Stack-ladders and Lanterns: Understanding Energy Poverty for Cooking and Lighting in Kano State, Nigeria and Exploring Solar Solutions

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Abstract

The model of the energy ladder has been adopted by energy researchers to study household energy poverty and energy transition in the developing countries. However, this model has been widely criticized for placing more emphasis on householder's income and overlooking other critical factors. Consequently, several energy researchers have suggested an alternative model, the so-called energy-stacking model. This study observes that conclusions from proponents of both models need to be revisited, because they fail to capture the reality of households energy systems. In addition, this study critically observes that household energy for lighting has received little attention in these models' assumptions and discourses. These models were combined in this research to study household energy poverty and transition. This study goes on to explore household energy for lighting in more detail, focussing upon opportunities of using solar RETs for alleviating energy for lighting problems in the metropolitan and non-metropolitan zones of the study area, Kano State, Nigeria.

This research adopts both quantitative and qualitative approaches informed by the pragmatic epistemological orientation of this study. The quantitative component evaluates the outcomes of a household energy survey (for both cooking and lighting). The results from this component were interpreted through existing and new models (ladder, stacking and integrated-'stack-ladder'). The context of the quantitative component is for both the metropolitan and the non-metropolitan of the study area. The qualitative component, in contrast, investigates the barriers to and opportunities for adopting solar RETs. This component adopts semi-structured interviews with key solar stakeholders.

The findings from this research indicate that the characteristics of household energy were better represented with the alternative model presented in this study than either the energy ladder model or energy stacking model. Thus, this study argues that neither the model of the energy ladder nor the energy stacking have the capacity to capture of household energy usage in the developing countries such as Nigeria. The majority of the households are found to be energy poor for cooking across all zones of the study area, using mainly traditional classes of energy. In contrast, this study reveals that the majority of households across both zones rely on transitional and modern energy classes for lighting. The study reveals that there are drivers for solar RETs uptake, however, these drivers are being obstructed by a series of economic, technical and political barriers. In conclusion, this thesis contributes to the field of energy poverty and energy transition literature in many ways; theoretically, empirically and methodologically by challenging the established work in these fields. This thesis argues that the two conceptual models that have been widely used to explore energy poverty at the household energy level in developing countries can usefully be integrated as demonstrated in this study. It also emphasizes the importance of policy intervention and participation of all actors in addressing solar RETs' barriers for uptake.

Declaration

I declare that the whole content of this thesis is the author's original work, and no part of this thesis has been submitted to any degree award at Lancaster University or elsewhere.

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Acronyms

AFDB	African Development Bank
CSP	Concentrated Solar Power
DPR	Department of Petroleum Resources
ECN	Energy Commission of Nigeria
EIA	Energy Information Administration
ESMAP	Energy Sector Management Assistance Program
FMPS	Federal Ministry of Power and Steel
GEA	Global Energy Assessment
GIZ	German International Cooperation
HHK	Household Kerosene
ICEED	International Centre for Energy, Environment and Development
ICREEE	Inter-Ministerial Committee on Renewable Energy and Energy Efficiency
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
LEDs	Light-emitting diodes
LGAs	Local Government Areas
LPG	Liquefied Petroleum Gas
MDGs	Millennium Development Goals
MW	Megawatt
NGO	Non-Governmental Organisation
NEMP	National Energy Master Plan
NERC	National Electricity Regulation Commission
NESP	Nigerian Energy Support Programme
NPC	National Population Commission
OECD	Organisation for Economic Co-operation and Development
PTDF	Petroleum Technology Development Fund

PV	Photovoltaic
RE	Renewable Energy
REB	Rural Electricity Board
REMP	Renewable Energy Master Plan
REN21	Renewable Energy Policy Network for the 21st Century
RETs	Renewable Energy Technologies
SDGs	Sustainable Development Goals
SPSS	Statistical Package for the Social Sciences
SSA	Sub-Saharan Africa
TCN	Transmission Company of Nigeria
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WHO	World Health Organisation

Definition of Terms

Energy carrier: a single energy vector from one of the three energy classes. An energy carrier resulted from a conversion of an energy source, which deliver the energy services. An example of modern energy carrier is electricity.

Energy class: the 3 classes of energy (traditional, transitional and modern) according to the model of the energy ladder. In addition, what distinguishes the three classes is the kind of carriers they include.

Energy ladder: this model assumes that households use one energy carrier at a time, then switching to more superior energy carriers as their economic condition improved.

Energy services: end-use derived from energy carriers such as cooking, lighting, heating, cooling, IT etc. It worth stating here that different energy carriers can provide similar energy services. For example, electricity and fuelwood can both be used for cooking, but differ in efficiency and quality of the service provided.

Energy sources: this refers to a primary sources where all energy carriers originated. It can be from fossils, renewable or biomass origins.

Energy stacking: the energy stacking model assumes that a household uses multiple energy carriers at the same time.

Energy stack-ladder: this is an integrated energy model introduced in this thesis to study household energy for cooking and energy for lighting. This model combines both assumptions of the energy ladder and the energy stacking models.

Energy system: Energy systems in this thesis refer to system of provision of energy for household use. Each household can use more than one energy system. Each energy system can have more than one energy carrier, but only of one energy class in the integrated model introduced in this thesis. The class can be modern, transitional and traditional, for both cooking and lighting.

Energy transition: use of transitional and modern energy classes for cooking or lighting at household or community levels. For historical reasons, society by default used traditional energy then transitioning to modern energy classes.

Modern energy carriers: energy carriers that are mainly derived from fossil fuels or renewable sources. They are highly effective and provide high quality energy services, examples of modern energy carriers for cooking and lighting are: electricity, LPG and solar.

Traditional energy carriers: energy carriers for cooking that are mainly derived from dried biomass, these include fuelwood, charcoal, animal dung and crop residues. Whereas traditional energy carriers for lighting include kerosene lamps and candles.

Transitional energy carriers: an intermediate energy carrier between the modern and traditional energy carriers. For example, transitional energy carrier for cooking in this thesis refers to kerosene/paraffin, whereas transitional energy carrier for lighting refers to lantern.

Zone: an aggregation of many households in a particular geopolitical entity of the study area. This thesis divided the study area into metropolitan and non-metropolitan zones.

Chapter 1: Introduction

"Energy is central to nearly every major challenge and opportunity the world faces today. Be it for jobs, security, climate change, food production or increasing incomes, access to energy for all is essential" (UN, 2018).

1.1 Energy Poverty Scales

This section presents an overview of challenges of energy poverty at different scales: global, regional, national and local, focussing on sub-Saharan Africa (SSA), Nigeria and Kano State. The main premise of discussion in this chapter is situated within the major dimensions of energy poverty and transition in the developing countries, which are lack of access to electricity for lighting and use of biomass for cooking as reported by the International Energy Agency, IEA (IEA, 2010). The chapter also presents the research motivation behind this study. It concludes that a thorough understanding of contextual (local) energy poverty problems might help in formulating sound policies for alleviating local energy challenges.

1.1.1 Global Energy Poverty Context

The Millennium Development Goals (MDGs) were established in 2000 with plans to complete eight key goals by 2015 (United Nations, 2015). Of paramount importance among these goals were goals numbers 1 and 7, which aimed to eradicate extreme hunger and poverty, and to ensure environmental sustainability respectively. Hitherto, these ambitions cannot be realized unless energy poverty is eradicated as many experts in the field of global energy studies have commented (See: Birol, 2007; Bazilian and Nussbaumer, 2010; Brew-Hammond, 2010; Shaad and Wilson, 2009; Karekezi et al., 2012; UN-Energy, 2005; and Tomei and Gent, 2015).

Fortunately, the UN sustainable development goals (SDGs) were launched by the end of year 2015. One of the key goals of SDG is goal 7, which aimed at providing 'access to affordable, reliable, sustainable and modern energy for all' by 2030 (World Bank, 2018, p.2 and REN21, 2016). Achieving this goal can drive tremendous benefits to the energy poor in the developing countries, particularly the most vulnerable segment- women and children. World Bank (2018) also reported that SDG's goal 7 has made a significant progress in alleviating household energy poverty, however, such progress remains uneven in different regions.

More than 1.1 billion people in the world are unable to gain access to electricity and 2.9 billion people depend on solid biomass such as fuelwood, animal or agricultural waste for cooking services (World Bank, 2015). In the case of energy for cooking, these figures represent about 40% of the world's population. Unfortunately, as shown in Tables 1.1 and 1.2, the vast majority of energy poor live in sub-Saharan Africa and south Asia (Ritchie & Roser, 2019). Moreover, the challenges of energy poverty in these regions, particularly access to electricity, differ significantly between the urban and rural areas, with less than 13% of the rural population in these regions having access to electricity (World Bank, 2018).

1.1.2 Regional Energy Poverty Context

Paradoxically, the African continent is blessed with abundant energy resources, but at the same time, consumes relatively little energy compared to other world regions. The continent accounts for 13.1% of the world population yet consumes only 5.5% of the world's total energy supply and generates only 3.1% of global electricity supplies (UNECA, 2006). Strikingly, energy consumption in SSA is on par with that of New York State in the USA (OECD/IEA, 2010). Less than half of the African population have access to modern energy services such as electricity for lighting (OECD/IEA, 2014). The majority of these populations live in sub-Saharan Africa.

Table 1. 1: Electricity Access by World Regions, 2013

Region	**Electrification Rate in 2013 (Proportion of population with access)**	**People without access to electricity in 2013 (millions)**
Africa	43%	635
North Africa	99%	1
Sub-Saharan Africa	32%	634
Developing Asia	86%	526
Latin America	95%	22
Middle East	92%	17

Source: REN21 (2016)

In 2010, SSA had a population of 791 million people, of which only 31% had access to electricity (OECD & IEA, 2010; REN21, 2016). With the exception of east Africa, the rate of electrification in SSA has been outpaced by population growth (World Bank, 2018). Low rates of electrification have been identified as key causes of energy poverty in developing countries (see section 2.6). Despite some progress in providing access to electricity around the world, SSA remains the most deprived region with the highest energy access deficit in the world (World Bank, 2018).

SSA is characterized by a heavy dependence on solid biomass as a primary source for domestic energy which is used by 82% of its population (WHO & UNDP, 2009). Moreover, energy poverty has forced most urban centres to rely on charcoal as their main fuel for cooking (Zulu and Richardson, 2013). In the more extreme circumstances, animal dung is widely used as the primary energy carrier for cooking in parts of sub-Saharan Africa and south Asia (Heltberg, 2004).

Table 1. 2: World Regions Relying on Traditional Energy for Cooking, 2013

Region	**Share of population using traditional Energy for Cooking**	**Population (millions)**
Africa	68%	754
Sub-Saharan Africa	80%	753
North Africa	1%	1
Developing Asia	51%	1,895
Latin America	14%	65
Middle East	4%	18

Source: REN21 (2016)

A number of studies have indicated that two important factors influence the dependence on traditional energy carriers in most parts of SSA. Firstly, these energy carriers are widely available in these countries, particularly in rural areas. Secondly, the vast majority of householders perceive traditional energy carriers as being 'low cost' (Schlaq & Zuzarte, 2008 and Hyman, 1994).

Although progress has been made in promoting access to energy around the world, a wide gap between urban and rural centres remains (Ritchie & Roser, 2019). The widest gaps in terms of access to electricity between urban and rural areas exist in SSA followed by South Asian countries (Saghir, 2005). This discrepancy extends to household energy use for lighting and cooking.

1.1.3 National and Local Energy Poverty Context

The country of Nigeria boasts the largest population in Africa, with a population of more than 178 million in 2014 (AFDB, OECD & UNDP, 2015), an annual growth rate of 3.2%, and a rural population accounting for 60% of the total population. More than half of Nigeria's population have no access to electricity (IEA, 2014), and around 15.3 million households have no access to electricity (Eleri et al., 2013). Despite decades of high oil prices and despite being one of the major oil producing countries in the world, Nigeria has failed to meet its own domestic energy demand. Consequently, its population have to pay high prices for domestic energy services, particularly for cooking and lighting (Maconachie et al., 2009).

There is consensus that one of the leading causes of energy poverty is lack of resources. Nigeria is endowed with abundant energy resources including oil and gas, nuclear and renewables (Brew-Hammond et al., 2014), however, the power sector in Nigeria has been plagued by a myriad of problems ranging from technical and administrative to manpower shortages (Sambo, 2009). Consequently, these have had adverse impacts upon the nation's power supply, leaving millions of households and industries without a reliable energy supply. The rural areas in Nigeria have experienced the most adverse impacts of this limited power supply. Given the real problems in energy supply, approximately 80% of power requirements for the industrial, commercial and residential sectors are met by diesel and gasoline generators (Energy Commission of Nigeria, ECN, 2014 and Cervigni et al., 2013). The power supply from the national grid covers only 20% of the energy demand for these sectors.

Contrasting energy systems exist side by side in Nigeria. Modern energy systems, which are predominantly fossil fuel based, are used for transport, industry and some residences. In contrast, traditional systems use solid biomass, predominantly for cooking (ECN, 2014). Similarly, ECN (2013) reported that about 60% of Nigeria's population depends on fuelwood for domestic energy use. This traditional energy system is placed on the bottom rung of the energy ladder (see section 2.3.1.1) and is absent from government policy in most developing countries (Sokona et al., 2012). Consequently, this will have a profound impact on the energy poor in these countries. For decades, Nigeria's energy for cooking has not been appropriately recognised in government policy, at both national and state levels (Eleri et al., 2012). Moreover, energy policy in Nigeria has traditionally focused on transition to modern energy sources (Cline-Cole & Maconachie, 2016). As result, challenges to household energy for cooking remains unsolved.

Unfortunately within the context of energy poverty, the northern geopolitical zones of Nigeria (which are the most heavily populated zones) experience lower levels of access to modern energy carriers than their southern counterparts (Eleri et al., 2012). The northern zones have a long history of over-dependence on fuelwood as their major energy source for domestic utilization (Naibbi & Healey, 2013; Naibbi & Healey, 2014). Eleri et al. (2012) noted that more than 90% of households rely primarily on fuelwood for cooking in northern Nigeria.

Kano State is the most heavily populated state in Nigeria according to the latest census which was held in 2006. Kano State, the heart of Northern Nigeria, is situated in the north-western geopolitical zone (National Population Commission, NPC, 2010). It contains more than 1.6 million households, however the level of access to modern energy carriers is low. Official energy figures (NPC, 2010) reveal that less than 30% of households use electricity for lighting and cooking. In contrast, more than 50% of households rely on fuelwood and kerosene for cooking and lighting respectively.

Naibbi & Healey (2013) identified other drivers that influenced over-dependence on fuelwood in the northern zones, including unemployment, poverty and social injustice, and poor government policy on agriculture. Furthermore, the fuelwood business has been well established in metropolitan Kano for decades (Cline-Cole & Maconachie, 2016). Additional factors include population increase, inequality of fossil fuel distribution and low levels of western education (Naibbi & Healey, 2014). Inequality of fuel distribution raises questions of energy justice at larger scales, however this is beyond the scope of this thesis. Naibbi & Healey (2015) recently noted that new opportunities have emerged for the northern states to obtain fossil fuels (including Liquefied Petroleum Gas, LPG) from neighbouring countries such as Niger and the Benin Republic at cheaper rates than from traditional suppliers in the southern part of the country. However, reliability and continuity of supply from these neighbouring countries remain problematic.

Further, the proportion of connections to the national grid, which is supposedly the major source of household energy for lighting, is also uneven between northern and southern states. For example, Eleri et al. (2012) noted that virtually all households in Lagos State are connected to the national grid. In contrast, less than half of all households in Kano State are connected to the national grid.

There has been a record breaking in connecting local government headquarters to the grid in Nigeria, however, Cervigni et al., (2013) noted that only 20% of rural households are connected to the national grid. Specifically, the majority of rural areas in the north are not widely connected to the grid, and instead rely primarily on kerosene for lighting (Sambo, 2005). Ahemen et al., (2016) found that some cities in the north central states in Nigeria receive electricity for only 2-4 days in a week and 4-12 hours per day.

In summary, this section has presented an overview of major dimensions of energy poverty - cooking and lighting - in developing countries. However, as shown in this section, energy poverty challenges differ at global, regional and local scales. Thus, understanding this problem may require application of conceptual models that can provide better understanding of contextual energy poverty challenges (section 1.3). This will be crucial, particularly, for policy formulation for addressing household energy poverty in the context of the study area.

1.2 Motivation for this Research

The term 'energy poverty' does not necessarily imply economic poverty, rather it is a qualifying terminology that reflects the literal meaning of poverty (i.e. lack of) in relation to supply or access to energy carriers and modern energy services such as lighting, cooking, cooling, heating and information technology. Bradshaw & Hutton (1983) noted that people above the poverty line could still be trapped in energy poverty situations. Energy poverty is not just a consequence of energy being unaffordable, but can also be the result of inadequate and/or unreliable supply, poor infrastructure, failing policies, adverse environmental conditions and restrictive cultural circumstances as in the case of most developing countries. These factors have been highlighted in many studies of household energy poverty in the developing countries (see sections 2.2.2 and 2.2.3).

Energy poverty (or fuel poverty) is one of the components of the 'energy trilemma' which encompasses inter-relationships between energy security, mitigation of climate change/environmental damage and energy poverty (Gunningham, 2013; Birol, 2007). Birol (ibid), acknowledged that the components of energy security and climate change usually receive more attention than energy poverty. This may be as a result of misconception and/ or underrating of the nature and consequences of energy poverty.

It is worth noting that the term 'energy poverty' has no universal definition. This may be due to differences in its drivers and impacts across different geographical and economic settings (section 2.2). However, the most popular definitions of energy poverty are associated with phrases such as 'lack of access' to high quality sources of energy or 'use of low' quality of sources of energy. For example, energy poverty has been defined as 'lack of access to modern energy services' (Li et al., 2014: p. 476; González-Eguino, 2015), or the 'use of traditional biomass' (Birol, 2007, p. 3).

In recent decades a number of conceptual models have been developed to investigate household energy poverty and transition (section 2.3.1). One such model is the so-called ‘energy ladder’ model. This model aims to represent transition of energy utilization from traditional and transitional carriers to modern energy carriers (Maconachie et al., 2009). The main premise underlying the energy ladder model is that income dictates transitions between the rungs of the ladder (Heltberg, 2004), however, the model thus obscures other possible influences on class of energy use. In other words, the energy ladder model has been criticized for failing to take other factors than household income into consideration.

An alternative, energy stacking model has been proposed to address some of the shortcomings of the energy ladder model. This model is based on the premise that a household uses multiple fuels at the same time without abandoning the low quality energy carriers for cooking (section 2.3.1.1). However, complexities surrounding this stacking model are yet to be fully explored or understood (for detailed discussion see sections 2.3.1.2 and 2.3.2).

Further observations have made in this study regarding the assumptions and conclusions based on these two models. Firstly, the most obvious weakness of these models is that the component of household energy for lighting has been neglected. Secondly, the energy ladder assumes use of a single energy carrier (from a particular energy class) at a time. In contrast, the energy stacking model explicitly assumes the use of multiple energy carriers (from different energy classes) for cooking at the same time.

Thus, this necessitates the need for an integrated model (*energy stack-ladder*) that combines elements of both the energy ladder and energy stacking models. This integrated model redefines multiple energy carriers into the 3 classes (i.e. modern, transitional and traditional) of energy use for both cooking and lighting as in the energy ladder model. This classification has been operationalized in more detail in Chapter 3.

There is a paucity of empirical evidence on the contribution that renewable energy can make towards addressing energy poverty as suggested by Muller & Yan (2016). This study assesses the solar potential and argues that barriers to the uptake of solar renewable energy technologies (RETs) need to be removed through the cooperation of multiple stakeholders. Little is known about RETs barrier removal measures in developing countries due to the complexity and peculiarity of this problem. Moreover, the penetration of solar and RETs in general has been very low due to lack of understanding of key dimensions of their barriers (Reddy & Painuly, 2004). Thus, this study intends to address this gap by using a qualitative approach to explore barriers preventing solar RETs transition at different levels in the study area and Nigeria as a whole.

