggunaan tenaga dan kesan alam sekitar. Dapatan juga menunjukkan bahawa isi rumah mengalami pelbagai kesan sosial, alam sekitar, dan kesihatan yang dikaitkan daripada penggunaan bahan api domestik, khususnya bahan api biojisim. Dapatan ini menunjukkan perbezaan kesan ketara dalam zon berbeza di dalam kawasan kajian. Berdasarkan objektif lima iaitu meramalkan corak penggunaan tenaga masa hadapan, hasil kajian menunjukkan

bahawa corak penggunaan di kawasan kajian dipengaruhi oleh empat pembolehubah iaitu pendapatan, harga, pembandaran dan dasar kerajaan.

GEOSPATIAL ANALYSIS OF DOMESTIC ENERGY CONSUMPTION IN KADUNA STATE, NORTHWEST REGION OF NIGERIA

ABSTRACT

Energy is a vital element for the socio-economic development of a country. However, many households in Nigeria lack access to modern energy sources and rely on traditional fuels. This has a negative impact on household health and the environment. This study geospatially analyzed domestic energy consumption in Kaduna State. The study had five objectives, namely to identify patterns of domestic energy consumption by household, to analyze factors influencing domestic energy choices, to analyze spatial distribution patterns and rates of domestic energy consumption, to assess the environmental implications of domestic energy consumption, and to predict future patterns of domestic energy consumption in the study area. This study used a multi-method approach, combining both quantitative and qualitative approaches. A survey of 400 randomly selected households was conducted and data was collected using the ODK questionnaire. Based on the household survey conducted, 357 were analyzed and used in this study. The study area was in Kaduna State which is divided into northern, central and southern zones. In addition, a qualitative approach, involving in-depth interviews with twenty stakeholders, community leaders and women was conducted. Triangulation method was used to ensure the validity of the results obtained. Geospatial techniques were used to analyze the spatial distribution patterns and rates of domestic energy consumption. Based on objective one, the household survey showed that firewood and charcoal were the main sources of fuel used, in rural areas. Gas was the main fuel used among urban households, in combination with charcoal. Based on

objective two, mixture of factors, namely age, fuel price, income, household size, location, influenced households' choice of a particular fuel. Based on objective three, Geospatial analysis showed distinct spatial distribution pattern of energy consumption, influenced by a combination of factors, including availability, socio-economic conditions, economic development, etc. Based on objective four, the findings revealed that household suffered from a variety of social, health and environmental impacts associated with the use of domestic fuels. Based on objective five, the analysis showed that urban households are switching to modern fuels while rural households still rely on traditional fuels and the future energy consumption patterns in the study area will be influenced by four variables, namely income, prices, urbanization, and government policies. The findings indicate a complex interaction between energy use, determinants and environmental impacts. This study recommends energy policies that promote clean and energy efficiency practice.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides information on the background of the study, research problem, research questions and objectives, significance, contribution of thesis and justification, scope, as well as the general structure of the thesis.

1.2 Background of Study

Energy is widely acknowledged as a fundamental requirement for socioeconomic development and human survival (Brew-Hammond, 2010). Therefore, access to clean, affordable and sustainable, modern energy sources is essential for eradicating poverty, improving living standards, supporting the provision of social services and promote sustainable human development (Bazilian et al., 2012; Karekezi, et al., 2012). The United Nations Development Programme (UNDP) (2010) describes accessibility and affordability of modern energy services such as electricity supply as a crucial necessity for poverty reduction, and an important aspect of economic growth and national development. Nations unable to provide adequate access to modern energy services, fall into a state known as the energy poverty, and subsequently, affect human life. Due to the importance of clean energy in socioeconomic development and human life, clean energy which seeks to 'ensure access to affordable, reliable, sustainable and modern energy for all by 2030" was listed as one of the 17 United Nation Sustainable Development Goals (SDGs) (United Nation, 2015).

Households use energy for various purposes, namely cooking, heating, cooling, lighting and powering electronic appliances. Based on usage, household energy is generated from fuel wood, dung, agricultural residues, charcoal, kerosene, electricity

and Liquefied Petroleum Gas (LPG). (Kadiri and Alabi, 2014). It represents a complex interplay of factors influenced by household demographics, socioeconomic, geographic location, cultural practices, technological advancements, energy policies among others (Salami, et al., 2023). In addition, the type and quantity of household energy use between rural and urban populations, low income and high come groups, within a country and between countries varies due to diverse levels of economic development, urbanization, types of energy sources available among others (Mashhoodi, 2019; Nakagami et al, 2008).

The International Energy Agency (IEA, 2008) report that the household energy sector accounts for 36 to 40% of global energy consumption, with a general increasing trend since 1970 (Abrahamse & Shwom, 2018). Accounting for a substantial share of the total national energy consumption in many developed and developing countries (Rafiee et al., 2019; Olanrewaju & Adegun, 2020). The share is estimated to be around 22% in the USA (Estiri, 2016). In Europe, the share account for nearly 30% of the total energy consumption (Vasseur, 2019). In most developing countries, the sector accounts for more than 90 % of total energy consumption (MacCarthy et al., 2010). For examples, in China, the sector is the second-largest energy consumer category (Yang et al., 2020). The sector is one of the largest in India, accounting for 40% to 50% of the total energy consumption (Patil, 2014). The Malaysia Energy Commission (2014) states that the residential sector is the third largest energy user in Malaysia. In Nigeria, the domestic sector accounts for the largest share of about 65 -78% of primary energy consumption in the country when compared to other economic sectors (Oseni, 2012; Oyedepu, 2012).