Finally, this study argues that the integrated energy stack-ladder systems model proposed in this study is better able to represent of the complexities and characteristics of household energy poverty and potential to transition to solar RETs in the context of this study area.

1.3 Scope

Energy poverty has many dimensions in relation to energy services at the household level (see section 2.2.3). The IEA (2010) identified two major dimensions of household energy poverty at household level, namely lack of access to electricity and reliance on traditional biomass for cooking. Access to electricity has tremendous impact on other household energy services such as IT and communication, cooling and heating. However, this study will look at the following energy services in relation to their primary carriers:

1. Lighting----------- electricity.
2. Cooking----------- kerosene, gas (LPG) and electricity.

The choice of the above parameters was informed by the energy ladder model (Figure 2.3). However, as highlighted in the section 2.3.1.1, studies based on energy ladder model pay less attention to the household energy for lighting component. This study aims to better understand the characteristics and barriers associated with energy for cooking and lighting. In case of energy for lighting, this study considers how households can move to the top rungs of the ladder which signifies modern energy carriers using solar technologies. These two questions are crucial in a research dealing with a contextual approach. Contextualization here means paying attention to the availability of energy carriers for both cooking and lighting peculiar to the study area. Moreover, the analysis of this context evolved from the two components of this study- household energy survey and solar RETs stakeholders interviews. The first component of this study evaluates the assumptions of the energy ladder and energy stacking models in relation to number of carriers and socio-economic characteristics of the householders. The second component focuses on solar RETs drivers, barriers and barrier removal measures for uptake at the level of Kano State.

1.4 Aim and Objectives

The aim of this study is to examine the key factors affecting household energy poverty in Kano State, Nigeria, and explore potential solutions using solar technologies and associated uptake mechanisms.

The specific objectives are to:

1. Explore suitable frameworks for studying energy poverty in developing countries;

2. Examine the characteristics of household energy poverty and the barriers preventing modern energy transition:

    a) For Cooking

    b) For Lighting

3. Explore drivers and barriers to the uptake of solar RETs for lighting.

4. Evaluate whether and how these technologies can help alleviate energy poverty (for lighting) at household level.

1.5 Structure of the Thesis

This thesis consists of 7 chapters. Apart from chapter one, all the remaining chapters address a specific research objective. However, Chapter 6 addresses the last two objectives (3 and 4).

Chapter One: Introduction

This chapter sets the agenda of the whole thesis. It provides the research motivation, aim and objectives, scope and the thesis outline. In other words, it provides the foundation for subsequent chapters in this thesis. The chapter also presents an overview of energy poverty at different scales. It first provides a global overview of access to energy for cooking and lighting, before considering regional, national and local contexts.

Chapter Two: Literature Review

This chapter explores all relevant literature related to this study including the detail of the two conceptual models (the energy ladder and stacking models) evaluated in this thesis. The chapter is broadly divided into two parts: household energy poverty and solar RETs transition. The first part of this study sets out to explore the major dimensions of household energy poverty and barriers preventing transition to modern energy systems (see chapter 4 and 5).

Moreover, this chapter introduces the most important contribution presented in this thesis regarding the integration of both energy ladder and stacking models. The idea of combining these models is then applied in two of the empirical chapters (Chapter 4 and Chapter 5).

The second part of this chapter evaluates possible contribution(s) of solar renewable energy technologies (RETs) in addressing energy poverty for lighting in the context of the study area (see chapter 6).

Chapter Three: Research Design

This chapter presents details of methods used for data gathering and analysis. Data collection in this study was divided into two main components. The first component deals with a quantitative survey of household characteristics and energy used. Also, in this component the idea of integrating the two energy models is operationalized. The second component deals with semi-structured interviews with solar RETs stakeholders in the study area. All methods are rooted in the pragmatic paradigm with intention to improve our understanding of household energy poverty for cooking and lighting as well as searching for opportunities for solar RETs uptakes. The justifications for choosing these methods are also presented in this chapter.

Chapter Four: Characteristics of Household Energy Poverty for Cooking and Barriers to Transition

This chapter examines the characteristics of household energy for cooking. In addition, it explores the application of both the energy ladder and the stacking models in the context of the study area. Furthermore, the chapter examines the association between the household energy class used for cooking and socio-economic status. Moreover, this association was tested with respect to the level of energy satisfaction across the whole study area. The chapter also examines the barriers preventing the use of modern energy classes for cooking. All these elements were examined through the lens of an integrated model of the energy stack-ladder model.

Chapter Five: Characteristics of Household Energy Poverty for Lighting and Barriers to Transition

This chapter investigates household energy for lighting using the integrated energy stack-ladder model introduced in this thesis. This chapter mirrors the composition of chapter 4, but its focuses on household energy for lighting. This chapter also synthesises the findings of chapters 4 and 5.

Chapter Six: Energy Transition: Exploring Solar Energy as a Solution to Lighting Energy Poverty and Barriers to Uptake

This chapter explores the drivers, barriers and policy solutions to adopting solar RETs for alleviating household energy poverty for lighting in the study area. It identifies and classifies both the drivers and barriers using a thematic method of data analysis. In addition, the chapter also discusses solar RETs barriers at household level based on quantitative data used in Chapter 4 and Chapter 5. The chapter concludes by stating that solar RETs cannot be adopted to alleviate household energy for lighting poverty without strong policy influence.

Chapter Seven: Conclusion and Recommendations

This chapter provides a summary of the whole thesis and a critical reflection on the aims and objectives set out in this introductory chapter. For example, one of the key conclusions drawn in this thesis is that the integrated model introduced in chapter 2 works and provides a better representation of energy poverty and transition than those in previous studies. In addition, this chapter also highlights the major theoretical, empirical and methodological contributions of this thesis. Finally, the chapter concludes with a review of limitations and recommendations for future research.

Chapter 2: Literature Review

2.1 Overview

The main focus of this chapter is to review the key topics surrounding the literature on energy poverty models in developing countries and potential solutions offered by renewable technologies. This chapter is organised in three broad sections: Section 2.2 presents the problem of energy poverty (following on from Chapter 1). The first segment of this section discusses the energy poverty definition at household and population levels. The second segment examines the major dimensions of energy poverty and influencing factors in a selection of developing countries. Section 2.3 develops a framework, which is used in this study to better understand the problem identified in 2.2. The first segment of this section presents a concept of the energy system in relation to energy poverty and transition. The second segment introduces two prominent models used to explain energy poverty and energy transition in developing countries, namely the energy ladder model and the stacking model. The chapter then argues that combining the two models into a single model can better explain the challenges of energy poverty and barriers preventing transition to modern energy carriers in the context of the study area. Section 2.4 examines a potential solution for household energy poverty through adopting solar RETs. This section explores renewable energy potentials, particularly solar RETs, their drivers and barriers.

2.2 Energy Poverty and Key Factors Affecting Energy Transition

Section 2.2 focuses mainly on concept of energy poverty for both cooking and lighting. It looks into definitions of energy poverty, factors affecting major dimensions of household energy poverty in developing countries and energy models used for studying energy poverty and transition.

2.2.1 Revisiting Definitions of Energy Poverty

Energy poverty may be defined as 'lack of access to modern energy services' (Li et al., 2014). Bouzarovski (2013) describes it as: 'a set of circumstances: the inability of a household to access socially and materially necessitated levels of energy services in the home'. This definition implicitly focuses upon energy end-uses (such as lighting, cooking and heating) at the household level in developed countries, where well established energy systems have been in operation for decades. In another study, Day et al, (2016), adopt Sen's capabilities approach that allows inclusion of all local circumstances across 'different cultures and climates'. They refer to energy poverty as:

'an inability to realise essential capabilities as a direct or indirect result of insufficient access to affordable, reliable and safe energy services, and taking into account available reasonable alternative means of realising these capabilities' (pp. 260).

However, they noted that this definition fails to link small-scale (household) and large-scale-(community) energy problems. Reddy (2000), defined energy poverty as:

'the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe, and environmentally benign energy services to support economic and human development' (pp.44).

All of the above definitions tend to consider energy services at the household level and to some extent include associated socio-economic benefits. However, they all fail to recognize the other components of the energy system, namely energy sources and carriers. These two components are indispensable in delivering energy services, which relate to energy poverty phenomenon in developing countries. Reddy's definition seems to capture most aspects of the previous definitions, e.g. 'access', 'adequate' and 'energy services', however, fails to consider 'availability' and other factors influencing choice, such as energy carriers.

Contextualization of an energy poverty definition based on energy carriers (their availability) could allow us to categorize the energy poor and thus explore solutions. In order to address the problem of energy poverty at any scale (household or region), there is a need to come up with a concise definition which reflects the major parameters affecting a particular component of an energy system. For example, energy poverty understanding and definitions in the developed world focus centrally on how to make energy services more affordable to vulnerable homes (for example see: Moore, 2012; Middlemiss & Gillard, 2014).

Arguably, energy poverty in the developing countries is not just about the price of energy services. Studies of energy poverty in developing countries should therefore extend to consider energy carriers within the energy system. This is crucial since it will help us to define the term 'energy poverty' (or fuel poverty) in relation to the availability of these carriers, in other words, who are the energy poor and who is responsible for eradicating energy poverty.

To this end, a definition of energy poverty in developing countries such as Nigeria should be based on a proportion of a particular energy class used at household or regional scale. In addition, this study argues that energy poverty should be defined around the frameworks of the energy ladder and energy stacking models as further discussed in section 2.3.1. Further, this can also allow us to understand whether a transition has been made.

2.2.2 Factors Affecting Energy Poverty at the Household

The two major dimensions of energy poverty are lack of access to electricity, mostly for lighting, and lack of clean energy for cooking (OECD/IEA, 2010). These dimensions are influenced by many factors, particularly household socioeconomic and socio-demographic ones. This has been documented in the vast majority of household energy studies, particularly the cooking dimension (For example, see: Hosier & Dowd, 1987; Baiyegunhi & Hassan, 2014; Rahut et al., 2014; Mensah & Adu, 2015, and Bisu et al., 2016). In addition, some of these studies also observe that household socioeconomic factors also affect transition from traditional to modern energy systems.

2.2.2.1 Key Factors Affecting Energy for Cooking

As highlighted earlier, many empirical studies have previously investigated the relationship between socioeconomic status and energy use for cooking at household level. Specifically, household income level has been identified as the key factor that influences energy transition in most developing countries (Leach, 1992). Studies have shown that wealthier households use more modern energy carriers for cooking than poorer ones (Hiemstra-van der Horst & Hovorka, 2008; Bisu et al., 2016; Baiyegunhi & Hassan, 2014; Özcan et al., 2013; Hosier & Dowd, 1987). Hosier & Dowd (1987) observed the use of modern energy for cooking is not primarily dependent on householder's income, rather it is determined by availability. Leach (1992) noted that wealthy households in rural areas in developing countries tended to use more traditional energy carriers than modern ones. This implies that availability of affordable modern energy carriers can better determine the types of energy class used in rural areas of most developing countries than the energy price.

Another important socioeconomic variable found to determine household use of modern energy is level of education. Several studies have indicated that households headed by people with higher levels of education tend to use less traditional energy carriers than those with lower educational qualifications (Hyman, 1994; Chen et al., 2006; Abebaw, 2007; Lee, 2013; Guta, 2014; Baiyegunhi & Hassan, 2014; Ifegbesan et al., 2016 and Bisu et al., 2016). However, none of these studies considered the impact of informal religious education on energy carriers used for cooking, although, Sadath and Acharya (2017) found that their energy poverty index differed significantly among different religious groups in India. More research is required to explore how religious education corresponds to household use of energy for cooking with the formal educational system in the context of this study.

In addition, householder’s occupation also plays a crucial role in determining household energy use. Kersten et al. (1998) found that those employed in the civil service were more likely to use modern energy for cooking than other occupational groups in south-western Nigeria.

Other socioeconomic variables have also been found to have a varied effect on household energy use for cooking in different developing countries. For example, Özcan et al. (2013) found that older householders tended to use more modern energy carriers for cooking than younger ones in Turkey. This contradicts what has been found in Ghana by Mensah & Adu (2015) and Nigeria by Baiyegunhi & Hassan (2014) where older householders tended to use more traditional energy carriers than their younger counterparts.

Some researchers have found that tenants tend to use more modern energy carriers for cooking than owners (Ouedraogo, 2006 and Bisu et al., 2016). This contradicts other studies that have shown that self-owned households used more modern energy carriers for cooking than tenants (Abebaw, 2007; Baiyegunhi & Hassan, 2014). Household family size is generally considered to have a negative effect on use of modern energy carriers for cooking. For example, Rao & Reddy (2007), Baiyegunhi & Hassan (2014), and Bekele et al., (2015) all found that with increasing family size, more households tended to use more traditional carriers for energy for cooking in India, Nigeria and Ethiopia respectively.

High price effects on household energy for cooking, potentially, have negative impacts on transition to modern energy use in most developing countries. For example, low income householders in Brazil were found to be descending the energy ladder because of an energy price hike (OECD/IEA, 2006). Equally, the initial price of modern energy appliances for cooking having been found to prevent householders from using LPG for cooking in Kano State, Nigeria (Hyman, 1994).

Maconachie *et al*, (2009) noted that price and availability of resource were the fundamental factors behind domestic energy choice in Kano State. Their research also revealed a dramatic change (between 2002 and 2008) in energy usage with households. They found that household kerosene (HHK) had been replaced with fuelwood and that there was an intricate relationship between the rise of global oil prices and energy choices in the local context of their study area. However, between the last quarter of 2015 and the last quarter of 2018, the world has witnessed a historic oil price downturn. Consequently, it is necessary to revisit and revise this relationship.

2.2.2.2 Key Factors Affecting Lighting Energy

As has been observed, household energy for lighting has received less attention than energy for cooking in the discourses of the energy ladder and stacking models. Likewise, household energy for lighting has received less attention among academic circles in sub-Saharan Africa (Lay et al., 2013). Kerosene (a transitional energy according to the energy ladder) is found to be predominantly used for household energy for lighting in Kenya

(Lay et al., 2013). Likewise, Urpelainen (2016) found that kerosene is also widely used for lighting in Uttar Pradesh, India. However, more than 90% of users expressed their dissatisfaction with their energy situation.

Like household energy for cooking, household income plays a crucial role in promoting the use of modern energy carriers for lighting. Rahut et al. (2014) and Rahut et al. (2017a) found that wealthy households in Bhutan used more modern energy than poor households. In addition, head of household's education, gender and age were found to correlate positively with the use of modern energy carriers for lighting (Rahut et al., 2014). However, the scarcity of alternative modern energy carriers for lighting in rural areas was found to have more influence on the use modern and transitional energy carriers than the influence of head of household education and income in Malawi (Adkins et al., 2010).

In summary, what is missing from all previous studies (in relation to both cooking and lighting) is an understanding of the strength of relationship between these socio-economic variables and the three types of energy class used (traditional, transitional and modern). Moreover, exploring these relationships in relation to geographical differences would be equally important in terms of understanding of application of the combined model introduced in this thesis.

2.2.3 Barriers to Modern Energy Transition in Developing Countries

As has discussed in section 2.2.2, there are numerous factors and barriers that affect energy poverty and transition for both cooking and lighting at household level in developing countries. However, there are also similar barriers that prevent transition to modern energy class at national or regional levels.

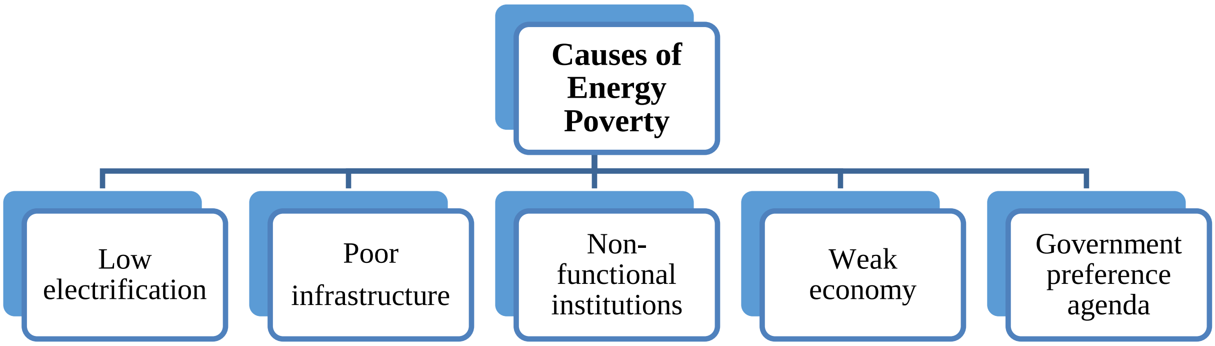

Figure 2. 1: Key Energy Poverty Causes in Developing Countries (Global South)

Source: Modified after Bouzarovski and Petrova (2015) and Muimun - Ecosoc (2014)

Figure 2.1 indicates that there is no single cause of energy poverty in the developing countries; it results from a combination of factors which vary according to different contexts as highlighted in the vast majority of the literature. It is worth noting that we cannot divorce energy poverty situations from external or internal factors at various scales (household, county/state, or country levels). These factors include the global energy market, government policy, income and culture.

Bouzarovski & Petrova (2015) have suggested that the primary causes of energy poverty in developing countries include low levels of electrification and other forms of networked energy provision due to economic under development, inadequate infrastructure and non-functional institutions (see Figure 2.1). These are the significant barriers that prevent developing countries from transitioning to modern energy systems. At household level, most researchers have found that low income prevents them from using modern energy carriers for both cooking and lighting (Hosier & Dowd, 1987; Leach, 1992 and Bisu et al., 2016). However, more research is needed in order to explore key barriers to modern energy services at household level in the developing countries, particularly SSA countries.

2.2.4 Consequences of Energy Poverty

The world's energy system is facing two challenges, namely, the depletion of fossil fuel reserves which poses a threat to security of energy supply, and over reliance on solid biomass as the primary source of energy in most developing countries (Raja & Abro, 1994). Dependence on biomass as a primary energy source has a great impact on climate and public health, either directly as a result of emissions of toxic gases to the atmosphere such as nitrogen oxide, sulphur dioxide and carbon monoxide; or indirectly as a result of uncontrolled deforestation (Muimun - Ecosoc, 2014). For example in Nigeria, the rate at which fuelwood is being consumed surpasses the rate of its replenishment (Bugaje, 2006a). Such unsustainable consumption has both ecological and socio-economic consequences. The health impacts of fuelwood e.g. smoke (indoor air pollution) are also significant, particularly on women and children (ECN, 2013).

Certainly, the combined effects of these impacts represent a great risk to our health specifically through indoor air pollution, and ecosystem sustainability as a whole. Indoor air pollution is one of the top ten health risks in the world and is clearly linked to the use of traditional energy carriers such fuelwood. It often known as the 'kitchen killer' disease as coined by the WHO. It was responsible for killing at least 1.5 million people in 2002 (WHO, 2006).

In its annual Energy Outlook, the International Energy Agency (IEA) reported that the existing scenario of world energy consumption fails to address either energy security or the three components of sustainability (IEA, 2006). This situation is likely to persist unless there are sound policies to tackle it (Chakravarty & Tavoni, 2013). However, most energy policies in developing countries are simply words on paper, and do not receive serious attention due to a myriad of problems that engulf these countries (Muimun - Ecosoc, 2014).

2.3 Energy Systems and Models of Energy Transition

To understand the problem of energy poverty and the barriers preventing a transition to the use of modern energy services at household or community level, there is a need to explore the components of the energy system. This will allow us to understand the nature of the problem and to propose solution(s) to energy poverty at local scales in relation to regional scales. The energy system has three major components, namely energy sources, energy carriers and energy services (González-Eguino, 2015). These components can be represented in a diagram as in Figure 2.2.