Despite the growing concern about the importance of providing modern energy for all, globally about 50% of all households and about 90% of rural households

depends on traditional solid fuels as their main domestic source of energy (Torres-Duque et al., 2008). It is estimated that approximately 2.5billion people in developing countries rely on biomass fuels to meets their domestic needs (Mekonnen & Kohlin, 2009).

The utilization of traditional energy has numerous negative effects for domestic needs has a range of adverse consequences. Fuelwood collection places a substantial burden on families, particularly women and children, its can place additional pressure on local forest resources, and endangers domestic ecosystems. Indoor air pollution caused by exposure to domestic smoke from biomass fuels is a major cause of respiratory diseases in the developing world (Smith et al., 2000). The situation is not much different in Nigeria, despite the abundant renewable energy potentials in the country, majority household do not have access to environmentally friendly modern energy sources (Adamu et al, 2020; Pokubu & Al Habaibah 2019). Traditional energy sources account for over 80% of household energy supply (Mshelia, 2012).

Available estimates show that Nigeria consumes over 50 million metric tons of fuel wood annually, a rate, which exceeds the replenishment rate through afforestation, (Intergovernmental Panel on Climate Change -IPCC, 2007). The Energy Commission of Nigeria (ECN, 2003) reported that based on available statistics, the nation's 15 million hectares of forest and woodland reserves could be depleted within the next fifty years. Sourcing fuel wood for domestic and commercial uses is a major cause of desertification in the arid-zone states and erosion in the southern part of the country (Sambo, 2005)

Therefore, for a developing country like Nigeria, where majority of the population are entangled in acute energy poverty, findings from the studies on household energy consumption are important contribution to policy decision

making on sustainable household energy transition to modern fuels, thus, for reducing poverty, improving human health and promoting sustainable development. This study, therefore, provides a comprehensive and contextualized understanding of the spatial dynamics of domestic energy consumption in Kaduna state, Nigeria.

1.3 Research Problem

Nigerian household's still experience acute energy poverty, characterized by limited access to affordable modern energy sources, such as stable electricity by a large portion of the population (Mshelia, 2013). This problem is more severe in northern Nigeria, where an estimated (90%) of households rely heavily on inefficient and polluting traditional fuel sources like firewood, especially in rural areas. This phenomenon has resulted in negative health impacts, environmental degradation, and hinder socio-economic development (Dioha & Emordi, 2019; NBC, 2011).

In Northwest regions, where the level of poverty at 71.2% and is the second highest in the country, the consumption of biomass fuels is stuck between 95.9% and 95.3% respectively (NBS, 2020). Kaduna states is among the states in the region with the highest percentage (83.2%) of household depending on fuelwood for cooking, together accounting to about 1,722,904 t/year. (Zaku et al. 2013; Simeon et al. 2019). High utilization of firewood in the region has over the years proven to be the major cause of deforestation in the state, resulting in soil degradation and loss of biodiversity. Indoor air pollution harms, the health of household particularly among women and children (Muazu et al. 2022; Sufyan et al. 2021; Simeon et al, 2019; Vivan et al., 2012).

Growing body of literature have analyzed domestic energy consumption in developed and developing countries at various time frame, using different methods and models (Liu, 2020; Griffin, 2014; Kowsari & Zerriffi, 2011; Naibbi, 2013; Dar-Mousa and Makhamreh, 2019; Okpara, 2020). In Nigeria, however previous studies showed

that, mostly of the studies used single methodology for their analysis. This study therefore, mixed methods where multivariate probit model in combination with geospatial techniques and qualitative data analysis were used to investigates multiple choices of households' energy options and their spatial distribution. Thus, this study seeks to fill this gap, by introducing spatial perspective to the understanding of context-specific analysis of domestic energy consumption in Kaduna state, Nigeria.

1.4 Research Questions

Based on existing literature, several questions persist and should be properly addressed.

i. What is the domestic energy consumption pattern of households in the study area?

ii. What are the major determinants of domestic energy choices in the study area?

iii. What is the spatial distribution pattern and rate of domestic energy consumption in the study area.

iv. What are the are the environmental implication domestic energy consumption in the study area?

v. What would be the pattern of future energy consumption in the study area?

1.5 Objectives of the Study

The main aim of this study is to geospatially analyze domestic energy consumption in Kaduna state, Nigeria. The specific objectives are to:

i. Identify the domestic energy consumption pattern of household in the study area.

ii. Examine the determining factors, influencing domestic energy choice in the study area.

iii. Analyze the spatial distribution pattern and rate of domestic energy consumption

in the study area.

iv. Assess the environmental implication of domestic energy consumption in the study area.

v. Predict the future pattern of domestic energy consumption in the study area.

1.6 Significance of the Study

The life of all humans depends directly or indirectly on the availability of affordable, reliable and sustainable energy. Thus, meeting household energy needs is important for enhancing household living standard, wellbeing and socioeconomic development (IEA, 2018). The significance of energy in reducing poverty and improving household welfare and living standards is further acknowledged by the United Nations Sustainable Energy for All initiative and Sustainable Development Goal number seven that seeks to provide universal modern energy for all by 2030.