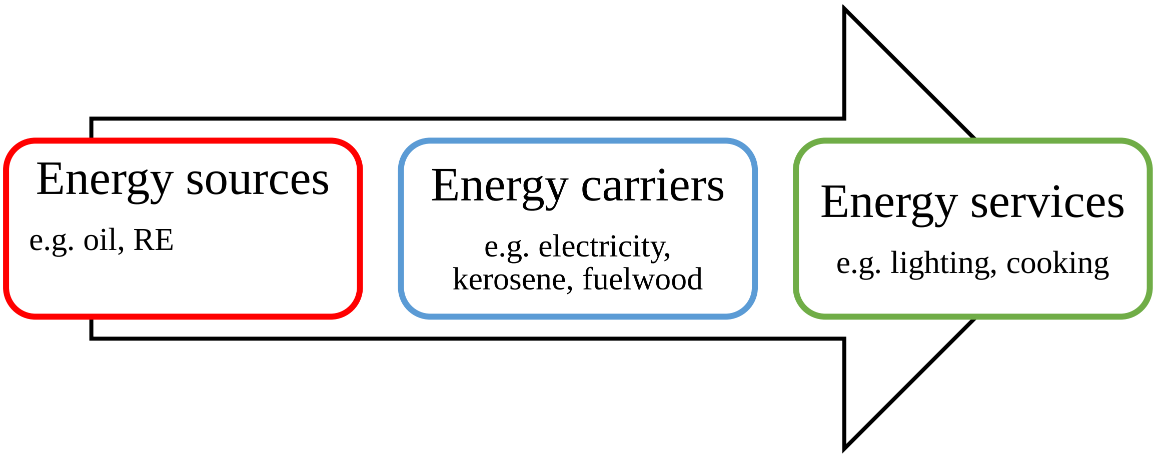

Figure 2. 2: Energy system components

As shown in Figure 2.2, energy sources can range from conventional sources (fossil fuels) to non-conventional sources (renewables). Based on conversion technologies and the quality of services generated, energy carriers from these components are largely classified into traditional and modern energy classes. However, a transitional energy lies between the traditional and modern classes.

Moreover, from an energy systems point of view, household energy services largely include lighting, cooking and heating, space heating, cooling and information and communication technology (Trace, 2016). Nonetheless, irrespective of the type of energy carrier, energy conversion systems are necessary for delivering the energy services.

It is worth stating here that energy sources may differ but essentially provide similar services. For example, traditional, transitional and modern energy sources provide light and/or heat, however, the quality and efficiency of the services differ. Energy quality and efficiency provide a basis with which to classify the energy systems into traditional, transitional and modern categories. For example, traditional energy systems for cooking include all solid biomass such as fuelwood, crop residue, charcoal and dried animal dung. The majority of sub-Saharan and south Asian households adopt this energy systems (Ritchie and Roser, 2018). Use of the traditional energy class in household energy system sometimes indicates a strategy against energy insecurity (Herington & Malakar, 2016). An example of such strategy has been demonstrated in Nepal, with the majority of households descending the energy ladder to traditional energy class (Herington & Malakar, 2016) as a result of scarcity of modern energy sources.

In contrast, modern energy classes include most liquid, cleaned energy sources. However, renewable energy sources can also be included within the modern energy class with the exception of biomass, which is conventionally classified as part of a traditional energy system (Ritchie and Roser, 2018). Thus, understanding energy poverty and barriers to transition for any given context requires a basic understanding of characteristics of the energy system in operation. However, this in turn requires an understanding of conceptual models of energy transition, such as the energy ladder and the energy stacking model.

These models have been used to study energy transition at the household scale and also for large geographical regions in many developing countries (Kowsari & Zerriffi, 2011, Zhang et at., 2016 and Muller & Yan, 2018).

As will be discussed in the next section, these models will be used as lens with which to view the energy poverty situation of households and larger geographical areas. In other words, this study looks at energy systems at the household level through the lens of the energy ladder and the energy stacking models. This is because both models acknowledge that there is hierarchical order (efficiency) between different energy classes in terms of their carriers as observed in previous studies.

2.3.1 Revisiting the Energy Ladder and Energy Stacking Models

There are numerous models that can be used to explain household energy poverty in relation to 'choice' and transition (Heltberg, 2004; Sovacool, 2014). The most popular among them are the energy ladder and energy stacking models (Figure 2.3). This section introduces these models, their central hypotheses, critiques, application and their relevance to this study. This study aims to adopt elements of these models to understand the energy poverty situation in Kano State and explore options for making the energy transition to solar RETs for lighting. These models will be used to explore characteristics of household energy carriers used for both cooking and lighting and the relationship between householder socio-economic status and energy carrier used for both cooking and lighting.

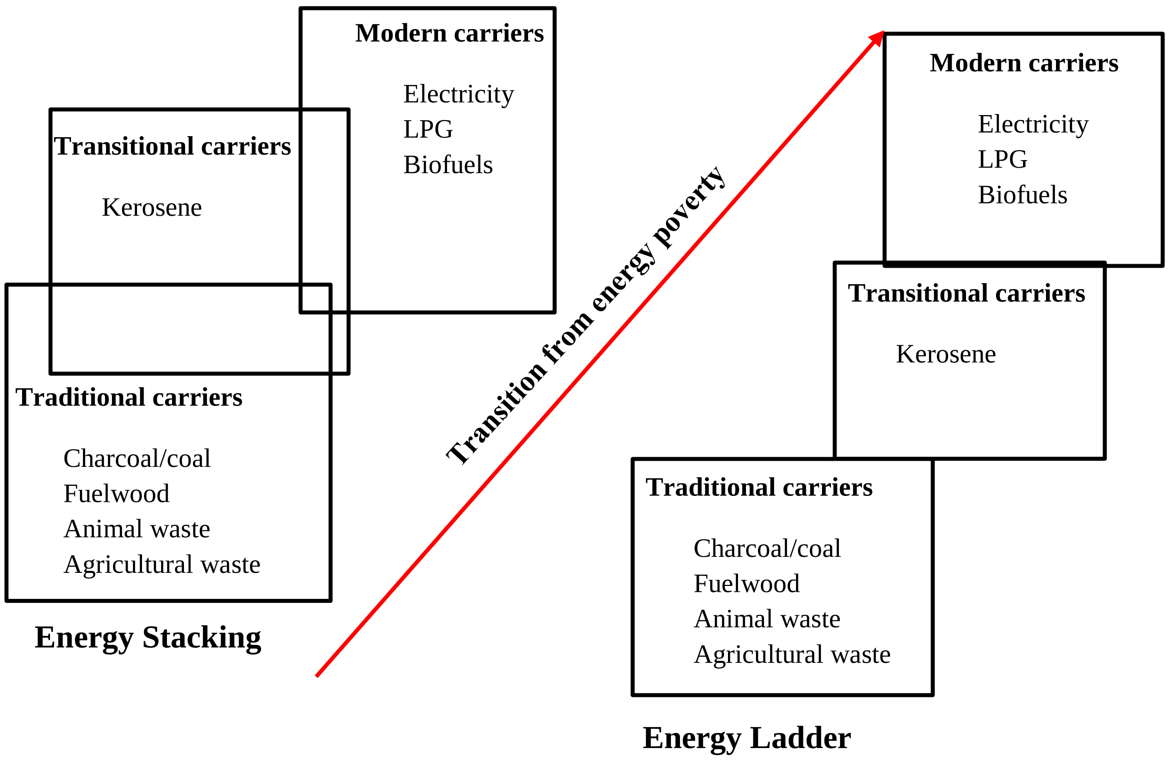

Figure 2. 3: The Energy Stacking and Energy Ladder Models

Adapted from Schlag & Zuzarte (2008); Herington & Malakar, (2016) and Leach, (1992)

2.3.1.1 Energy Ladder Hypothesis

The energy ladder is one of the key models that best explains transitions in household energy use in relation to household income. Its main premise is that income dictates transitions across the rungs of the energy ladder (Heltberg, 2004). This indicates that this concept is deeply rooted in economic theories (Hosier & Dowd, 1987). Indeed, the energy ladder places more emphasis on income than any other independent variable such as tradition, technology, climate, energy policy and, to some extent, energy context.

The basic premise of the energy ladder is that energy transition progresses from cheap, low quality sources such as animal dung, wood and charcoal to more expensive and high quality sources, such as electricity or natural gas as society develops (WHO, 2006); specifically, as household income increases. The bottom rungs of the ladder represent traditional energy systems which use low quality energy sources (e.g. animal dung, crop waste, fuelwood, etc.) and 'low technology conversion' with negative impacts on ecosystems. In contrast, the top rungs of the ladder consist of modern energy carriers and services which are classified as clean sources of energy (UNDP, 2000). Between the top and the bottom rungs there is zone of transition.

Over the last 30 years a number of researchers have adopted the energy ladder model to examine both community and household energy poverty and energy transitions in a number of developing countries (Hosier & Dowd, 1987; Masera et al., 2000; Heltberg, 2004; Ouedraogo, 2006; Hiemstra-van der Horst & Hovorka, 2008; Maconachie et al., 2009; van der Kroon et al., 2013; Mensah & Adu, 2015). The model assumes that the economic dimension is always the most important factor determining energy choice.

Some researchers have tested energy ladder's assumptions against economic indicators. For example, Hosier & Dowd, (1987) tested the validity of the energy ladder in Zimbabwe using National Household Energy Survey data in multinomial logic regression analysis. Other studies have used multinomial logic regression or other forms of regression, including Ouedraogo (2006) who investigated the relationship between household expenditure and factors determining energy choice in urban Ouagadougou, Burkina Faso. Similarly, Mensah & Adu (2015) investigated factors affecting household energy choice in Ghana using data from the Ghanaian living standards survey. Zhang et al., (2016) examined relationships between income growth and household energy transition in China using survey data from the Chinese government. More recently, Rahut et al., (2017) investigated factors determining household use of electricity in four African countries, using survey data from the respective governments of the four countries investigated.

2.3.1.2 Energy Stacking Hypothesis

The energy stacking model assumes that a household may use multiple energy carriers for cooking at the same time without abandoning the inferior ones. In other words, the central premise of the energy stacking model is that householders use their energy carriers interchangeably (Masera et al., 2000). This implies that a single household could use all three classes of energy (traditional, transitional and modern) interchangeably rather than a single class of energy in the ladder model. As revealed by findings from Zimbabwe, use of multiple energy carriers represents a 'coping mechanism' in response to other socioeconomic factors (Chirau, 2015). Likewise, findings from Brazil indicate that one of the reasons for adopting multiple energy carriers for cooking is that they can adapt in situations of energy vulnerability. This strategy provides some resilience to price and supply fluctuations (OECD/IEA, 2006).

It has been observed that the crucial factor determining energy stacking household level is income as is the case with the energy ladder (Kowsari & Zerriffi, 2011). However, the impact of increasing income on household energy transition differs between the two models. In the case of the energy ladder, an inferior energy carrier may be abandoned in favour of a superior one. In the case of the energy stacking, increased income simply indicates the addition of one or more energy carriers alongside the existing one(s) (El-katiri, 2011). Kersten et al. (1998) observed that use of multiple energy carriers in urban areas reduced the amount of traditional energy used in energy stacking. This situation might be more common in rural areas where access to modern energy carriers is limited as highlighted in Chapter 1.

Multiple energy users were found to spend more than single energy households in Mexico (Masera et al., 1997). This may be because those involved in stacking spend more on modern energy carriers, which are more expensive than other energy carriers. Income and other socio-economic factors also influence transition towards more use of modern energy carriers (Masera et al., 2000). However, in the energy stacking model use of additional modern energy carriers does not necessarily indicate a permanent switch (Masera et al., 2000), since these carriers are used interchangeably for different purposes and also due to other socio-economic circumstances.

Studies based on these models also acknowledge a hierarchy between energy carriers (for example see: Choumert-Nkolo et al., 2019; Bisu et al., 2016; Takama et. al, 2012; Nansaior et al., 2011 and Masera et al., 2000). However, such hierarchy and transition (observed in these studies) are yet to be comprehensively evaluated with respect to the energy stacking model. This may be due to a lack of methodological robustness in previous studies designed to capture the detail of primary energy carriers used within households.

The energy ladder is based on the assumption that a single carrier is utilized at a given transition stage. In contrast, the energy stacking model assumes multiple energy carriers are utilized irrespective of any increase in income (see Table 2.1 for more details).

2.3.2 Critiques and Application of Energy Ladder and Stacking Models

As highlighted earlier, both models have some weaknesses. Firstly, the energy ladder fails to take the sources and carriers of energy for lighting into account. Lighting is an important component of household energy systems which enhances commercial activities, education, health and the safety of people. Increase in income does not necessarily correspond to energy ladder's hypothesis, where a modern energy carrier replaces traditional or transitional energy carriers. Rather, the findings from Mexican study suggest that increase in income stimulates ‘accumulation’ of more energy carriers, rather than abandonment of existing ones (Masera et al, 2000).

In addition, Masera et al, (2000) noted that in some developing countries households on the bottom rungs of the ladder do not rely on a single energy carrier for their cooking, but multiple carriers at a time, sometimes interchangeably. This observation led to the development of the ‘multiple fuel model’, better known as the energy stacking model. Furthermore, the energy ladder fails to recognize rural-urban diversity or the temporal nature of energy consumption in the developing countries (Hiemstra-van der Horst & Hovorka, 2009). Moreover, the energy ladder represents a complex situation as a rather simplistic, linear relationship between income and household energy use.

Although, the energy stacking model better represents the household energy profile (Masera et al, 2000; Nansaior et al., 2011; Bisu et al., 2016), it has been poorly developed in relation to its ranking of energy carriers in regard to hierarchy of the 3 classes of cooking energy. In addition, the ‘substitution’ hallmark of the model has been empirically criticized. For example, findings from Maun, Botswana show that different carriers of energy were used for different forms of cooking (Hiemstra-van der Horst & Hovorka, 2008). This indicates that the notion of fuel substitution as claimed by the energy stacking model is also empirically weak. In addition, Zhang et al., (2016), argue that trends in household energy transition cannot be properly studied with the energy stacking model, because the ‘definition of transition becomes blurred’ in the energy stacking model. Likewise, application of the energy ladder model hypothesis remains ‘poorly understood’ (Cline-Cole & Maconachie, 2016, p. 169).

Recently, Choumert-Nkolo et al. (2019) attempted to improve understanding of energy transition behaviour for both energy for cooking and lighting in Tanzania, using the energy stacking model. However, this study suggests that the energy ladder model and the stacking model can be integrated to provide better understanding of household energy characteristics for both cooking and lighting without neglecting fundamental assumptions of either of the two models.

2.3.3 Building a Framework for Studying Energy Poverty and Transition

As indicated earlier, the energy stacking model was designed to improve on the weaknesses of the energy ladder model. However, looking at the complex factors which underline household energy use, researchers tend to develop more 'sophisticated' energy models in their studies (Muller & Yan, 2018). Nevertheless, use of sophisticated modelling could make the complexity of household energy profile and transition more distorted. This is because complexity tends to masked important details of household energy profile. However, this work intends to contribute to this debate by simply integrating the two models- the energy ladder and stacking. This can provide more realistic picture of household energy poverty in the developing countries.

Most empirical studies tend to reach generalized conclusions regarding the [lack of] applicability of either of the energy ladder model (Hosier & Dowd, 1987) or the energy stacking model (Nansaior et al., 2011 and Bisu et al., 2016). Despite this, there is still debate over the suitability of these models in understanding energy poverty and transition in the developing countries (Kowsari & Zerriffi, 2011; Zhang et al., 2016). The most appealing insight observed in the majority of the literature regarding the two models is that there has been lack of discussion as to how they may be combine, as proposed in this study.

Table 2. 1: Summary of the Energy Ladder and Energy Stacking Models Assumptions

Assumptions	Energy Ladder	Energy Stacking	Integrated Model: Energy Stack-Ladder
1. Income effects	Income	Income and other factors	Income and other factors
2. Energy carriers	Single	Multiple	Multiple and single (cooking & lighting)
3. Transition	Switching/ Displacement	Not well understood	Proportion of class (based on primary energy carrier)
4. Scale	Household and society	Household and society	Household and society

Source: Adapted after (Masera et al., 2000; Kowsari & Zerriffi, 2011; van der Kroon et al., 2013)

Through critiquing of these models (observed in this study as well as in the vast majority literature), it becomes apparent there is scope to integrate them. This *energy stack-ladder* framework assumes that a household or society uses, primarily, one energy carrier at a time as highlighted by the energy ladder model (see Figure 2.4). Likewise, a household or society can use 2 or 3 energy carriers in different proportions as highlighted by the energy stacking model. This study intends to improve on the energy stacking model's assumption regarding the number of carriers of energy used. Energy class hierarchy and ranking need to be visible in a revised model (Figure 2.4). Thus, the energy stack-ladder operationalizes energy carriers as classes in the following ways:

1. Energy for Cooking:

a. Traditional energy system/class: fuelwood, charcoal, animal dung and crop residue.

b. Transitional energy system/class: kerosene, and

c. Modern energy system/class: electricity and LPG.

2. Energy for lighting:

a. In line with the energy model proposed in this study, the traditional energy carriers for lighting are defined as kerosene/paraffin oil (used in a wick lamp) and candles. Traditional carriers provide poor levels of illumination, are hazardous to human health and more expensive than transitional carriers (Bensch et al., 2015).

b. Transitional carriers include battery and solar powered lanterns. Transitional energy carriers provide limited energy services; they are mainly use for household lighting (Kumar, 2015).

c. Modern energy carriers for lighting include the national grid, solar electricity and small scale generators. These provide high levels of illumination as well as other multiple energy services such as IT and communication, space heating and cooling.

It has to be acknowledged similar classification has been proposed by Choumert-Nkolo et al. (2019), however, such classification needs to be revisited and improved (for more detail see section 3.3.8).

Figure 2.4 presents the general framework for the energy stack-ladder used to describe energy classes in this study. However, detail of methodological framework will be discussed in the methodological chapter (Chapter 3). The model assumes that a household or community can use a single or multiple energy carriers at a time or over a period of time. However, with the regard to multiple energy carriers, there should always be a primary energy carrier that can be used frequently, due to socio-economic, socio-cultural or socio-political factors. Therefore, this primary carrier in the stack represents one of the three classes of the energy stack-ladder as presented in Figure 2.4.