Consequently, the findings of this study will provide reliable and comprehensive information about demographic, socioeconomic and geographic characteristics of household in order to address the complexity of these intertwining factors and their influence on domestic energy choice in Kaduna state. Similarly, the study will provide understanding on the spatial distribution pattern of domestic energy consumption including the environmental impacts in the area. This will serve as essential framework for formulating energy policies and programs that promote access to clean energy and stimulate households to switch away from traditional biomass to the adoption of cleaned fuel sources which will improve household general welfare and promote and sustainable energy development pathways. In addition, the study will reawaken environmental consciousness of the citizens on the adverse environmental and effect of biomass fuels consumption and facilitate a positive change of attitude in

household energy choices and decisions. Finally, the study will serve as a reference material for future study.

1.7 Scope of the Study

The study focuses on geospatial analysis of domestic energy consumption in Kaduna state, Northwest, Nigeria. The state is delineated into three senatorial zones; Kaduna North, Kaduna Central and Kaduna South senatorial Zones and comprises of 23 local government areas (LGAs). For the purpose of this study, six (6) LGAs were selected out of 23 LGAs. Two (2) LGAs (i.e., urban and rural) were selected from each senatorial zones in the state. The selected local government areas represent urban and rural areas in the state. The types of domestic energy that will be covered in the study include, fuelwood, charcoal, kerosene, electricity and gas.

1.8 Thesis Structure

The study is divided into of six chapters. Chapter one which is the introductory chapter, consist of background of the study, statement of the problem, research questions and objectives of the study, significance of the study, scope as well as organization of the study. The conceptual review, related theories of energy consumption and examples of empirical studies were in chapter two. Including the conceptual framework and theoretical framework of the study. Chapter three describe the methodology of the study, Sample size and sampling techniques, method of data collection, ethical consideration, validity and reliability of the instrument and data analysis techniques. Chapter four presents analysis of the profile of respondents and energy consumption pattern. The analysis of objectives two and three were discussed and presented in chapter five. Chapter six presents the analysis of objective five. The summary and recommendations of the study, contribution to knowledge and limitation of the thesis were presented in chapter seven.

1.9 Conclusion

This chapter provides background information on the importance of energy consumption to the overall socioeconomic development of a society, especially in improving, household welfare and wellbeing developing countries, with particular emphasis on Kaduna state, Nigeria where the majority of household do not have access to environmentally friendly modern energy sources. They have to depend on traditional biomass fuels for their domestic needs, despite of its adverse environmental externalities. Finally. the chapter explained the targeted objectives of the study as well as the significance of conducting the study.

CHAPTER 2

DOMESTIC CONSUMPTION: CONCEPTUAL AND EMPIRICAL REVIEW

2.1 Introduction

This chapter reviewed concept on the major component of the study. The first section presents the definition of the major concepts of the study. The subsequent section provides explanation on the various existing theories on domestic energy consumption and behavior, with a view of evaluating their efficiency and applicability in the context of real-world data and scenarios. The final section provides examples of empirical studies on domestic energy consumption undertaken at global and local level (Nigeria) in order to gain insight on the variables under study and concludes with the summary of their contributions, weakness and gaps identified in the literature.

2.2 Definitions of Concepts

2.2.1 The Concept of Household

Isaac and Ephraim (2004) defined a household as a person or group of persons, related or unrelated, who live together in the same dwelling unit, who make common provisions for food and regularly take their food from the same pot or share the same grain store, or who pool their income for the purpose of purchasing food. According to National Population Commission (2006) household consist of a person or group of persons living together usually under the same roof or in the same building/compound, who share the same sources of food and recognize themselves as a social unit with household head. Thus, the most commonly used criteria in the definition of a household are co-residence (living together in the same dwelling unit), a pooling of income and resources, the sharing of expenditures (including joint provision of the essentials of living such as food) and, the existence of family or emotional ties.

Therefore, households in the context of this study refers to a group of persons living together under the same roof and consume certain types of energy sources and services collectively.

2.2.2 The Concept of Energy

According to Jekayinfa (2006) and Britanica (2009) energy is the capacity for doing work and the basic driving force in man's development. It may exist in potential, kinetic, thermal, electrical, chemical, nuclear, or other forms. Usable mechanical or electrical energy is, for instance, produced by many kinds of devices, including fuel-burning heat engines, generators, batteries, fuel cells, etc. Jessy, (2009) reported that the energy is required for doing any type of work in life. It is required for cooking, heating, cooling, lighting in our homes (Adamu, et' al, 2020).

Ahuja and Tatsutani, (2009) opined that since, the dawn of the industrial age, the ability to harness and use different forms of energy has transformed living conditions for billions of people, enabling them to enjoy a level of comfort and mobility that is unprecedented in human history, and freed them to perform increasingly productive tasks (Akinlola et'al, 2017; World bank, 2007). Thus, in the context of this study energy refers to the various fuel types used in our homes, e.g., fuelwood, charcoal, kerosene, electricity and LPG for domestic needs.

2.2.3 Definition of Energy Consumption

Energy consumption is the amount of energy consumed by a person or an apparatus shown as a unit (PHC.) (Ogunniyi, Adepoju, & Ogunwole, 2012). Encyclopedia of Energy, (2004) pinpoint that energy consumption is often measured as the ratio of the energy (E) of a society to its economic output (GDP), measured in dollars of constant purchasing power (the E/GDP ratio).