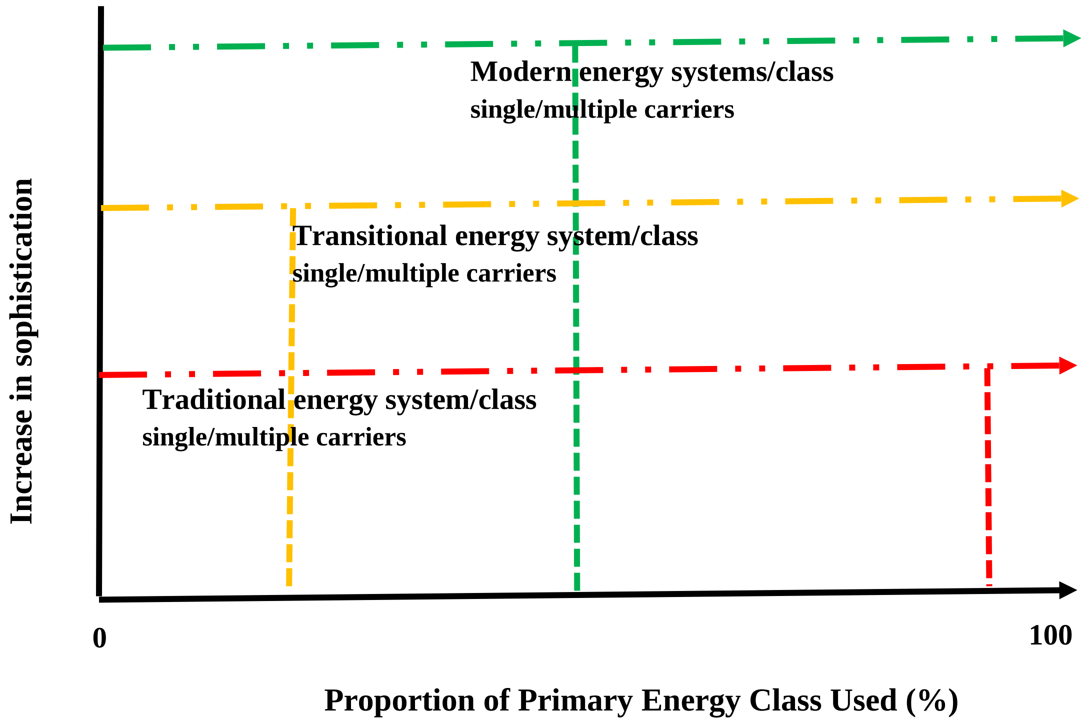

Figure 2. 4: An Integrated Energy Stack-Ladder (An example of energy profile for developing countries)

2.3.4 Conclusion

As has already been discussed in this section, the energy system model can be adapted to bridge the gaps in the energy ladder and energy stacking models. Most of the obvious gaps identified in the literature can be addressed by integrating the two models into an ‘energy stack-ladder’ in order to comprehensively represent both energy poverty and transition in the context of the study area. This can then be used to yield further contextual understanding of household energy poverty and barriers to transition for both energy for cooking and lighting in the study area.

2.4 Renewable Energy Solutions: Potentials, Drivers and Barriers

In Chapter 1 the problem of energy poverty was introduced for both cooking and lighting. The purpose of this section is to review the literature on renewable energy (RE) and its potentials for addressing challenges of energy poverty for lighting. This section of the review focusses specifically on potential solutions from solar renewable energy technologies (RETs). Section 2.4 is organized as follows; Section 2.4.1 presents a brief overview of benefits from using RETs. Section 2.4.2 presents different types of RE potentials and Section 2.4.3 examines global RE potentials for power generation. Section 2.4.4 examines Nigeria's solar potential for generating power in its three solar zones Section 2.4.5 explores the drivers for RE and solar RETs adoption in Nigeria. Section 2.4.6 examines the barriers to solar RETs adoption and barrier removal measures in developing countries. Finally, section 2.4.7, highlights area of further research in the field of solar RETs transition in developing countries. It argues that successful implementation of renewable energy strategy to remedy energy poverty is dependent upon a good understanding of contextual energy problems, stakeholder involvement and a viable resource base.

2.4.1 Benefits from Using RETs for Power Generation

Unlike non-renewable energy sources, renewable energies can be replenished, are clean and more environmentally friendly without harmful impacts (Panwar et al., 2011). The OECD/IEA (2014) indicate that RETs can be installed as part of a main grid or in form of a decentralized system. Decentralized RET systems are more viable in remote areas that are a long distance from central infrastructure. Sambo, (2009) noted that use of RETs for power generation could create job opportunities through empowering local industries in rural areas of the developing countries.

2.4.2 Different Types of RE Potential

RE potential for power generation can be broadly divided into five categories. (1) *Theoretical*: based on natural settings such as local climatic conditions; (2) *geographical*: this relates to physiographic conditions with restrictions based on biogeographical factors such as land use and land cover; (3) *technical*: this is the potential to obtain full access to RE resources, that is from geographical potentials, then convert to energy using different mechanisms; (4 and 5) *economic* and *market potentials*: these are RE resources that have been converted into a particular energy carrier that have undergone cost-benefit assessments (Hoogwijk & Graus, 2008). Researchers have mostly focused on technical or economic dimensions of RE potential. What is yet not yet clear is the impact of RETs on addressing energy poverty at the community or household level.

2.4.3 Overview of Global Renewable Energy Potentials for Power Generation

Renewable Energy (RE) refers to: 'free sources of sustainable energy, such as wind or solar energy that produce no negative impacts during conversion processes like the emission of hazardous substances' (Wee et al., 2012). There are number of different sources and forms of energy that may be used to address problems of energy poverty at different scales (e.g. household, community or region), and in different geographical settings. Wee et al. (ibid) identify five major sources of RE at the global scale: solar, wind, hydropower, geothermal and biomass. A further form of RE is energy from the ocean (Hoogwijk & Graus, 2008). These different forms of RE can undergo numerous conversion processes to enable different forms of end-use (see Table 2.2).

Undoubtedly, the global renewable resource for power generation is far greater than human demand. For instance, annual solar insolation is more than 10, 000 times higher than the amount of energy used in the commercial sector (UNDP, 2000). Nearly all forms of RE can be transformed into electricity using various RET options as summarized in Table 2.2.

Table 2. 2: Types of Renewable Energy Sources

Energy source	Power (technology)	Energy product (example)
Hydro	**1.** Hydropower (small and large scale combined)	**1.** Electricity
Solar Irradiation	**2.** Photovoltaic solar energy conversion (PV) **3.** Concentrated Solar power (CSV) **4.** Passive solar energy use **5.** Low-temperature solar energy use	**2.** Electricity **3.** Heat, steam, electricity **4.** Heat, cold, light, ventilation **5.** Heating (water and space, cooking, drying) and cold
Wind	**6.** Onshore turbines **7.** Offshore turbines **8.** Small wind machines	**6.** Electricity **7.** Electricity **8.** Movement, Electricity
Biomass	**9.** Combustion (domestic scale) **10.** Combustion (industrial scale) **11.** Gasification/power production **12.** Gasification/fuel production **13.** Hydrolysis and fermentation etc.	**9.** Heat (cooking, space heating) **10.** Heat, steam, electricity, CHP **11.** Electricity, heat, CHP **12.** Hydrocarbons, Methanol, H_2 **13.** Ethanol
Geothermal	**14.** Power production **15.** Direct heating **16.** Heat pumps	**14.** Electricity **15.** Heat, steam **16.** Heat
Ocean	**17.** Wave energy **18.** Tidal **19.** Osmotic **20.** Ocean Thermal Energy Conversion (OTEC)	**17.** Electricity **18.** Electricity **19.** Electricity **20.** Heat, cold, electricity

Source: Adapted from: Hoogwijk & Graus, (2008) and GEA (2012)

However, RE resources are not equally distributed across all locations. For example, it is unrealistic to expect high solar potential from the world's polar region, which, in contrast, is abundant in tropical/equatorial regions including savannah and desert environments.

Recently, there has been a significant increase in RE production around the world. Approximately, 150 gigawatts (GW) of RE were added to the power sector in 2015 (REN21, 2016). The solar and wind sectors witnessed considerable growth in 2015 (12% and 4% respectively) compared to other RE sectors. Furthermore, the current trend of investment in RE in developing countries is encouraging. For the first time in history the developing countries have demonstrated higher levels of investment in every sector of RE, except for large hydro, than the developed world. In addition, the price of RET has started to decline to affordable levels (UNEP Bloomberg New Energy Finace, 2016). This presents a significant opportunity for diffusion and adoption for RE by stakeholders and consumers alike. Nonetheless, the question remains as to whether the current RETs price fall can help remove barriers to adoption of these technologies in poor households and communities in developing countries.

Table 2. 3: Renewable Electric Power Global Capacity

Technology	**Installed Capacity (GW)** **REN21 (2016)**
Hydropower	1,064
Wind power	433
Solar PV	227
Concentrated solar thermal power (CSV)	4.8
Bio-power	106
Geothermal power	13.2
Ocean power	0.5
Total	**1,849**

Source: Adapted from: REN21 (2016)

Although solar RET adoption is thought to be increasingly in some developing countries, the exact number of adopters cannot be officially ascertained in most cases (World Bank, 2018). This might be due to availability of numerous appliances ranging from portable lanterns to solar home systems (SHS).

2.4.4 Nigeria's Solar Potential

As indicated earlier, Nigeria has significant solar resource potential which could be exploited through solar RETs for power generation, particularly in remote parts of the country where only LGA headquarters are connected to the grid (see Sambo, 2005). Solar RETs use two distinct technologies to generate electric current, photovoltaic (PV) cells and concentrated solar power (CSP). The PV implementation requires direct solar irradiance (light) which is then converted to electricity. This electricity is then stored before being converted from direct current (DC) to alternating current (AC). In contrast, CSP generates an electric current from indirect solar irradiance by creating steam and using this to power the turbine in the boiler (FMPS, 2006a).

Fortunately, Nigeria is endowed with abundant resources for both PV and CSP exploitation. Nevertheless, the solar potentials vary significantly between the north and south of the country (see Figure 2.5). For example, the average solar energy generation capacity in the far south, the coastal region is 3.5 $kWh/m^2/day$ while energy generation in the far east is 7.0 $kWh/m^2/day$. In addition, the total solar radiation for the whole country is estimated to be 17.439 TJ/day (FMPS, 2006a). It has been estimated that energy poverty in Nigeria can be solved using <1% of the solar energy falling on its vast land area (Bugaje, 2006; Sambo, 2009).

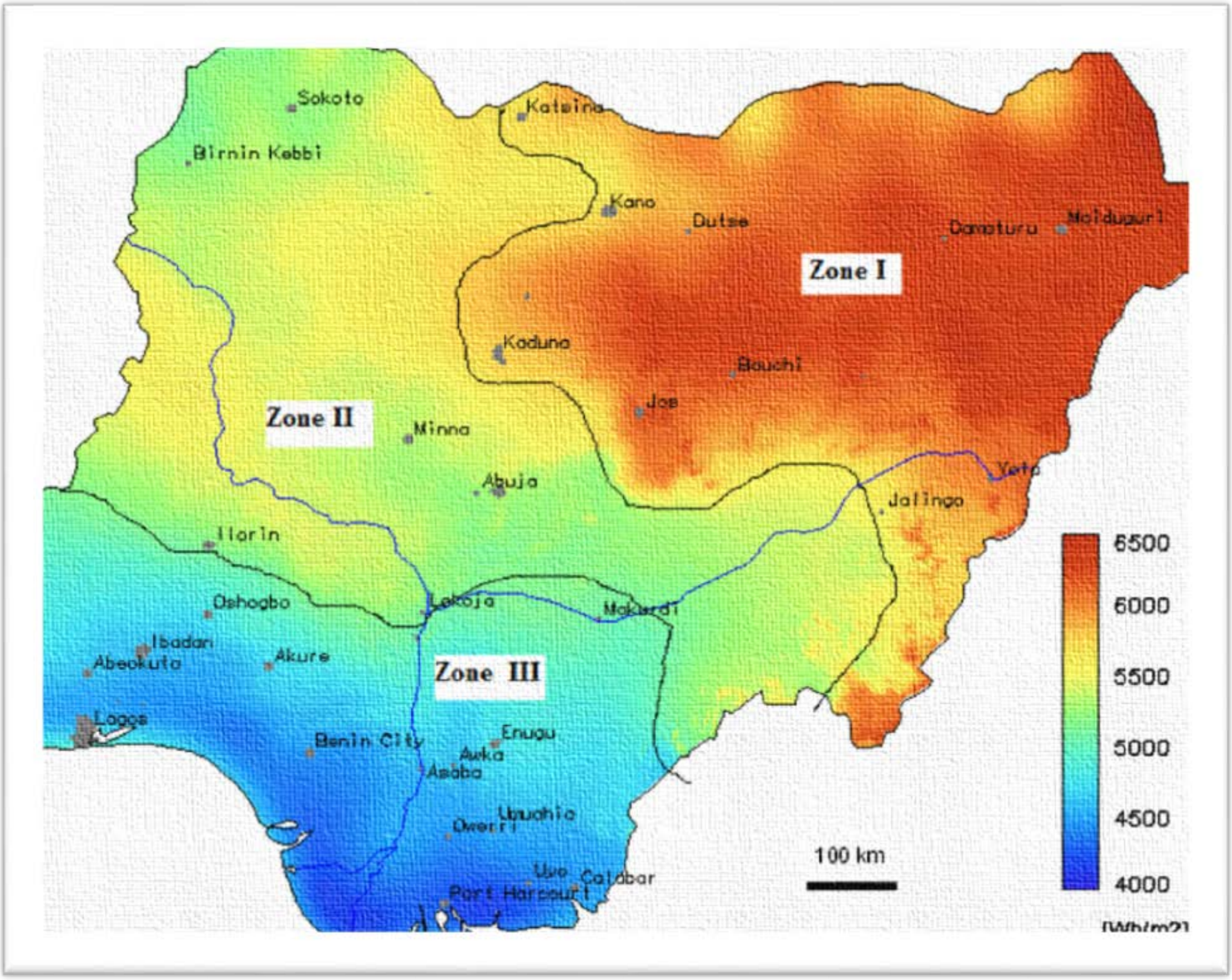

Figure 2. 5: Zones of solar radiation of Nigeria

Source: Huld et al, (2005) and Ohunakin et al. (2014)

The solar resource in Nigeria is further divided into three zones (Ohunakin et al., 2014). As shown Figure 2.5, Zone I comprises largely core north-eastern states and some north-western states including the research area, Kano state. This zone has an estimated solar irradiance ranging from 5500 to 6500 Wh/m^2 (5.5 to 6.5 kWh/m^2). Zone II, in contrast, has an estimated solar irradiance of 4500 to 5500 Wh/m^2 (4.5 to 5.5 kWh/m^2). This zone comprises large parts of north-west, north central and some parts of north-east Nigeria. Zone III comprises all southern parts of Nigeria; south-west, south-south and south-east and has an estimated solar irradiance of 4000 to 4500 Wh/m^2 (4 to 4.5 kWh/m^2).

Previous studies have confirmed that the northern states receive less fossil fuels e.g. for cooking (Naibbi & Healey, 2014), lower voltage electricity profile through the national grid (FMPS, 2006a) and have higher population and unemployment levels than other states (NPC, 2009). Consequently, these are drivers towards the adoption of solar technologies.

Apart from hydropower, solar RETs, especially PV, emerges as a viable candidate for energy for lighting especially in rural regions. Two decades ago there were few PV power installations in Nigeria - these PVs were used for rural lighting, water pumping and telecommunication projects (Adurodija et al,, 1998). Also, findings from previous studies in Nigeria suggest small solar RETs appliances were not popular (for example see Hyman, 1994 and Sambo, 2005). This might be because the solar market was not well developed and established.

However, in spite of its low installation capacity when compared to desired demand, solar technologies have been used in both rural and urban centres in Nigeria. For example, its use for rural electricity supply, street light in urban centres, solar water pumps and solar cookers have been well documented (ECN, 2014; Ohunakin et al., 2014). Unfortunately, most of the street light projects suffer from gang vandalism and lack of maintenance as is the case with national grid facilities. This highlights the need to finding lasting solutions from both government and community perspectives.

Solar RETs in Nigeria are broadly classified into off-grid and small appliance categories. The off-grid category includes pilot and demonstration projects funded largely by the federal government under the auspices of the Energy Commission of Nigeria (Ohunakin et al., 2014). Such projects are carried out by the Energy Research Centre, Usman Danfodio University, Sokoto State and National Centre for Energy Research and Development, University for Nigeria, Nsukka, Enugu State (Sambo, 2009). However, recent developments indicate that a number of large scale solar PV projects are underway which have been designed to link to the national grid. This is known as 'on-grid solar' and is mostly carried out by state government in partnership with federal government or external organisations within the European Union such as Germany, UK and France (Ley, Gaines, & Ghatikar, 2015).

In contrast, small solar appliances such as solar lanterns and rechargeable batteries for small businesses are widely patronized by both urban and rural dwellers (Ohunakin et al., 2014). However, these appliances are mostly imported from China. The Chinese solar RETs for lighting are cheaper than most alternatives, but are perceived as low quality products in many developing countries ((Müggenburg et al., 2012; Karakaya & Sriwannawit, 2015).

2.4.5 Drivers for RE and RET Transition in Nigeria

Nigeria is a country with varied geographical characteristics in terms of climate, vegetation, soils, hydrology and geomorphology. This gives it a unique opportunity to exploit its considerable RE potential for biomass, solar, wind and hydropower (Sambo, 2009). Nonetheless, biomass, such as fuelwood, is not a clean RE source. The most important RE source is the sun. It is the primary source of all energy sources prior to conversion, e.g. into electricity (GEA, p.773, 2012). Fortunately, Nigeria is located in one of the highest solar intensity zones in the world, particularly, the northern part of the country, as shown in Figure 2.5.

In spite of being the most highly populated country in Africa (more than 170 million), Nigeria only has an installed capacity of 6000MW electricity (from, largely, thermal gas stations and partly from hydroelectric power stations). The average output transmitted is about 4000MW (ECN, 2014). Even this has proven to be erratic as result of sporadic incidents of vandalism in the Niger-delta, water level fluctuations and technical problems as indicated by Ley et al. (2015) and ECN (2014). Moreover, Oparaku (2002) noted that the spatial coverage of the transmission network for the national grids was very low. This results in low supply of the so called available power, especially in remote areas.

A combination of such factors and the need to develop alternative energy sources to the national grid, pave the way for new thinking of harnessing available RE resources for electricity generation by some state governments and individuals alike. Furthermore, the existential threats facing the future of Nigeria's fossil fuels regarding its reserves' lifespan, demand and supply imbalance and environmental concern posed by climate change plus desert encroachment have forced the federal government to start incorporating RE into its energy mix projection (Inter-Ministerial Committee on Renewable Energy and Energy Efficiency (ICREEE), 2016). It can be observed that the main driver for RE transition in Nigeria is diversification of its energy supply (electrification), which may eventually improve access to electricity for over 90 million people that have no access to electricity (refer to 1.1.3 for more detail).

Electricity consumption in Nigeria is equally divided between the domestic and industrial /commercial sector. Despite a significant increase in electricity generation in Nigeria, from 1,273 GWh in 1970 to 28, 573 GWh in 2012, the country still faces major power shortages (ECN, 2014). This is because population increase has outpaced power production. This demand-supply imbalance could be addressed by using the available renewable energy resources.

In spite of such drivers, the renewable energy contribution to Nigeria's power sector (electricity) remains very small, representing only <1% of the total generating capacity as indicated by Federal Ministry of Power and Steel, FMPS (2006). In contrast, the use of energy from fossil fuels in all scenarios for electricity generation is quite high. This is clear when we consider Nigeria's RE target for 2025, which will be 10 % of total electricity consumption (ECN, 2014).

Table 2. 4: RE Resources Capacity and Utilization in Nigeria

Energy Sources	**Capacity**	**Utilization Level**
Large Hydropower	11, 250 MW	1,900MW
Small Hydropower	3, 500 MW	64.2MW
Fuelwood	11 million hectares of forest and woodlands (2014)	43.4 million tonnes of firewood/yr
Animal waste	243 million assorted animals in 2001	-
Municipal waste	30 million tonnes/yr (2014)	-
Energy crops and agricultural waste	28.2 million hectares of Arable land	8.5% cultivated
Solar Radiation	3.5-7.0kWh/m^2/day	15MW solar PV stand-alone No solar thermal electricity
Wind	2-4 m/s (annual average) at 10m height	2x2.5KW electricity generator; 10MW wind farm in Katsina

Source: Adapted from ECN, (2014) and Bala, (2014)

2.4.6 Barriers to Solar RETs Uptake and Barrier Removal Measures

The realization of RE potential from its theoretical stage to end-uses may encounter barriers. These barriers can be natural or artificial in nature (Verbruggen et al., 2010). Natural barriers include: resource distribution, climate, location, land use and land cover and resource flow fluctuation. Artificial barriers include: technology, market, capital, labour, institution and policy; and quasi-natural: land use and ecological interaction, building siting options (de Vries, van Vuuren, & Hoogwijk, 2007; OECD/IEA, 2014; UNDP, 2000).