The U.S. Department of Energy divides energy consumption into different categories: residential (domestic), commercial, industrial, electric power, and transportation. Energy consumption is important for economic growth and development, and it also plays a major role in improving conditions at the household level (DFID 2002). According to Enger & Smith, (2004) developed countries used energy within three sectors; residential, transportation and industrial in contrast to the predominant use of energy for residential purposes by the developing countries. This study is focused on domestic energy consumption.

2.2.4 Domestic Energy Consumption

Domestic energy consumption refers to the energy consumed in homes to meet the needs of the householders. (Suleiman; 2017; Kadiri & Alabi, 2014; Nwofe, 2013; Ogunniyi, Adepoju, & Ogunwole, 2012). Based on their usage domestic energy includes fuel wood, dung, agricultural residues, charcoal, kerosene, liquefied petroleum gas (LPG) and electricity (Adamu, Adamu, Ade & Akeh, 2020). They have been categorized by sBolaji (2012) as follows: traditional (dung, agricultural residues and fuel wood), intermediate (charcoal and kerosene) or the modern sources (liquefied petroleum gas, biogas, ethanol gel, plant oils, dimethyl ether and electricity). Reinders, Vringer, & Blok, (2003) and Ozcan et al (2013) posits that households use energy directly through (lighting and heating) and indirectly through production, transportation, and disposal of consumer goods and services. In the context of this study domestic energy comprises of all forms of energy available to the household for consumption.

2.2.5 Domestic Energy Consumption Pattern

Domestic energy consumption pattern refers to the total end-use of energy either for cooking, lighting, heating, refrigeration, amusement, transportation and other use. (Jangali & Nagesga, 2019; Akhter Hossain, 2012). According to Olanrewaju & Adigun, (2021) and Olatunji, et al, (2020) household energy demand and supply pattern varies considerably between rural and urban areas, lower and higher income groups within a country, across different geographical region due to climatic variations across cities and household formations.

In addition, Hetelberg, (2003) posits that household energy consumption pattern in the rural areas is determined by availability and affordability of fuels; access to infrastructural services. Others includes, cooking and consumption habits; dependability of supply, cost household and cultural preferences and taste; uncertainty of alternative supplies; price of alternatives household size, dietary patterns of the household among others (Dzioubinski & Chipman, 1999; Alem u & Kohlin, 2009).

2.2.6 Determinants of Domestic Energy Consumption

Determinant of domestic energy consumption refers to the numerous factors driving energy choice and consumption at the household level (Soltani, et al, 2019). Understanding the numerous internal and external factors that act as key determinants that drives energy consumption, as well their interactions are central to decision making policy on sustainable household energy transition to modern fuels and natural resources management (Holmes 2005, Odada et al. 2009). These determinants have been extensively studied in the literature from variety of thematic domains (economics, sociology, geography, psychology, and engineering (Vasseur, 2019; Cayla et al., 2011). However, each approach is limited by its own assumptions. For example, Olaniyan, Sulaimon & Adekunle, (2018); Sa'ad and Bugaje, (2016). Therefore, in this study, the determinants of energy consumption at the household level are summarized into socioeconomic factors, demographic factors and geographic characteristics as illustrated in figure below.

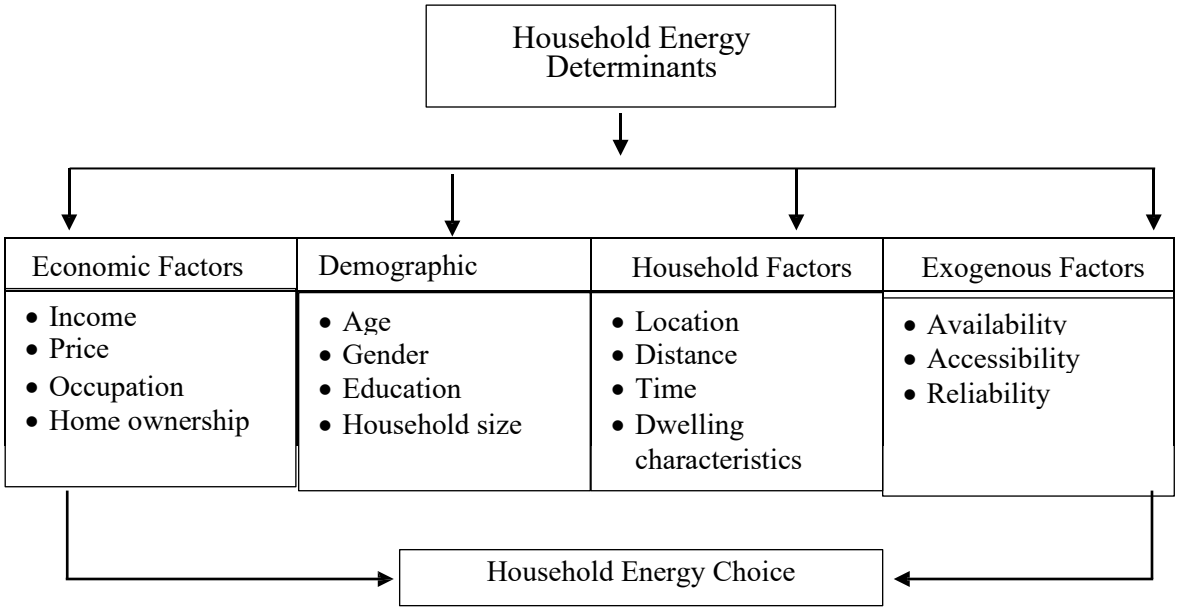


Figure 2.1: Determinants of Household Energy Choice.