Nevertheless, such barriers can be grouped into issues of technological robustness and the affordability from a consumer's perspectives (UNDP, 2000). For example, Müggenburg et al (2012) noted that the poor quality of solar appliances caused high levels of concern in relation to adopting them for lighting projects in Ethiopia. Consequently, solar RETs quality challenges might send a bad signal on their reliability and pose a great threat to future acceptance among local communities adopting these technologies. Both studies acknowledge that the solar appliances coming from China are cheaper than other alternatives, which are expensive and unaffordable for many households in developing countries. Urpelainen (2016) found that levels of awareness in Uttar Pradesh were very high, however, most of the solar appliances were being supplied China and perceived to be of low quality.

Despite recent reduction in the price of solar RETs over the last decade, initial capital has proved a major obstacle to adoption (Ohunakin et al., 2014). However, Reddy and Painuly (2004) criticized narrowing the RETs barriers to only economic or technological dimensions, suggesting that without stakeholder views, effective energy policies could never be accomplished. This suggests that barrier removal for RETs requires a holistic approach comprising of many parameters.

Another dimension of RETs barriers relates to awareness and policy intervention. It has been observed that lack of awareness by the consumers limits adoption of RETs in many parts of Nigeria (Adurodija et al., 1998; FMPS, 2006b). FMPS, (2006b) also noted that lack of RE policy promoting external investment in RE created a barrier to uptake in Nigeria. Moreover, the RE sector in Nigeria has suffered from inadequate fiscal funding and incentives for implementing full RE projects across the country. Basically, RE and RETs projects require large investment of capital not only in the initial cost of RE, but also in terms of maintenance, training personnel, research and development.

Consequently, lack of such support from government will have great impact on RE markets, foreign investment, security of supply (ECN, 2014).

Reddy & Painuly (2004) studied barriers to RETs in Maharashtra, India. Major barriers were technological, institutional and economic in nature. The authors employed a quantitative approach (multi-phase, stakeholder- based) to elicit information from various stakeholders regarding barrier removal measures. Indeed, understanding contextual barriers will be the first step for policy intervention in energy transition (World Bank, 2018). However, it is obvious that a quantitative approach can only provide limited information regarding the solar RETs barrier removal measures. Arguably, adopting a qualitative approach could provide deeper insights into drivers and barriers of solar RETs in the context of their research.

Recently, Aly et al. (2019) adopted qualitative techniques to investigate barriers to large scale solar power in Tanzania. They interviewed 30 stakeholders from different sectors. Their findings revealed that 'institutional' barriers were the largest obstacle to overcome. The government, or international organizations, traditionally implement large scale solar projects for rural electrification. However, small solar appliances and stand-alone systems have also played an important role in household energy for lighting in parts of sub-Saharan Africa (Bensch et al., 2015). This suggests that studies of solar RETs should consider both large and small scale projects. However, a major problem with RETs barrier-removal measures is the failure to match the contingent characteristics of the energy poverty problem with suitable RETs at the local level, especially in developing countries. This may necessitate further investigation on both energy poverty and evaluating solar power for its potential solutions.

2.4.7 Conclusion

This section has reviewed key literature in relation to renewable energy resource potentials and technologies that use RE to generate different forms of energy. It specifically focused on solar RETs for power generation. It highlighted the contributions of renewable energies for power generation at global, regional and national scales and revealed key drivers for solar RETs uptake in the Nigerian context. The most outstanding among these drivers are poor power supply and limited coverage of national the grid in rural areas.

This section has also highlighted various barriers preventing realization of RE potential. The RETs barriers differ across different geographical, social, economic, and political settings. Therefore, in order to address energy poverty in any context, it is necessary to capture the views of different stakeholders as suggested by Reddy & Painuly (2004). This study advocates the adoption of qualitative techniques in this information gathering exercise.

Chapter 3: Research Design

3.1 Overview

This chapter provides the foundation for all methods used in this thesis regarding the design for data collection, analysis and presentation. Quantitative techniques were used to examine household energy for cooking and lighting based on responses to household questionnaires issued across 4 Local Government Areas (LGAs) in both the metropolitan and non-metropolitan zones of Kano State. Qualitative techniques were used to explore drivers for solar adoption; barriers to uptake and prospects for reducing energy poverty for lighting. Interviews were conducted with 4 major stakeholders. The qualitative approach allows an in-depth understanding of barriers preventing solar RETs uptake (highlighted in Chapter 2) to be obtained.

The chapter is divided into 3 main sections: Section 1: synthesis; section 2: quantitative approach: household energy survey; Section 3: qualitative approach: solar energy stakeholder interviews.

SECTION 1: Synthesis

3.2 Synthesis: Quantitative and Qualitative Methods

This study adopts both quantitative and qualitative techniques for data collection in order to achieve the key objectives of this research. Pragmatic researchers adopt a specific research design to achieve their research goals without subscribing to any ontology or epistemology (Creswell, 2013). The quantitative approach was adopted to gather information regarding household energy for lighting and cooking, whilst the qualitative approach explored stakeholder views in relation energy transition using solar RETs. Further, the quantitative approach incorporated some aspects of solar RETs, using both closed-ended (972) and open-ended questions (108).

However, the primary goal of the two surveys of solar RETs was to identify the major barriers preventing their diffusion among households and to understand levels of acceptance. Thus, interviews were undertaken with key solar stakeholders in order to explore these barriers to uptake and identify appropriate intervention strategies. In other words, the findings from household energy survey were linked to the interviews with the solar stakeholders as shown in Figure 3.1. Thus, the outcomes from the datasets provided a subset of information regarding finding possible solutions for household energy for lighting.

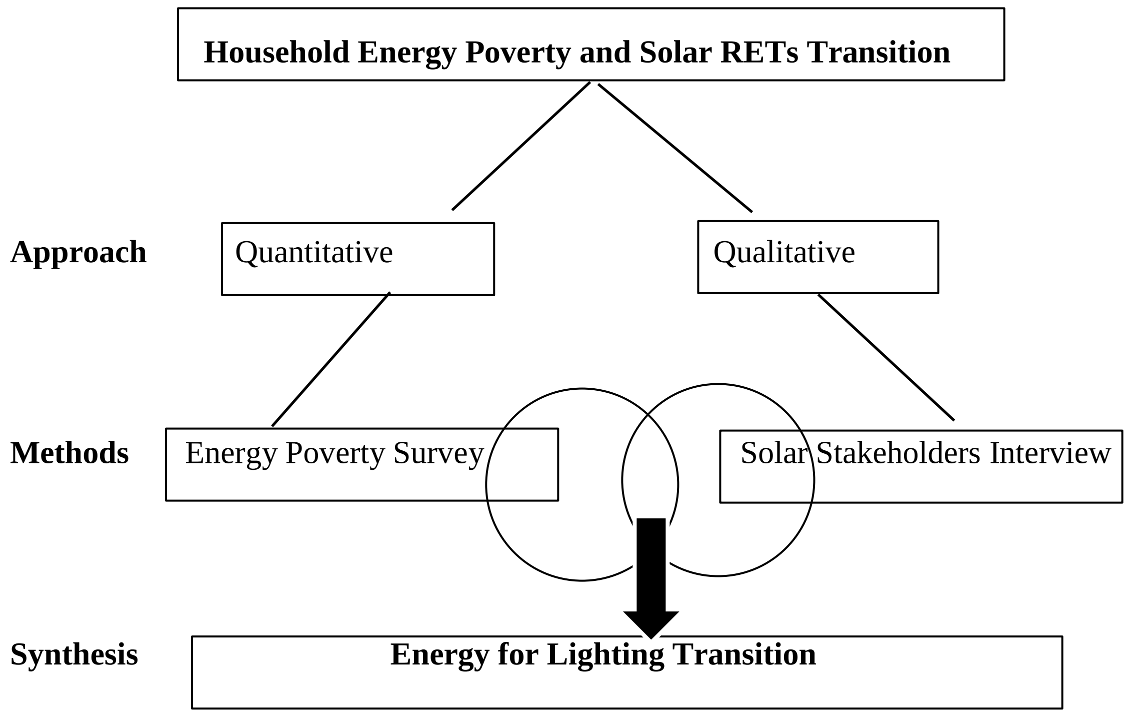

Figure 3. 1: Methodological Framework for Data Synthesis

As shown in Figure 3.1, the method employed in this study differs from many previous studies that adopted the energy ladder and energy stacking models to explore the use of energy for cooking. However, the aspect of energy for cooking is also included as shown in Figure 3.1 (in the energy poverty survey). This is significant in understanding the relationship between the dependant variable (energy use) and independent variables (householder's socio-economic status e.g. monthly income, education, occupation) in the context of this research.

SECTION 2: Household Energy Survey

3.3 Survey Design

The design of the household energy survey was informed by that of a pilot study conducted in the study area in 2016. Use of pilot studies is crucial in quantitative studies (van Teijlingen & Hundley, 1998). The pilot study presented an opportunity to consider what worked and what did not work, and new strategies for data collection. For example, the pilot study revealed problems with the backgrounds of the field assistants recruited to administer the survey. This was because the participants were suspicious of the pilot exercise which they associated with the government and its efforts to implement tax policy (see section 3.5). Nonetheless, this was addressed by recruiting a group of local field assistants in the main survey. The survey was primarily designed to determine the characteristics of household energy poverty, which in turn would feed into an evaluation of the energy ladder and energy stacking models as a means of exploring energy transitions at the household scale.

The survey aimed to address the following objectives:

Objective 2: To examine the characteristics of household energy poverty and the barriers preventing modern energy transition:

a) For Cooking

b) For Lighting

The survey involved the collection of primary data using an anonymous questionnaire. The questionnaire contains 4 sections relating to different themes. Each section comprised both fixed-response (with multiple responses) and opened-ended questions. The four sections were as follows:

- Section A: Basic Household Information: location, age, family size, housing ownership, number of rooms, educational attainment, occupation and monthly earnings.
- Section B: Household Energy for Cooking: energy sources, expenditure, cooking appliances, energy choice, energy transition, barriers to energy transition and solutions.
- Section C: Household Energy for Lighting: energy sources/appliances, duration of national grid/day, expenditure, energy choice, energy transition, barriers to energy transition and solutions.
- Section D: Solar Energy Technologies: solar RETs adoptions, types, barriers to adoption and prospects of solar RETs in addressing household energy poverty.

Questions related to energy carriers for cooking and lighting were deliberately formulated in order to allow ranking of energy use per household (see appendix I). These questions allow the basic assumptions of the energy ladder and stacking models to be tested. Furthermore, it allows the conclusions of others who have used these models in the developing countries to be reassessed. For more details on the questionnaires used during the survey see Appendix I.

3.3.1 Rationale for Conducting the Questionnaire Survey

Firstly, the questionnaires were designed to assess the assumptions of both the energy ladder and energy stacking models. These assumptions include the number of energy carriers (one carrier for the energy ladder model and multiple carriers for the energy stacking model). Also, ranking of the carriers provided opportunity to assign each stack to a particular energy class.

In order to operationalized this assumption, it is important to rank the primary energy used for both cooking and lighting (for more details see section 3.3.8). Furthermore, questionnaires were designed to explore the relationship between socio-economic variables and energy classes used for cooking and lighting. This was purposely designed in order to integrate the frameworks of these models. To date, this has been missing previous studies of household energy in developing countries. Secondly, the survey was adopted in order to have a reasonable representative coverage of the population and to draw valid conclusions (i.e. statistical generalization).

Nonetheless, use of questionnaire has both its advantages and disadvantages. One of the advantages of using a questionnaire includes its flexibility in accommodating different types of response such as fixed-response and opened-ended response questions as was the case in this study. It is also an important tool use to understand '*people's experiences, opinions,* attitudes, behaviour, and resilience and adaptations strategy' (McLafferty, 2010, p. 82). In addition, the last section of the survey aims to elicit participants' opinions on solar RET diffusion, adaptation and barrier-removal. The household survey enabled a useful data set for a large population to be assembled. Moreover, it serves as a supplement to secondary data, especially where there is paucity of comprehensive up to date information (McLafferty, 2010). For example, the latest official survey of household energy was conducted in 2006 (NPC, 2006).

In contrast, adopting questionnaires requires a significant amount of resource (time or money) to administer. Equally, outputs from questionnaire surveys can take a considerable length of time to code. In addition, the face-to-face approach of administering questionnaires is not always free from interviewer bias (McLafferty, 2010).

The importance of conducting a questionnaire survey in this study cannot be overemphasized, since the first component of this research seeks to gain a good understanding of strength and weakness of energy poverty models at household level in a particular geographical context. Thus, contextualization needs a wide range of information and broad coverage of participants as demonstrated in this study. Further, outputs from this type of questionnaire can be used to explain the models objectively, and to expand understandings of energy poverty phenomenon and transitions to modern energy carriers.

3.3.2 The Study Area

Kano State is located 12^0 02' N and 8^0 30' E at an altitude of approximately 450m above sea level (Sambo, 1986). It experiences a tropical dry climate (Okoye et al., 2016) and has Sudan savannah vegetation (Lynch et al., 2001). By virtue of its geographical location, Kano State enjoys high solar intensity, falling within the highest solar potential zone in Nigeria (Ohunakin et al., 2014). This is crucially important in exploring barriers preventing the adoption of solar technologies to address household energy poverty, particularly for lighting, in the study area.

Kano State has 44 local government areas (LGAs) spread across three senatorial zones. These are Kano North, Kano Central and Kano South (see Figure 3.2). These are political zones with distinct population and economic characteristics (NPC, 2010). Kano Central comprises metropolitan LGAs and is densely populated. In contrast, Kano North and Kano South are largely rural LGAs with lower levels of population and economic activity. The metropolitan LGAs are more connected to the national electricity grid (the main source of household energy for lighting) and access to modern energy carriers for cooking than their counterparts in the non-metropolitan zones. This variation was anticipated to play an important role in determining the composition of the final sample. Each LGA is further sub-divided into smaller geographical entities known as wards.

However, in spite of the stated distinctions between Kano Central and Kano North and South, there are some LGAs in Kano Central that possess similar attributes to LGAs in Kano North and South. For this reason, this research uses a simple Metropolitan and non-Metropolitan classification for sampling. Two broad clusters were adopted for data collection: Metropolitan LGAs and non-Metropolitan LGAs.

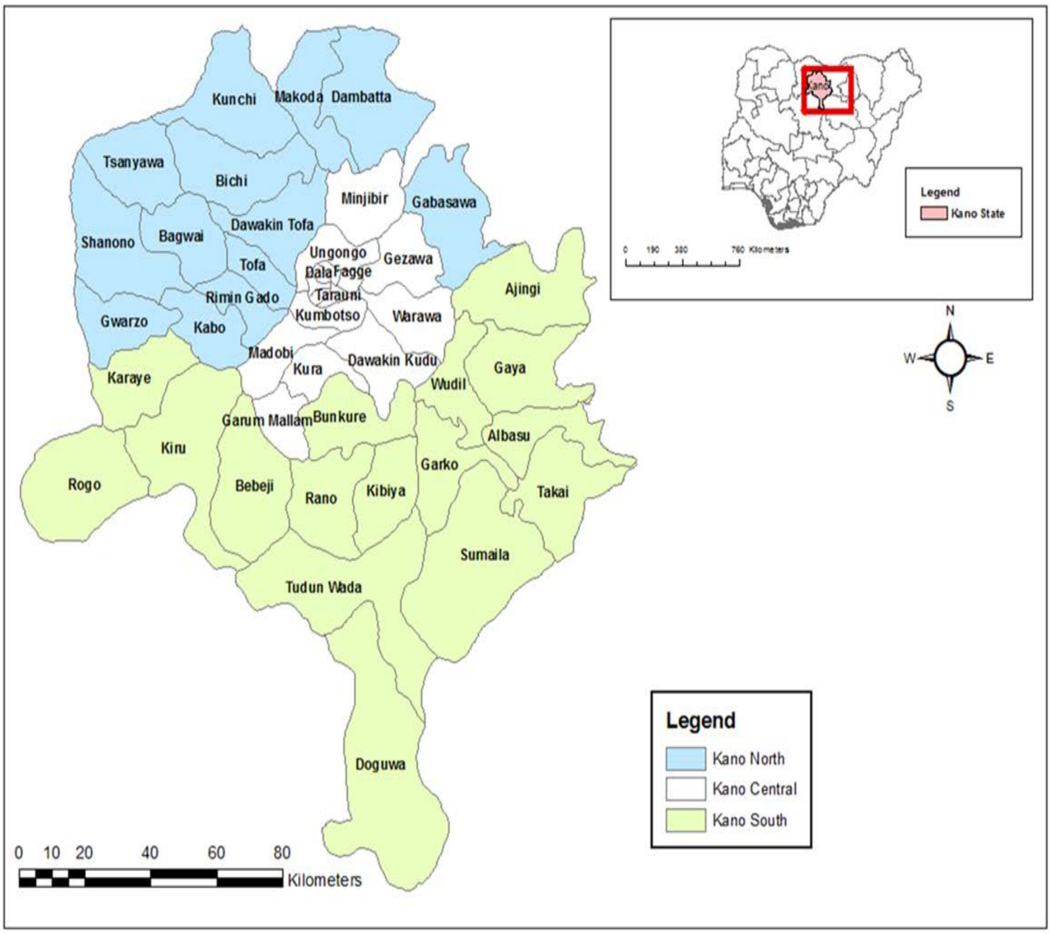

Figure 3. 2: Kano Senatorial Zones. Inset map shows Kano State in relation to the rest of Nigeria.

Source: Modified after NPC, (2010)

3.3.3 Sampling Techniques

The target population of this survey was the head of the household. It is worth stating here that data on the total number of households in Kano State is available at both state and LGA level, but not at ward level.

A simple random sampling method was employed to sample 2 LGAs from each zone (Metropolitan and Non-metropolitan). Further, 3 wards from the sampled LGA were also randomly selected. Random selection provides equal chance of selection within the sampling frames of both LGAs and wards of the two zones. Tables 3.1a and 3.1b indicate that the sample size was achieved at 95% confidence level (CL), 10% margin of error (ME) and at 60% estimated response rate. This ME may appear large, but is acceptable in an exploratory study where more understanding of a particular phenomenon is of paramount importance.

Thus, the final sample size calculation at LGA level is as follows:

Table 3. 1: Metropolitan LGAs

LGA	**Ward Name**	**No. of HH per LGA**	**Estimated No. of HH per ward**	**Sample size per selected ward (at 95% CL & 10% ME)**
1. Kano Municipal	Chedi Jakara Yakasai	53,303	53,303/13 = **4,100**	94 x 3 = **284** ≈90 x 3 = 270
2. Tarauni	Tarauni Daurawa Gyadi-Gyadi (S)	37,553	37,553/10 = **3,755**	94 x 3 = **284** ≈90 x 3 = 270
Total		**90, 856**	**7, 855**	**540**

Source: NPC, 2010

Table 3. 2: Non-metropolitan LGAs

LGA	Ward Name	No. of HH per LGA	Estimated No. of HH per ward	Sample size per selected ward (at 95% CL & 10% ME)
1. Makoda	Jibga Maitsidau Makoda	41, 285	41, 285/11 = **3,753**	94 x 3 = **284** ≈90 x 3 = 270
2. Ajingi	Balare Kunkunrawa Ajingi	32, 647	32, 647/10 = **3, 265**	94 x 3 = **284** ≈90 x 3 = 270
Total		**73, 932**	**7, 018**	**540**

Source: NPC, 2010

Total of number of HH per LGA: 90, 856 + 73, 932 = **164, 788**

Total estimated number of HH per ward: 7, 855 + 7, 18 = **14, 873**

Average: 14, 873/4 = **3, 718**

Total sample size per ward: 540 + 540 = **1080**

Therefore, the sample distribution for the metropolitan zone (**A** = 90, 856) was 540 and the sampling distribution for the non-metropolitan zone (**B** = 73, 932) was also 540.