2.2.7 Environmental Implication of Domestic Energy Consumption

Smith et al, (2013) assert that, although energy consumption is central to human society, it's may have some environmental implications, which vary based on the type of energy of used. According to Risseeuw, (2012) and Solomon, (2004). Such environmental implication scenarios encompass environmental, health and socioeconomic effects that is directly and indirectly associated to the consumption and production of any type of energy (Murphy, 2009; Holmes, 2010) which will further be discussed in the following sub section.

2.2.7(a) Environmental Effect

Environmental effects refer to the effect created directly or indirectly as a result of energy production and consumption on the natural or built environment in the form of creating environmental imbalances, that can have adverse effects on air, land water, wildlife or the inhabitants of the ecosystem (Abdallah, 2017; Smith & Parmenter, 2016). Studies such as Atieno (2012) and Risseeuw (2012) posits that the consumption biomass fuels among the households are considered to have negative environmental effects. These effects include degradation of forest, soil erosion, desertification, biodiversity loss, indoor air pollution, human morbidity and mortality, climate change, among others (Smith, Mehta, & Maeusezahl-Feuz, 2004).

Environmental Impact Assessment (EIA) was developed to evaluate such effects on ecosystems and was designed according to sustainable development indicators, such as reducing carbon footprint, biodiversity preservation among others (Solomon, 2004).

2.2.7(b) Health Effect

Health effect refer to changes in human health resulting from the long-term exposure to air pollutants such as carbon monoxide (CO) and particulate matter (PM). Exposure to these substances could lead to increased risk variety of diseases including pneumonia, bronchitis, tuberculosis, chronic respiratory diseases and lung cancer among others (Kadafa et al., 2017; Bruce et al. 2002). According to Bruce, Preze-padilla & Albalak, (2000) health effect is determined not just by the pollution level but also, and more importantly, by the time people spend breathing polluted air, i.e., the exposure level. The 2013 Global Burden of Disease Study (GBD), Household air pollution (HAP) is the single most important adverse environmental health risk factor globally and accounts for about 4.3 million premature deaths annually (Burnett, et al, WHO, 2014).

2.2.7(c) Socioeconomic Effect

Socioeconomic effect in this study is focused on how the use of energy for domestic purposes affects human welfare and social wellbeing. For example, one of the greatest socioeconomic threats posed by biomass combustion is its direct effect on human welfare, particularly women and children ((Reg & Nag, 2017; Risseeuw, 2012; Smith et al, 2013). Studies by Jan (2012) and Smith et al., (2000) found that fuel collection places a substantial time-labor burden on families in developing countries, thereby preventing them earning a living and pursuing education among others. The Integrated Development Association (IDEA, 2010) states that women and children in rural areas spend several hours a week fetching wood, causing them severe social hardship and are subjected to mental and physical agony, time that could be spent in education and other productive activities. environment health and socioeconomic.

2.3 The Concept of Geospatial Analysis

Geospatial Analysis refers to a collection of techniques and tools for geographic analysis and GIS data processing software engines (Haller, 2010). The term can further be defined as, "pertaining to the geographic location and characteristics of natural or constructed features and boundaries on, above, or below the earth's surface (Mahavidanage, 2011). The invention of geospatial technology is among the most highly applicable technological advancement over the last decade. This technique comprises a variety of modern tools that aid in geographic mapping as well as earth and human society analysis (Moghadam, Mutani, Lombardi, 2016). Geospatial technology has a wide range of applications in most of the utility sectors, particularly in the energy sector, where it has brought more efficient strategy for the spatial representation of energy consumption, analyzed and geo-referenced visualization of energy data and optimized the energy potential of territory (Belay, Mao, Li, 2019). The power of geospatial information can be effectively used in effective decisions making with regard to spatial energy consumption.

GIS is one of the examples of geospatial technology that holds tremendous promise for boosting the analytical power of energy planning and modeling techniques. Other examples of geospatial technology include Global Positioning System (GPS), Remote Sensing, and Geo-referencing. GIS are decision making tools that integrate Geographic knowledge, Database Management and Information Technology. GIS are information systems for importing, storing, analyzing, managing, exporting and presenting data which are spatially referenced (linked to location). Data management, Analysis and visualization are three views in GIS. The technology analyzes and view information in ways not previously possible (Resch et al., 2014).

2.4 Prediction of Future Domestic Energy Consumption

Predicting future domestic energy consumption patterns involves using historical energy usage data, weather information, and other relevant factors to forecast how much energy a household will consume in the future (Jain et al., 2024; Samuel et al., 2017). Prediction energy consumption is fundamental for improved energy policy and decision making, energy conservation, efficiency and sustainability (Olu-Ajayi & Alaka, 2022). Thus, understanding the determinants of energy consumption is a precondition for implementing effective energy policy, as well as predicting future energy consumption (Duresic, 2019). Olabisi, (2020); Bhattacharyya and Timilsina, (2009) categorized energy prediction and forecasting models, based on two major modelling approaches used in the energy sector namely; the simple and sophisticated approaches. Simple approaches provide easy answer to energy demand calculation using four simple indicators: growth rate, elasticities, unit consumption, and energy intensity.