A total of 1080 questionnaires were administered in this research. The information used to determine the sample size was derived from Survey Monkey (https://www.surveymonkey.co.uk/mp/sample-size-calculator/).

3.3.4 Sampling Strategies

A multi-stage sampling approach was adopted, combining both systematic and convenience sampling techniques. These sampling techniques can be used when dealing with a large population size, especially in a vast geographical area. They require application of probability techniques at each stage of sampling (Bryman, 2012). However, in a situation when dealing with rigid application of probability sampling can be problematic, as in this case where there is no comprehensive list of primary sampling units or the target population; a valid assumption may be used to address such shortcomings. The unit of analysis is the population of households in a particular zone.

The adopted sampling strategy may be summarized as follows:

1. Classify Kano State into Metropolitan and non-Metropolitan zones.
2. Select two LGAs from each class (using simple random sampling techniques).
3. Sample three wards from the selected LGAs using the same method above.
4. Estimate the number of households (HH) per ward (based on published figures reporting the number of HH per LGA). This estimate was based on the assumption that each ward would contain approximately the same number of households. For example, Ajingi LGA has 32, 647 households and 10 wards. Thus 32,647/10 = 3, 265 HH per ward. In reality, some wards have a higher number of households than others, however, such differences are insignificant if a sample size is above 1000.
5. Sampling the number of HH per ward (using online tools for sample size calculation). This stage determines the primary sampling unit (PSU) for this research.

3.3.5 Method of Delivery and Participants' Recruitment

The questionnaires were delivered with the help of trained field assistants (nine field assistants per LGA). This proved to be effective and efficient means of administering questionnaires, however, it took more than 8 weeks to complete due large number of questions included within the questionnaire (see appendix I and II). The field assistants were recruited from higher education colleges and universities. A training session was given to ensure high quality data collection. This was conducted to reduce the chances of interviewers making mistakes when administering the questionnaires face-face. Adkins et. al, (2010) used field assistants to read questions to the participants in his household energy survey. Likewise, the field assistants in this study were also trained to translate the English text into the local language (Hausa Language) for those that could not read or write.

The questionnaires were administered at ward level. Each LGA in Kano State has between 10 and 15 wards (INEC, 2013). The wards were numbered 1-15 and selected using a simple random sampling technique. As stated earlier, each of the four LGAs received 270 questionnaires. Thus, 90 questionnaires were issued to each randomly selected ward.

A convenience sampling method was adopted to select households at ward level. The target population was the head of the household. There was no comprehensive list of household addresses (number) at ward level. Hence, this necessitated the researcher (and field assistants) adopting a convenience sampling approach. Participants (householders) were recruited at a variety of locations including their houses, farms, markets, business places and public places. In addition, snowball methods were used for further recruitment. The questionnaires were administered face-face, as suggested by McLafferty (2010).

NPC (2010) provides definition of a household and its size as follows:

"a household consists of a person or group of persons living together usually under the same roof or in the same building/compound, who share a source of food and recognise themselves as a social unit with a head of household. It ranges from 1 - >25 persons" (NPC, 2010, p. iii). In the core northern states of Nigeria such as Kano, a household contains at least a couple (husband and wife) and may include their family and older relatives. The head of household is always a male. Thus, the questionnaires were administered to male householders. This was due to the religious and cultural norms of the context of the study area, which prevented the researcher and field assistants from getting direct access to interview female members of the households. However, it can be acknowledged that all household energy decisions are commonly taking by both female and male householders in the study area.

3.3.6 Methods of Data Analysis

As stated earlier, the aim of this component of the research is to explore the relationship between the constructs (dependent and independent variables). Thus, data gathered from the field was subjected to statistical analysis using SPSS version 22. SPSS includes many options for exploring relationships between two or more categorical variables (McKendrick, 2012), for example, a relationship between class of energy use and level of educational attainment at household level. There are some assumptions that must be tested before appropriate statistical tests are conducted (Creswell, 2013). In this study, non-parametric techniques, consisting of a simple descriptive statistic, cross-tabulation, recoding and Chi square were adopted. Data are presented as a series of tables, charts and graphs.

3.3.7 Data Entry and Coding the Questionnaire Responses

The returned questionnaires were numbered serially according to LGAs in both zones, and then entered directly into SPSS. All variables were defined (including missing values), named, and labelled on the variable view. The multiple response questions were coded with numerical values for statistical analysis using SPSS workspaces (data and variable views). In contrast, data from the opened-ended questions were categorized according to unique themes.

3.3.8 Cleaning Process and Recoding in SPSS

Data cleaning is an iterative process that includes logical checking and crosschecking of all entries. Other cleaning processes include sorting, recoding and splitting (Kent State University Libraries, 2018). All these processes were combined to provide a high quality and comprehensive database for analysis in this study. For example, in order to find out relationship between householder's income and class of energy use, data were sorted according to different income groups (see section 4.4.5) etc.

Data recoding is part of the data management and cleaning process. In addition, it allows data to convey message that is more meaningful at final stage of analysis (McKendrick, 2012). In this study, most of the responses from the field survey were recoded into different variables using an SPSS function. For example, there were more than 30 entries for both occupation and the combination of energy carriers used by the householders. Not all of these can be run through a cross tabulation analysis because of their large number of cases per each zone. Thus, in order to overcome such challenges, the raw data has to be recoded into manageable categories. For instance, householder's occupation was categorized into 3 major occupational groups: civil servant, business and farmer and 'others'.

One of the methodological contributions of this study is the recoding of the household energy carrier data (for both cooking and lighting). Responses from the household energy survey were recoded into 3 classes as prescribed by the model of the energy ladder (Heltberg, 2004). The questionnaire asked respondents to rank their primary, secondary, tertiary energy carriers for cooking and lighting. SPSS was then used to group responses into new variables (Bryman, 2012). This presented an opportunity to classify a particular energy class based on primary energy carrier ranked by a respondent. Further, it allowed the possibility of weighing both the assumptions of the models of the energy ladder and stacking in terms of number of carriers.

It is worth mentioning that these three energy classes are named after the primary energy carrier used by each household. This was achieved by first considering the dominant energy carrier used by a particular household. For example, to be classed in the traditional energy class a household must use one of the traditional energy carriers for the majority of their cooking or lighting requirements with other alternatives to a lesser degree. The number of different carriers used will then be counted for each individual stack.

Moreover, these 3 classes were used to explore relationship between household socio-economic status and primary energy carrier used for both cooking and lighting (see chapters 4 and 5).

It is worth stating here that the ranking system employed in this study does not indicate the percentage of each class of energy used by a householder, rather it indicates its frequency and importance as the major energy carrier used for either cooking or lighting. The order of the energy classification reflects the quality and sophistication of appliances used for cooking and lighting at household level.

3.3.9 Cross-Tabulation and Chi square Test

Cross-tabulation tests were used to establish the descriptive relationship between the dependent and independent variables. For example, the relationship between household income (independent) and energy class (dependent) was explored through this method. Cross-tabulation was also used to evaluate differences between metropolitan and non-metropolitan zones. There were some questions with multiple responses (more than 30) which proved not to be suitable for cross- tabulation analysis. This problem was overcome through data recoding technique (see section 3.3.8). This allowed the energy carriers to be combined into 3 classes (see section 2.3.1.1).

With the exception of Choumert-Nkolo et al. (2019) few researchers have conceived energy carriers according to 3 classes of the energy ladder. However, this study intends to further classify these energy classes based on primary energy carrier used by a particular household. In addition, this classification can be for both the energy stacking and the energy ladder models. Moreover, this was extended to operationalize the component of energy for lighting carriers as presented in Chapter 5.

This research adopted Chi square of independence in order to find out whether association were statistically significant. This type of Chi square is primarily used to test ‘association between variables'(Franke et al., 2012). Moreover, this Chi square differs from the conventional Chi square of goodness of fit, which tests differences and the Chi square of 'homogeneity', which tests 'differences in proportions' between more than one sample (Franke et al., 2012, p. 451).

$$X^2 = \sum_{i=1}^{n} \frac{(O-E)^2}{E}$$

Where:

n = number of cells

O = observed value

E = expected value

Therefore, for the Chi square of independence, a Pearson's value was adopted to satisfy the fundamental assumptions of the Chi square test for larger tables, namely that all expected frequency should exceed 5 or there should be ≥20% of all cells with expected value less 5. Fortunately, Likelihood ratios were used where any observation was found violating the Chi square's assumptions. Likelihood values are used for contingency tables with more than 2 rows and 2 columns (Field, 2013). Null hypotheses assumed no significant associations between dependent and independent variables and were tested at the 0.005 level of significance.

Chi Square in social research can provide a detailed explanation (that is beyond cross-tabulation) between two or more categorical variables (Mchugh, 2013). However, relying on the significance of a relationships alone, may concealed further details regarding, for example, the strength of such relationship.

3.3.10 Cramer’s V Test of Strength

Cramer’s V test was used to examine the strength of the association between the energy class and householders’ socio-economic status, energy satisfaction and power duration in both metropolitan and non-metropolitan zones. This is because the expected outcomes would go beyond only examining significant relationships, but to consider which among the relationship matters the most. Interestingly, Cramer’s V technique has the ability to capture the strength of a particular relationship between categorical variables with more than two categories (Field, 2013). This test is rarely used independently. It is more typically used following a Chi square test (Bryman, 2012). The Cramer’ V test statistic ranges from 0 to 1; zero indicates absence of relationship, while one indicates a strong relationship (Akanji, 2016; University of Toronto, n.d).

3.3.11 Response Rate

A total of 1080 questionnaires were administered across the four LGAs of the study area. Two were selected from the metropolitan zone (Kano Municipal and Tarauni) and two from the non-metropolitan zone (Makoda and Ajingi). This included a total of 972 closed-ended questionnaires and 108 closed and open-ended questionnaires. A total of 484 and 485 valid responses were received from the metropolitan and non-metropolitan zones respectively, for the closed-ended questionnaires. A total of 100 valid responses were received for the open-ended questionnaires. Overall response rates of 99.7% and 92.5% were achieved from the closed-ended and open-ended questionnaires respectively. This exceptionally high response rates were achieved because of the face-to-face method of questionnaire administration. Despite the high response rate, it is worth stating that not all participants responded to all questions as shown in the subsequent sections.

3.3.11.1 Household Income

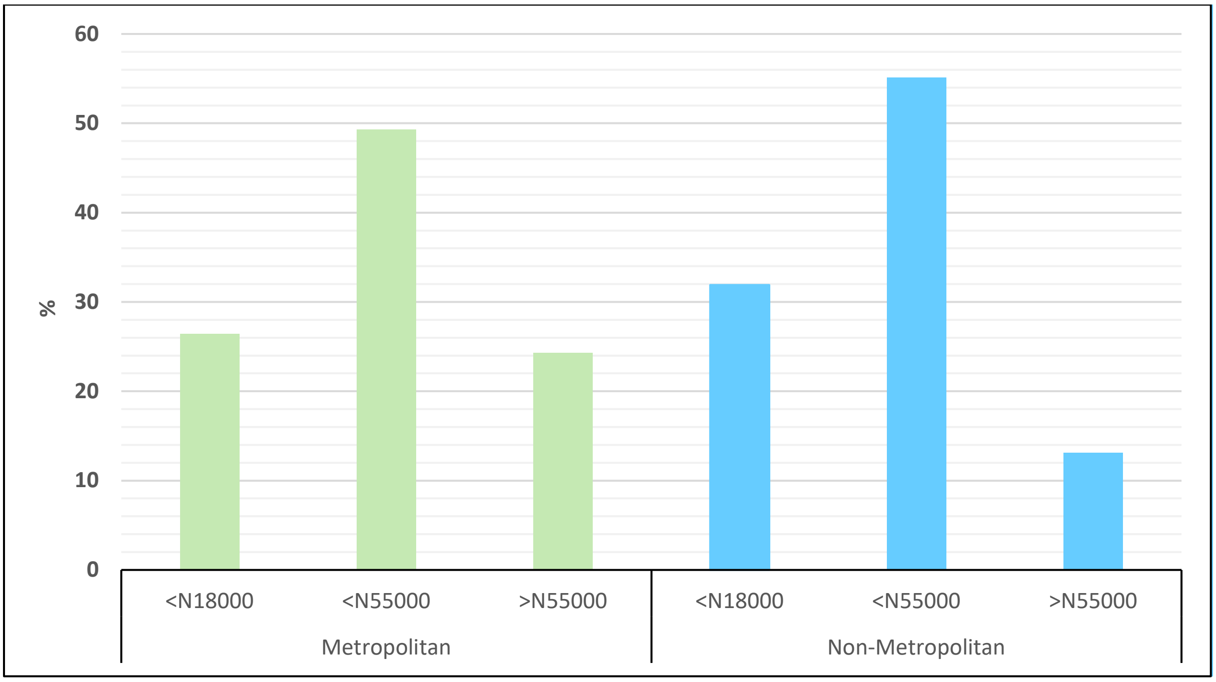

Figure 3. 3: Head of Household Monthly Income

Metropolitan: N= 428 (88.4%); **Non-metropolitan: N= 474 (97.7%)**

Source: Author's Fieldwork

Figure 3.3 indicates that the majority of the households in both metropolitan and non-metropolitan zones earned <N55,000 per month. In addition the figure reveals that the metropolitan zone has the highest proportion of high income households, >N55,000 (24.3%) compared to the households (13.1%) in the non-metropolitan zone. Moreover, the metropolitan zone has the smallest number of low income households, <N18,000 (26.4%).

3.3.11.2 Household Major Occupation

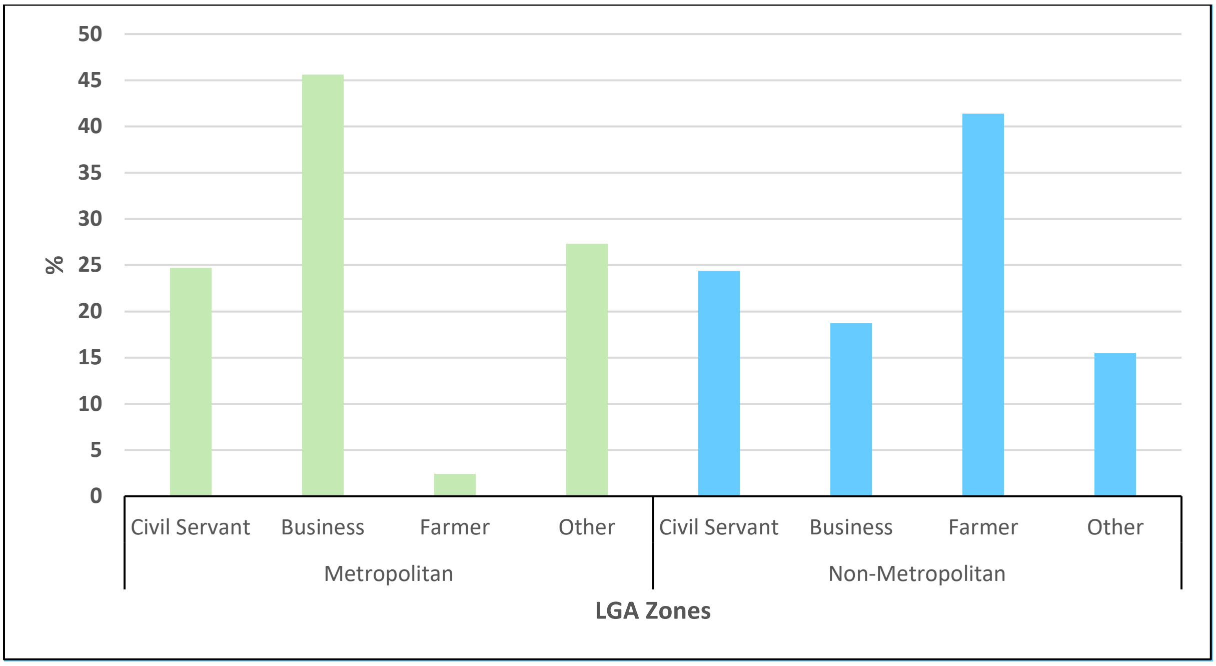

Figure 3. 4: Major Occupation

Metropolitan: N= 425 (87.8%); Non-metropolitan: N= 459 (94.6%)

Source: Author's Fieldwork

Figure 3.4 shows the major occupations in the study area. Three major occupations were selected with all other occupations classified into the 'other' category.

The results from Figure 3.4 shows that a sizeable proportion of the householders who responded to this question were engaged in business (45.6%) and farming (41.4%) in the metropolitan and non-metropolitan zones respectively. Unsurprisingly, Figure 3.4 shows that there were fewer households (2.4%) in metropolitan zones claiming to be they were farmers. More than 24% of the households in both metropolitan and non-metropolitan zones identified themselves as civil servants.

3.3.11.3 Family size

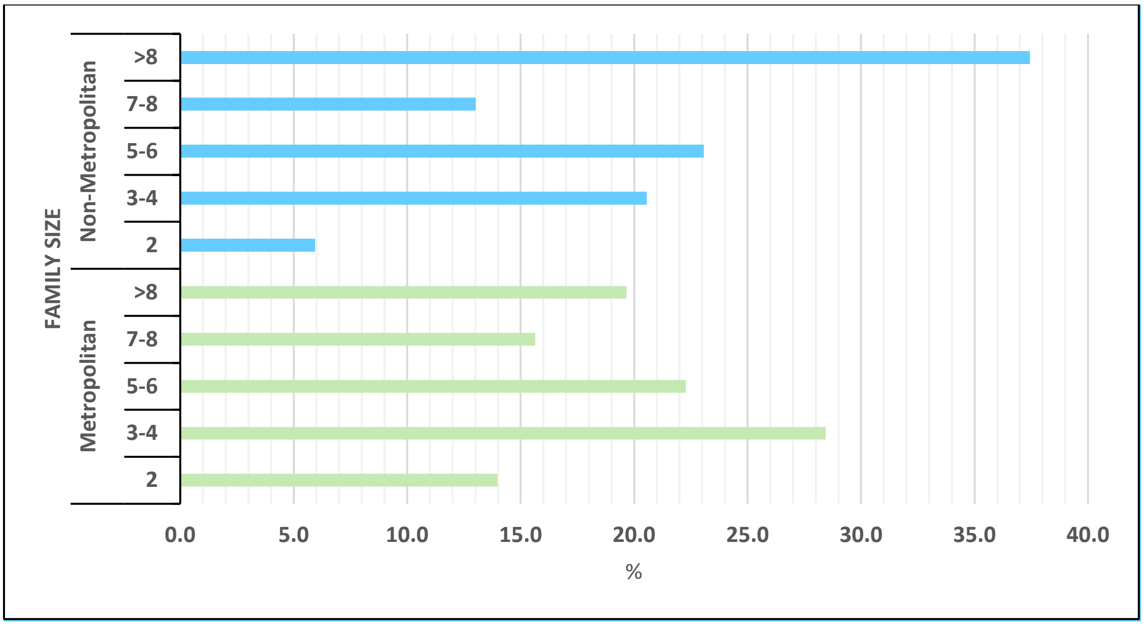

Figure 3. 5: Household Family size

Metropolitan: N= 422 (87.2%); **Non-metropolitan: N= 438 (90.3%)**

Source: Author's Fieldwork

Figure 3.5 shows 5 categories of family size. There are only slight differences in the distribution of family size between zones, however, striking differences exist in terms of households with larger (>8) and smaller (2) numbers of occupants. The non-metropolitan zone has a higher percentage of the largest family size and the smallest percentage of small family size. This difference may have a direct influence on the household energy class used for cooking, number of carriers, satisfaction or type of barriers.

3.3.11.4 Mode of Housing Ownership

Figure 3.6 shows 3 types of housing ownership in the two zones, namely: self-ownership, tenant and family house. A 'self-ownership' household is owner occupied; a tenant is a person renting a house while a family house is a type of household in which a male child (grew up and) established his family along with his parents. More than half of the respondents in the study area occupy their own houses, followed by tenants in both metropolitan and non-metropolitan zones as shown in Figure 3.6. Only a small number of respondents live in ‘family houses’. As also shown in Figure 3.6, the non-metropolitan zone has a higher percentage of family houses than the metropolitan zone. This suggests that a greater number of extended families live in the non-metropolitan zone than the metropolitan zone. This difference could also affect the household’s energy choice for cooking.

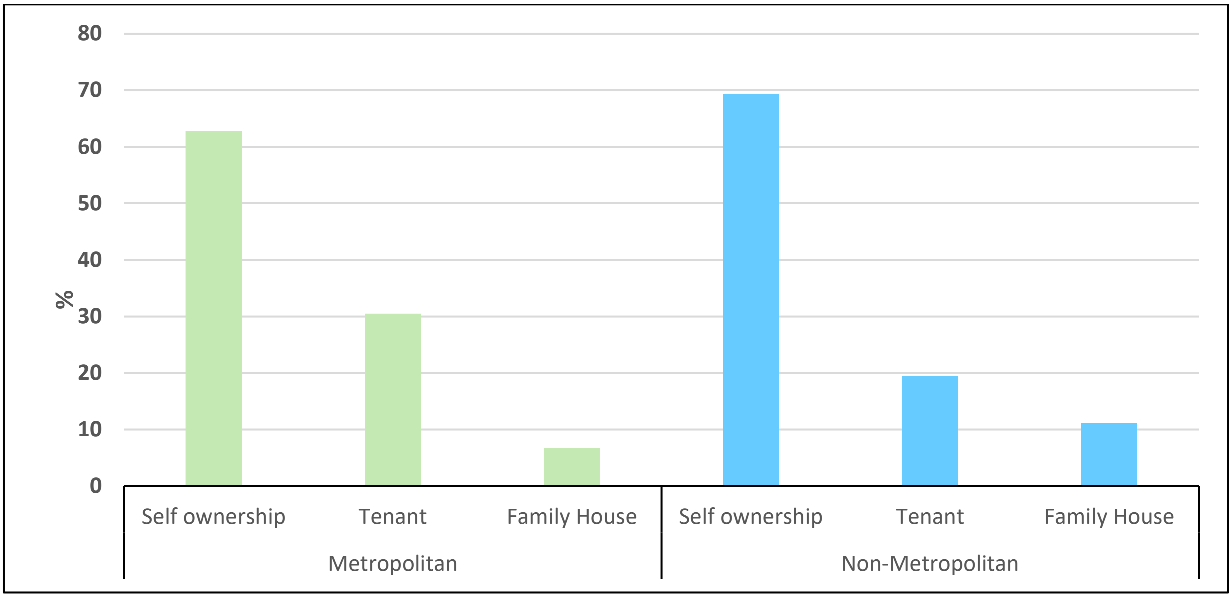

Figure 3. 6: Household mode of housing ownership

Metropolitan: N= 446 (92.1%); Non-metropolitan: N= 461 (95.1%)

Source: Author’s Fieldwork

3.3.11.5 Number of Rooms

Figure 3.7 indicates that there are only slight differences in the numbers of rooms per household for the two zones of interest. A sizeable number of houses in both metropolitan and non-metropolitan zones have 3 rooms.

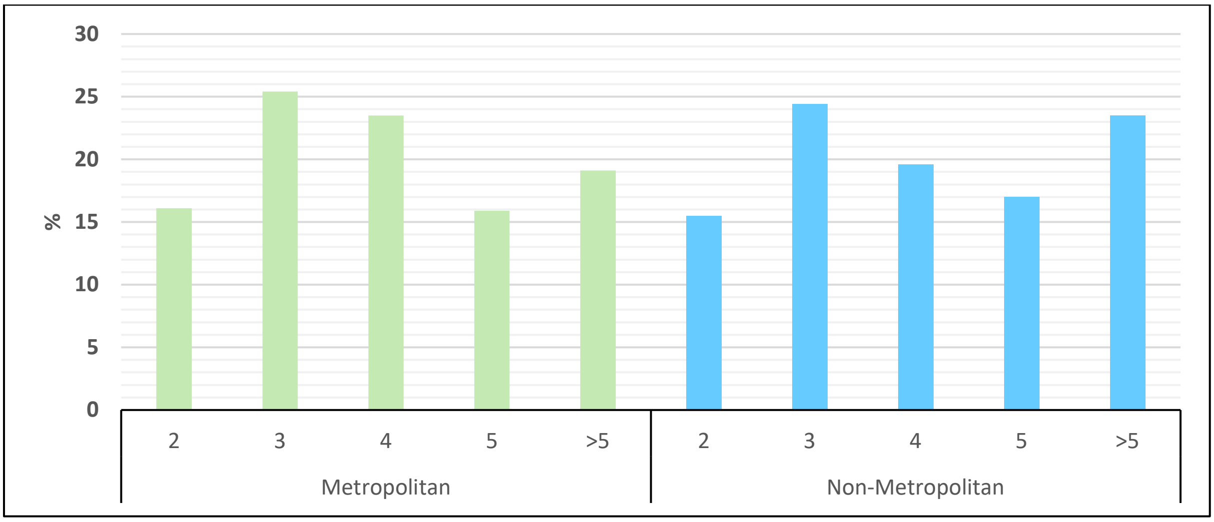

Figure 3. 7: Household Number of rooms, Source: Author's Fieldwork

Metropolitan: N= 460 (95.0%); Non-metropolitan: N= 464 (95.7%)

3.3.11.6 Education

As shown in Figure 3.8 many (45.2%) householders in the metropolitan zone have experienced higher education. In contrast, many (44.3%) of householders in the non-metropolitan zone have experienced Islamic education. This difference could impact upon choice of proportion of a particular energy system used for cooking.

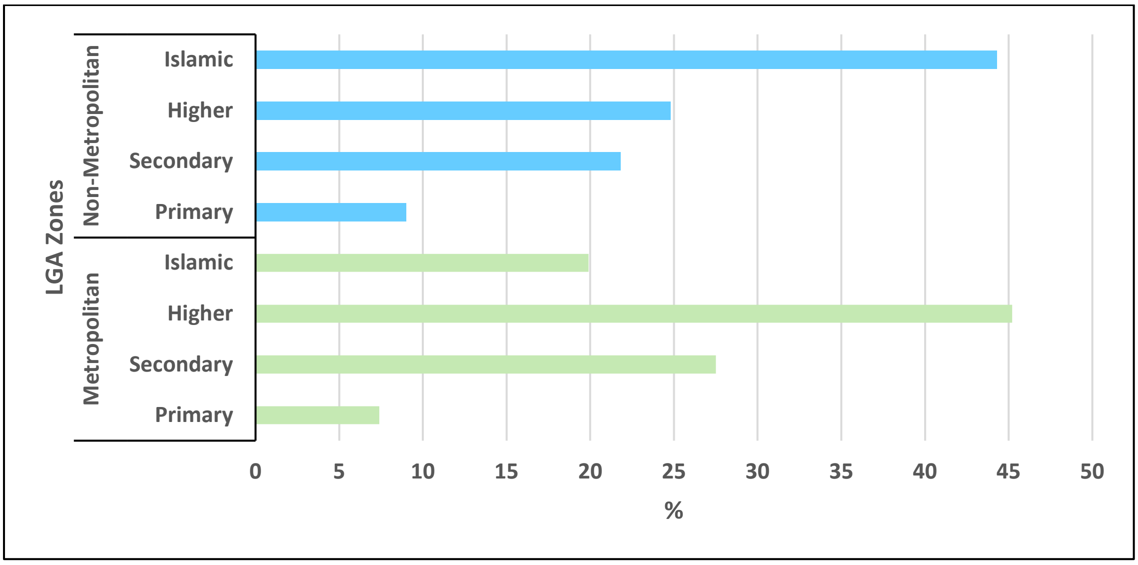

Figure 3. 8: Householders Level of Education, Source: Author's Fieldwork

Metropolitan: N= 462 (95.5%); Non-metropolitan: N= 476 (98.1%)

3.3.11.7 Age

Figure 3.9 shows the age groups of the respondents across the two zones. It is clear that the 31-40 age group dominates in both metropolitan and non-metropolitan zones. This suggests that most of the participants are young adults. In contrast, only a small percentage of participants are above 60 years in both zones. There is no apparent disparity among all age groups between the two zones.

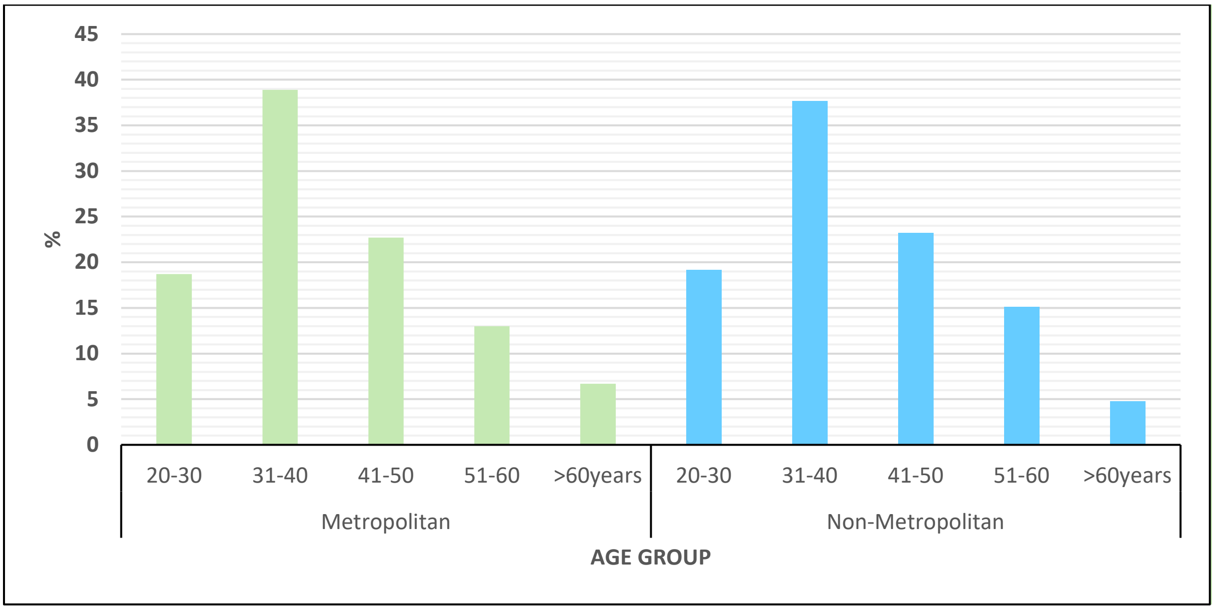

Figure 3. 9: Household Age Groups

Metropolitan: N= 476 (98.3%); Non-metropolitan: N= 478 (98.6%)

Source: Author's Fieldwork

To sum up, section 3.3.9 presents participants' socio-economic and socio-demographic characteristics. Some of these characteristics vary across the two zones whilst other show no clear differences. Such differences might have influence in determining the characteristics and proportions of primary energy classes used for both cooking and lighting in both zones of the study area (see Chapter 4 and 5).

SECTION 3: Solar Energy Stakeholders' Interviews

3.4 Solar Interview Design

Semi-structured interviews were designed to explore drivers and barriers to adopting solar RETs for energy for lighting and evaluate whether they could help alleviate energy poverty at household level.

Interviews were based on a pre-determined set of themes. Semi-structured interview techniques can be highly effective for capturing different theories or investigating a problem with multiple methods and can yield highly detailed information (Longhurst, 2010). However, the major drawback of semi-structured interviews is that power relations between the interviewer and interviewee can cause bias in response (Longhurst, 2010).

The interview comprises themes that have been identified in the literature such as drivers of solar RETs diffusion and adoption, barriers and barrier-removal measures, solar projects trends, stakeholders' role in solar RETs diffusion and prospect of solar RETs in addressing energy poverty (for more details, see appendix III).

The following stakeholders were interviewed during the fieldwork:

- 2 representatives from two federal government ministries
- 2 representatives from two state government ministries
- 11 Vendors or companies
- 4 Non-governmental organisations, NGOs (international/local)

3.4.1 Interview Justification

The reason for selecting the above stakeholders is that they are largely responsible for influencing solar RETs uptake to the public at different scales (FMPS, 2006; ECN, 2014; Sambo, 2009; Ley et al., 2015 etc.). Basically, the aim is not to replicate the data and make unacceptable generalization; rather is to understand the problem qualitatively using stakeholders' different views (Fereday & Muir-Cochrane, 2006; Longhurst, 2010). Outcomes from these interviews might help policy makers and other energy experts better understand key problems associated with solar RETs transition for lighting and intervention strategies for addressing them.

Other reasons behind the choice of stakeholders in this research were as follows:

- They were actively participating in solar RETs diffusion, research, marketing and policy formulation.
- They have acquired in-depth knowledge and experiences of solar RETs at various scales.
- Their specific views can help us infer acceptable generalizations and conclusions.

3.4.2 Participants Recruitment

As has been already indicated above, the stakeholders are broadly divided into 4 groups:

3.4.2.1 Federal Government Officials

Representatives from the Federal Ministry of Power and Steel (FMPS) and the Energy Commission of Nigeria (ECN) were purposely selected for interviews. These organisations have the responsibilities for formulating national energy policy and overseeing energy projects and energy research in Nigeria (Ley et al., 2015).

3.4.2.2 Sokoto Energy Research Centre (SERC)

A representative from the Energy Research Centre, Usman Danfodio University, Sokoto, Nigeria were purposely selected for interview. SERC has been a leading solar research centre in Nigeria for decades (Sambo, 2009). Therefore, an interview was conducted with a representative from this centre.

3.4.2.3 State Government Officials

It is widely known that there is a board overseeing power transmission in rural and some urban parts of Kano State. Electricity transmission is a primary responsibility of the state government through the rural electricity board (REB) (Sambo, 2005). An interview was therefore conducted with a representative from this board regarding current government activities in relation to solar uptake in the state. During the fieldwork, information was released regarding a memorandum of understanding (MoU) between the state government and Dangote Foundation for installing a 200MW solar project in Kano. This project aims to increase the electricity supply within the state.

3.4.2.4 Solar Vendors

A number of vendors (companies) were interviewed across Kano Metropolitan area. A snowball technique was used to identify additional relevant companies or vendors (Bryman, 2012). Eleven (11) solar RETs vendors participated in interviews. The reason for recruiting such a large number (compared to other stakeholders) is that they are the interface between the solar RETs consumers (the householders) and government projects.

3.4.2.4 Non-Governmental Organisation (NGOs)

Four NGOs were interviewed through convenience sampling technique for the purpose of this study. Unfortunately, not many NGOs were found to be promoting solar adoption, most were promoting alternative renewable energies such as biofuels.

3.4.3 Methods of Data Collection

Interviews were primarily conducted face-to-face, with the exception of the interview with an energy expert from the Sokoto energy research centre which was conducted via telephone. This was because the centre was engaged in strike action during the period of data collection. All interviews were recorded. Prior to the commencement of each interview, the participant was asked to read and then sign a consent form indicating his/her voluntary agreement to take part in the research. Each interview lasted for approximately 30-40 minutes. The whole exercise took 2 months to complete (See Appendices IV and V).

3.4.4 Data Processing and analysis

As already stated, interviews were recorded using a digital voice recorder. The recorded interviews were subsequently transferred to a laptop and stored in a secure folder. The interviews were then transcribed. Transcription involves the transformation of audio voice into text by software or manual processes (Bryman, 2012). Transcription in this study was conducted through a combination of transcription software ('Express Scribe') and manual means (i.e. listening word-to-word, pause/play and typing verbatim in word documents). The transcribed documents were crosschecked thoroughly with audio recordings before being thematically coded (Gormally et al., 2014; Fereday & Muir-Cochrane, 2006).

3.4.5 Interview Coding and Thematic Analysis

A code is defined as a 'descriptive or conceptual label that is assigned to excerpts of raw data in a process called coding' (Gale et al., 2013, p. 2). Two levels of coding were used during the data analysis: descriptive and analytical coding. The descriptive coding used a phrase from participant's word or a description of a salient meaning from data. In contrast, analytical coding goes beyond simply describing data to underlying meanings. These meanings may reflect an existing theory or may have relevance in building a new theory (Cope, 2010). Coding and theme generation can be conducted manually, or with the aid of software such as Nvivo. In this study all coding was conducted manually.

The interview transcripts were read and re-read thoroughly. Subsequently, the data extracts were coded deductively. Thematic deductive coding involves using pre-existing themes derived from the literature or theoretical framework (Braun & Clarke, 2006).

Numerous codes were coded inductively. This was because new unexpected themes were also generated (see Appendix IV for an example of codes Table). The combination of the two approaches (deductive and inductive) is known as hybrid coding (Fereday & Muir-Cochrane, 2006).

Braun & Clarke (2006) prescribed six steps for effective coding in qualitative thematic analysis. These are (1) familiarization with the data (i.e. after transcription), (2) coding, (3) theme generation, (4) theme review, (5) theme definition, (6) labelling and report (write up).Thematic analysis can be used to assess different worldviews, or different theoretical frameworks (Braun & Clarke, 2006). For example, one of the objectives of this study was to be pragmatic in finding solutions for household energy poverty for lighting using solar RETs. In other words, this study embeds a thematic approach in understanding household energy transition in a contextualized manner. The results and discussion from the thematic analysis are presented in chapter 6.

SECTION 3: Positionality, Limitations and Ethical Considerations

3.5 Positionality and Limitations

As a person who was born and grew up in the study area, I am an 'insider' and this helped me to set up the themes for the data collection easily. It also helped me understand energy landscapes at the household level for the two broad zones of the study area (metropolitan and non-metropolitan zones) prior to fieldwork. Equally, this helped when making decisions about who to select, for example, male head of household for survey, educational level categorisation and solar stakeholders. Moreover, data analyses and interpretations are also shaped by my past experiences. However, being and insider could also have its disadvantages for the entire research design and data interpretation. This includes overlooking some important themes in the qualitative data that might improve our understanding of the solar RETs barriers and transition in the context of the study area. Also, it might create atmosphere of suspicion among the research participants. Nevertheless, the researcher acknowledge the sensitivity of dealing with public officials, particularly on government projects.

During the fieldwork campaign it became obvious that not many of the solar RETs NGOs operated in the study area. Most of these were developmental in nature. An effort to reach some international NGOs was not successful as the multiple email sent to them received no replies. In addition, the pre-arranged meeting with the SERC in Sokoto State was not held face-face. However, this was overcome with the aid of telephone interview. This proved productive, because the intended objective of the interview was achieved.

Moreover, during the pilot study there was an element of suspicion among the local people in the study area. Some of them were sceptical about the study and thought that the researcher was conniving with the government in its effort to enforce new taxation schemes. Others anticipated payment from the researcher or the field assistants. Some of the solar RETs stakeholders were very suspicious of spying their activities, particularly those in government and marketing activities. However, suspicions and anticipations were overcome in a number of ways: by making formal introductions to village heads, recruiting indigenes of particular ward/LGA and by categorically letting them know that their participation in the research was voluntary and free (for the survey) and by recommendation (for the interviews).

Finally, challenges emerged when analysing the open-ended questionnaires, as some respondents provided little additional information to that acquired by the closed-ended questions.

3.6 Ethical Considerations

All data generated in the field during household energy survey was anonymized. As part of the requirement of university ethics, all research participant(s) were required to sign a consent form. However, it is not necessary in the case of anonymous surveys that participants have to sign a consent sheet (cf. FSTREC Lancaster). Nevertheless, each copy of the questionnaire carried a consent request which was completed prior to the survey taking place and all participants had the right to withdraw from the research at any point. However in anonymous survey research, participants cannot withdraw their data unless they can say so on the spot, since the response sheets will be anonymous after the exercise. The data generated were kept secured using encrypted and password devices.