The sophisticated approach uses advanced and complex methodologies, comprising of top-down approach and bottom-up engineering approach. The top-down approach is based on the principles of macroeconomics, such as Time Series models, Regression Models, Econometric Models and Input-Output models. The bottom-up engineering approach modelling techniques is based on disaggregation and focuses more on the detailed technology aspect and future evolution of the energy system. Such as, Optimization models, Simulation model, accounting models, hybrid models. The third modelling type is the hybrid or combined approach. This approach integrates the bottom-up and top-down approaches. The strength and weaknesses of these approaches compensate for each other. This study will predicate future pattern of energy consumption based on econometric model.

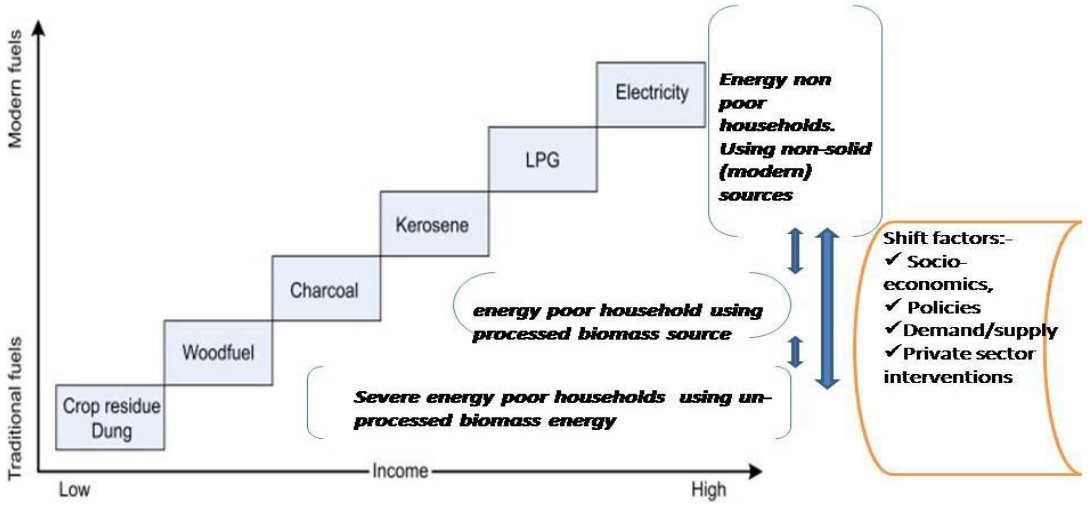
2.5 Theories of Household Energy Consumption Behavior

The stronghold of any meaningful research is theories. Several household energy consumption models have been developed in the social science research in order to provide a comprehensive explanation about energy choice, consumption and switching behavior. There are four relevant theories namely Energy ladder theory, Energy stacking model, Energy Leap Flogging theory and Poverty-Environment Hypothesis that can potentially be used to analyze this study. These theories are relevant in explaining the household energy consumptions decisions. However, based on the four theories, this study adopted the energy stacking model, which will further discussed in the following section.

2.5.1 The Energy Ladder Model

The energy ladder model is the most prominent theoretical and functional framework often used to explain the dynamics of domestic fuel choices in developing countries (Heltberg, 2003). The model placed more prominence on household income and relative fuel prices as the basis for fuel choices (Barnes and Floor, 1999; Barnes et al., 2005). Based on household income, the energy ladder model illustrates a linear three-stage switching process. The first stage involves a heavy reliance on traditional fuels in the form of dung, crop residue and wood, while in the second stage household moves to "transition" fuels involving the use of kerosene, coal and charcoal, and in the third stage, they switch to the use of LPG, natural gas or electricity (see fig). However, the energy ladder model has been criticized by many studies (Heltberg, 2003; Masera et al., 2000; UNDP/ESMAP, 2003; Jebra & Iniyan, 2006) for placing emphasis on income as a determinant of household fuel choice and ignoring other social, cultural and environmental factors. For instance, there is also growing evidence in literature that other than household income, the distance of the household from biomass sources

(Hyde and Kohlin, 2000; Pachauri, 2004) increased fuel wood availability (Narain et al., 2008) and fuel wood shortages as a result of deforestation (Veld et al., 2006) may also be an important factor influencing household fuel choices, which the energy ladder hypothesis has failed to acknowledge. Accordingly, the fuel-switching process is not unidirectional, and households can both use more advanced fuels for certain purposes, albeit in combination with more traditional ones for other purposes of the household (Kroon, Brouwer, & Beukering, (2013). This practice is known as fuel stacking. It therefore suggests that income, although very important, is not the only determinant of household cooking energy source.



Source: Adapted from WHO (2002)

Figure 2.2 Energy Ladder

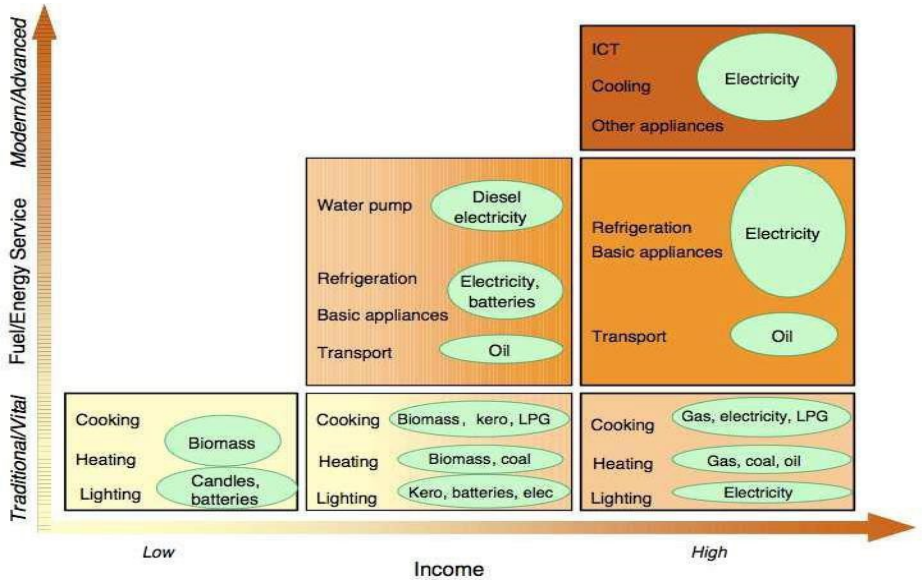
2.5.2 Energy Stacking Model (ESM)

Masera et al. (2000) criticized the energy ladder theory for failing to adequately describe the dynamics of household energy consumption. Instead observed that fuel stacking is common in both rural and urban areas of developing countries. The concept of 'Fuel Stacking' or 'Multiple Fuel Model' has gained more relevance in explaining the household energy consumption behavior. According to the 'Fuel-Stacking'

concept, with increasing income, households do not fully switch to different fuel types, they rather use an energy mix or as of a menu (Mekonnen, Gebreegibher, Kssie, 2009; Kroon, Brouwer & Beukering, 2013). Based on this concept various cooking fuels are used at the same time albeit for different purposes, rather than fuels being abandoned and substituted for cleaner ones a combination of superior fuels in mixture with inferior one's fuels is used. The model emphasizes that household energy consumption choices are driven by multiple factors rather than, unidirectional factor.

Fuel stacking is commonly practiced in rural regions of the developing world and, to a lesser extent, in urban centers (Heltberg, 2004). In Nigeria, fuel stacking is practiced by a majority of the population. Instead of households abandoning traditional fuels as income increases, households tend to stack different forms of fuels which are consistent with consumer preferences in the face of supply constraints (Ogwumike et al, 2014).

A number of studies have disclosed different rational for multiple fuel use such as, occasional shortages of modern fuels (Hosier and Kipondya 1993; Kowsari and Zerriffi 2011), high cost of appliances associated with using exclusively modern fuels (Davis 1998), fluctuations of commercial fuel prices (Leach 1992) and preferences inducing households not to fully adopt modern fuels (Masera et al. 2000). The complexity of the fuel switching process thus suggests that there is a multiplicity of factors, besides income, that may affect fuel use.



Source: Adapted from Hosier (2004)

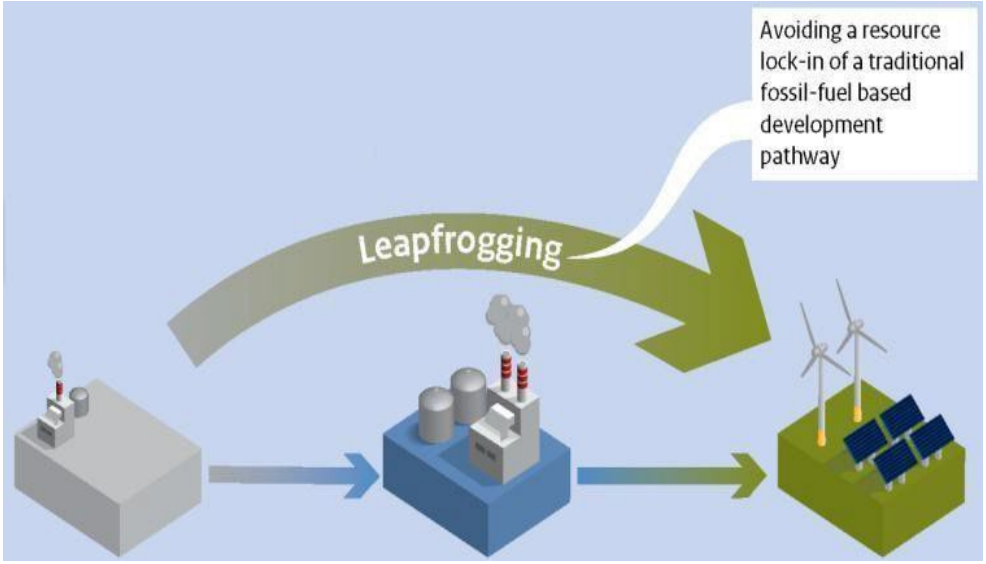
Figure 2.3 Foley's Energy Demand Ladder Model.

2.5.3 Energy Leap Frogging Theory

Energy Leap Frogging Theory proposes the development of household energy, through fast introduction of modern fuel sources in a cost-effective manner and by so doing counter degradation caused by the traditional fuels (Lenssen & Flavin, 1996). According to the model developing countries can bank on the negative experiences of the developed ones, and by so doing the environmentally destructive trails would not be threaded and a more sustainable future would be built concurrently. The model advocates the introduction of stove distribution programs, stove subsidies, and promotional campaigns as typical examples of technological experiences and transfers, in which emphasis is placed on the poor household affordability (Lenssen & Flavin,1996). The proposed direct movement to advanced energy from traditional to modern fuels. As such, the environmental and health challenges attached to the traditional fuels are totally avoided.

Technical, organizational and institutional challenges are the major limitations of the model as categories by Murphy (2001). Through the organizational

lens, resources to effectively disseminate technologies are not available in most countries. From the technical knowhow lens, technologies can be challenging when it comes to manufacture, keeping cost-efficient, safe and durable. The institutional lens reveals that technological adoption is usually constrained by social structures in place. In summary, household cooking energy leap frogging offers opportunities for improving health, reducing environmental impact, and enhancing sustainability. Thus, understanding the dynamics, barriers, and implications of leap frogging can inform targeted policy interventions to facilitate a successful transition to cleaner and more efficient cooking energy. In the context of this study, ELF theory is relevant as it seeks to explore the impact of technology an innovation as the most important drivers of access to sustainable clean energy.



Source: Modified from PBL (2017)
Figure 2.4 Energy Frogging Theory

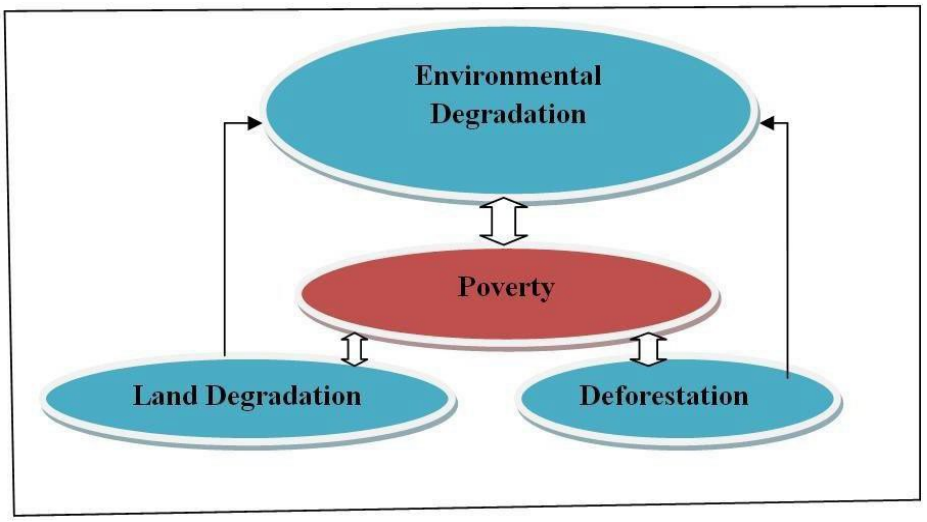
2.5.4 Poverty-Environment Hypothesis (PEH)

According to the poverty-environment hypothesis (Wunder, 2001) the level of development, particularly when a country is poor, is conditioned on the use of wood as an energy source. There is a strong support for the poverty-environment hypothesis since household economic wealth is a significant and negative determinant of firewood

consumption. As noted by World Bank, (2003) empirical literature on the poverty-environmental hypothesis (PEH) addresses this question and states that poor households rely more on environmental resources than the non-poor. Where evidence of the PEH can be found, there are at least two main policy implications. Firstly, poverty alleviation is a precondition for environment sustainability. Secondly, environmental protection policies, based on a drastic limitation of access to common resources, increase rural inequality and deepen poverty because poorer households suffer more intensively from the deprivation of the resource. Moreover, a potentially important side-effect is that increased inequality and poverty may in turn hamper environmental protection by weakening social cohesion that is needed for enforcing a sound environmental management (Demuger & Fournier, 2011).

The World Bank, (2002) stated that poor families, who have to meet short-term needs, undermine the natural capital by excessive cutting of trees for firewood and failure to replace soil nutrients. Unfortunately, poverty offers the poor a few choices to intensively rely on and use available natural resources. This reliance creates complex, dynamic interactions between environmental conditions and poverty. Because when ecosystem functions are impaired, its inevitably leads to narrowing of livelihood choices, which increases the vulnerability of the poor and they suffer disproportionately from more frequent and severe storms, floods and droughts, health impacts of toxic pollution, and insecurity of access to productive resources such as arable land, freshwater and sustainable energy (UNDP, 2014). The application of the poverty-environment hypothesis in this study aimed to ascertain the extent to which poverty acts as a primary driver of environmental degradation as illustrated in figure 2.4. Consequently, environmental policies, strategies, programs and projects must be focused and effective towards making a difference in people's lives and the global

environment, thereby contributing to sustainable development.



Sources: Modified from Gatahun et al, (2018)
Figure: 2.5 Poverty-Environment Hypothesis (PEH).

In summary, this subsection discussed four theories explaining domestic energy choice, consumption and switching, the conclusions drawn from each of the theories were examined. The first theory reviewed is the energy ladder model which based on the view that as households' income increase, they tend to switch to cleaner energy sources that the previous. The model was criticized for been narrow and oversimplified. Energy stacking model on the other hand explained household 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 used them complimentarily. Energy Leap Flogging model focuses on the overall pathway that could be followed by developing countries to avoid the consumption of traditional fuels that have environmental implication and to move quickly to the consumption of modern fuels with no environmental impacts. Finally, the Poverty-Environment hypothesis posits that when a country is poor, it is conditioned on the use of wood as an energy source, thus wealth is a significant and