Likewise, the data generated from the interviews were also made and kept anonymous and confidential, unless the participant wished to be named. Participants from interviews could withdraw from this research at any time up to the publication period as enshrined in the university ethical code. In addition, all their data recorded and transcribed were held with utmost security using encrypted and password devices (See Appendix V).

3.7 Conclusion

This chapter has described the basic components of research design used for data collection. The first component involve collecting data at household level using a survey techniques. This comprises closed-ended and open-ended questionnaires administered to the head of the household. The second component deals with gathering information from solar RETs stakeholders using semi-structured interviews. In subsequent chapters, the results obtained from the field will be analysed and discussed.

Chapter 4: Household Energy for Cooking and Barriers to Transition

4.1 Introduction

For decades, the energy ladder model has dominated the literature on household energy poverty and energy transition in developing countries (Hosier & Dowd, 1987; Leach, 1992; Schlag & Zuzarte 2008 ; Maconachie et. al, 2009; Rahut et. al, 2017). However, in recent years the model has received increased criticism (Masera et al., 2000; Hiemstra-van der Horst & Hovorka, 2008; van der Kroon et all., 2013; Chirau, 2015; Zhang et. al, 2016). This has led to the alternative, but related, energy stacking model (Masera et al., 2000). This model acknowledges use of two or more energy carriers at a time without abandoning the previous ones.

However, most of these studies have come to generalized conclusions regarding the [lack of] applicability of the two models. This study argues that such generalizability is problematic in assessing energy poverty and energy transition at community or regional levels in developing countries. In addition, most researchers have failed to consider the possibility that the two models may be combined.

The aim of this chapter is to examine the characteristics of household energy for cooking and barriers preventing transition to modern energy classes. In other words, this chapter will explore application of the integrated model through examining the characteristics of household energy cooking.

Outcomes from this chapter will be used to address the first objective of this thesis:

- To examine the characteristics of household energy poverty and the barriers preventing modern energy transition in Kano State, Nigeria.

This chapter focuses on four major themes: characteristics of household energy for cooking, the socio-economic impacts on types of energy used for cooking, energy satisfaction and barriers to using modern energy sources. The chapter is organised as follows: section 4.2 examines the characteristics of household energy carriers used for cooking based on the combined energy ladder and stacking model. Section 4.3 examines how the respondents' social status determines the class of energy used for cooking. Section 4.4 presents the findings of the respondents' level of satisfaction with different classes of energy use for cooking. Section 4.5 explores major barriers to adopting modern energy carriers for cooking. Finally, section 4.6 contains the chapter summary and conclusions.

4.2 Characteristics and proportions of Household Energy Classes for Cooking

This section presents the characteristics of household energy classes used for cooking. These characteristics include the number of carriers in each of the 3 different energy classes. The section also explores the proportion of each energy class used in each zone of the study area. The 3 energy classes and their associated carriers are as follows:

1. Traditional: fuelwood, charcoal, animal dung and crop residue
2. Transitional: kerosene, and
3. Modern: electricity and LPG

4.2.1 Traditional Energy Class for Cooking

Table 4.1 shows that 4 categories of traditional energy are used for cooking. The traditional class dominates in households in both the metropolitan and non-metropolitan zones. However, there is a big difference in terms of the number of households using a single carrier of traditional energy for cooking in the metropolitan (10%) and the non-metropolitan zones (35%). In the case of the non-metropolitan zone, the data shows that a sizeable proportion of households use a single-traditional energy carrier for their cooking. These findings suggest that traditional energy carriers (such as fuelwood and crop residues) are the most accessible energy class available to them.

Table 4. 1: Traditional Energy Class for Cooking

Number of Energy Carriers	Metropolitan (No. of HH)	Metropolitan (%)	Non-Metropolitan (No. of HH)	Non-Metropolitan (%)
1	50	10%	169	35%
2	185	38%	128	26%
3	58	12%	158	33%
4	1	0%	0	0%
		61%		**94%**

Contrary to a single carrier of traditional energy being used for cooking, Table 4.1 shows that the majority of households in both metropolitan and non-metropolitan zones use multiple energy carriers at a time. This could be the result of a combination of socio-economic, socio-cultural, socio-technical and socio-political factors. This will be explored in more detail in section 4.3.

Schlag and Zuzarte (2008) similarly note that numerous factors influence the use of multiple energy carriers in the developing countries. Bisu et al. (2016) found that 85% of families in Bauchi State Nigeria adopted a stacking approach for their cooking. They attributed such practice to scarcity of modern energy products and seasonal change. Bisu et al. (ibid) also noted that the highest level of stacking in their study area was four. This is closely related to the findings of this study where some of the householders used up to 4 types of energy for cooking (see Table 4.1). It is worth stating here that the ranking and counting of energy carriers in this study is innovative, and was absent in previous studies such as Odihi, (2003) Baiyegunhi & Hassan, (2014) Bisu et al., (2016). In addition, these researchers have not classified the carriers into the 3 energy classes (traditional, transitional and modern) as presented in the combined energy ladder and energy stacking model (see Figures 4.1 and 4.2).

Plate 4.1: Pile of fuelwood

Plate 4.2: Fuelwood in Three-stone stove

Source: Author's Fieldwork, 2016

Plate 4.3: Charcoal

Source: Author’s Fieldwork

Table 4.1 shows that 61% of households in the metropolitan zone and 94% of households in the non-metropolitan zone use one of the traditional energy carriers (fuelwood, charcoal and animal dung) as their primary energy carrier for cooking (see Figures 4.1 and 4.2). This result indicates prevalence of energy poverty in both zones. Similar trends have been observed elsewhere, where the majority of households in Nigeria rely on traditional energy for cooking (Sambo, 2005). Moreover, this finding suggests that use of traditional energy for cooking is not restricted to rural dwellers.

However, as indicated from the table, the severity of energy poverty in relation to cooking is more striking in the non-metropolitan zones. Odihi (2003), IEA (2006), Schlag & Zuzarte (2008) Nansaior et al. (2011) and Rahut et al. (2016) have reported similar findings in other developing countries. These findings correspond to the IEA’s findings that over 90% of households in rural parts of developing countries rely on traditional energy for cooking.

Overall, this traditional energy class for cooking is characterised by moderate levels of stacking in the metropolitan zone and high levels of stacking in the non-metropolitan zone. These findings reflect the availability of a range of traditional energy carriers, such as fuelwood, crop residues and animal dung in the rural areas of Kano State and the scarcity of modern energy supplies. Other researchers based in northern and southern Nigeria such as Hyman (1994) and Ifegbesan et al. (2016); and in Thailand: (Nansaior et al., 2011) and Botswana: (Hiemstra-van der Horst & Hovorka, 2008) have observed similar trends where householders use multiple energy carriers for cooking with one of the traditional energy carriers used as the primary energy source for cooking. In other words, primary energy use varies between households. As observed earlier, this depends on many other factors such as scarcity and price of modern energy carriers (Cline-Cole et al., 1988; Naibbi et al., 2014), energy policies (Odihi, 2003) and other socio-economic factors.

4.2.2 Transitional Energy Class for Cooking

Table 4.2 shows that there are only 2 levels of stacking related to transitional energy class used for cooking. Strikingly, very few (1%) of the non-metropolitan households use a single-transitional cooking energy carrier, whilst, in contrast the metropolitan households use all the 3 categories of transitional energy but in small proportion. Nevertheless, few households adopt this energy class across the study area. As highlighted earlier in section 3.3.9.3, the non-metropolitan zone has a higher proportion of extended families. This could hinder the use of kerosene or more specifically kerosene stoves as the primary energy carrier for cooking for a large family in the context of the study area (see Plate 4.3). Similar observations were made by Cline-Cole et al. (1988), Maconachie et al., (2009) and Naibbi (2013).

Table 4. 2: Transitional Energy Class for Cooking

Number of Energy Carriers	Metropolitan (No. of HH)	Metropolitan (%)	Non-Metropolitan (No. of HH)	Non-Metropolitan (%)
1	17	4%	2	0.5%
2	25	5%	0	0%
3	14	3%	0	0%
		12%		**1%**

Plate 4.4: Kerosene stove

Source: Author's Fieldwork

The relatively low use of transitional energy carriers in the study area contradicts the findings of Bisu et al. (2016) and Kersten et al. (1998) in the metropolitan zones of Bauchi State (northeast) and Osun State (south-west) of Nigeria respectively where kerosene makes up around 50% of their energy profile. In addition, they found that kerosene was the primary energy carrier used for cooking in their respective study areas.

Table 4.2 and Figure 4.1 show that 12% of the households in the metropolitan zone rely on kerosene, which has been classed as a transitional energy carrier from transitional energy class. In contrast, only 1% of households in the non-metropolitan zone use this type of energy (Figure 4.2and Table 4.2). This possibly reflects variation in the supply of kerosene between different geopolitical zones of Nigeria as suggested by Odihi (2003) and Naibbi & Healey (2013). Kerosene use is very low compared to other energy carriers from both traditional and modern classes. A plausible explanation for this is that kerosene is mostly used to ignite traditional energy carriers rather than used for cooking in its own right. This was also observed and acknowledged by Sambo (2005).

Furthermore, it is a well-known that the typically large family size in the study area discourages the use of kerosene in cooking activities especially during the ceremonial occasions (see for example Maconachie et al., 2009 and Bisu et al., 2016). Consequently, this indicates that low usage of transitional energy is directly or indirectly linked to a lack of compatibility between participants' culture (lifestyle) and their cooking appliances.

4.2.3 Modern Energy Class for Cooking

Table 4.3 show that households in the metropolitan zone used up to 4 categories of modern energy, in comparison to only 5% of households using up to 3 categories of modern energy in the non-metropolitan zone. As revealed by the data, household stack ranges from 2 to 4 carriers in the metropolitan zone. In contrast, only one type of stacking (three-modern energy) is observed in the non-metropolitan zone. Strikingly, the metropolitan households with modern primary energy carriers have higher levels of stacking than their counter parts in the non-metropolitan zone. Nonetheless, the number of energy carriers within the modern energy class is higher than in all other classes (traditional and transitional) in the metropolitan households. This may be because there is generally more choice of modern energy carrier in the metropolitan zones than in the non-metropolitan zones as shown in the table. Interestingly, Heltberg (2005) also found that nearly half of Guatemala's urban households used modern energy stacking compared to only one-quarter in the rural areas.

Table 4. 3: Modern Energy Class for Cooking

Number of Energy Carriers	Metropolitan (No. of HH)	Metropolitan (%)	Non-Metropolitan (No. of HH)	Non-Metropolitan (%)
1	25	5%	2	0%
2	56	12%	0	0%
3	45	9%	25	5%
4	4	1%	0	0%
5	1	0%	0	0%
		27%		**5%**

Overall, these findings indicate that there are higher levels of stacking of energy for cooking in the modern energy class than any other energy class, particularly in the metropolitan zone. This suggests that despite those householders identifying modern energy as their primary carrier for cooking, alternatives are used due to uncertainties around modern energy supplies (Herington & Malakar, 2016). This contradicts the findings of 4.2.1 where a lot of stacking of traditional energy occurs in the non-metropolitan zone.

Plate 4.5: Cooking gas cylinders, Source: Author's Fieldwork

Findings form Table 4.3 and both Figures (Figure4.1 and Figure4.2) show that 27% of households in the metropolitan zones use one or more energy carriers from the modern energy class as their main energy carriers for cooking. This contrasts with only 5% of households in the non-metropolitan zone. This indicates a wide gap between households in urban and rural societies in the study area. Similar findings have been reported by Baiyegunhi & Hassan for Kaduna State (2014), Nigeria, Mensah & Adu for rural-urban Ghana (2015), Heltberg for parts of Guatemala (2005) and Nansaior et al. for north-eastern Thailand (2011). Factors contributing to such disparity in the case of northern Nigeria include disparity of modern energy supplies, poor infrastructure, parallel market and smuggling to neighbouring countries (Hyman, 1994; Odihi, 2003).

Furthermore, the findings from this work suggest that these differences are attributed to a number of factors: scarcity of modern energy in the rural areas, households' education, income and occupation (see section 4.3.1 and 4.3.6).

4.2.4 Conclusion

Section 4.2 has presented an overall picture of energy carriers used for cooking in the study area from the 3 energy classes: traditional, transitional and modern. The results from this section show that the majority of households in the study area depend on energy carriers from either traditional or modern energy classes for their cooking, with the use of transitional energy minimal (see Figure 4.1 and 4.2). The energy profile for cooking is characterised by high use of traditional energy and a large amount of stacking in both metropolitan and non-metropolitan zones. Interestingly, this finding reflects the characteristics of energy use for cooking in most developing countries (Bisu et al., 2016; Ifegbesan et al., 2016 and Hiemstra-van der Horst & Hovorka, 2008). Further, this suggests that there are other factors affecting household energy choice that are not accounted for in the energy ladder model (Schlag and Zuzarte 2008).

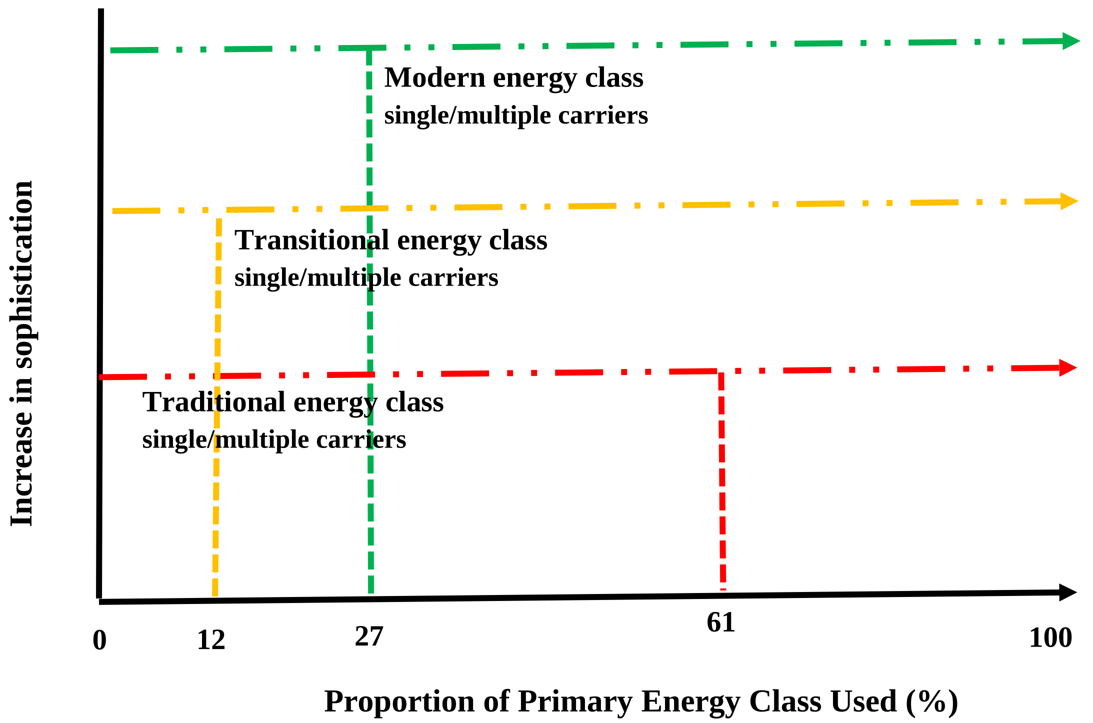

Figure 4. 1: An Integrated Energy Stack-Ladder for Cooking (Metropolitan zone)

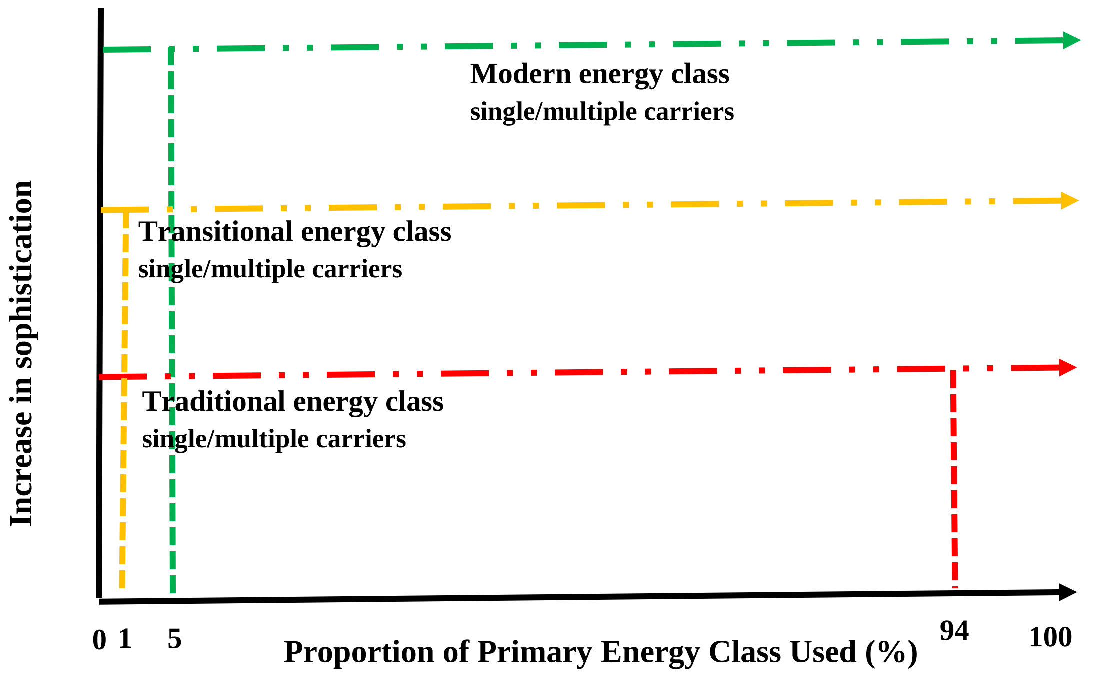

Figure 4. 2: An Integrated Energy Stack-Ladder for Cooking (Non-metropolitan zone)

Figures 4.1 and 4.2 place household energy classes (irrespective of number of carriers) on the ladder. This goes beyond previous studies where investigation of household energy use were limited to examine whether they are in conformity with the energy ladder or energy stacking models' assumptions. For example, see: Hosier & Dowd (1987), Nansaior et al. (2011) and Bisu et al. (2016). Thus, results from the integrated energy stack-ladder model better presents household energy characteristics in both parts of the study area. This could not be achieved through adopting either the energy ladder or the energy stacking model.

In conclusion, this study has highlighted two findings in the field of household energy poverty and energy transition. Firstly, the findings are broadly consistent with those summarized in the energy ladder and energy stacking models. By all accounts, the energy stacking model provides a more accurate account of energy use at the household level than the energy ladder in the context of this study. However, the integrated energy stack-ladder model precisely captures the hierarchy of the stacking alongside the single carriers according to 3 classes of the energy used in both the metropolitan and non-metropolitan zones.

Based on this, it can be argued that neither the energy ladder model or energy stacking model can be used to successfully generalize the energy situation of a particular geographical entity such as metropolitan or non-metropolitan zone, rather, these two models have to be combined into an energy ladder-stacking model as demonstrated in this study.

Secondly, the findings of this section contribute to the literature on energy stacking by extending its assumption to provide a ranking of its carriers (for the first time) according to the combined energy ladder-stacking model. As noted in section 2.7.4, the energy stacking model is based on the premise that multiple energy carriers are available at the same time and can be used as substitutes due to intricate factors associated with household energy choice. However, from that, it is difficult to differentiate between primary and secondary energy carriers. In this study respondents were asked to rank their first choice of energy among multiple sources of energy available to them (see: Appendix I). This gives more opportunities to understand areas that are more vulnerable to energy poverty.

Finally, the results from this section highlight that a wide gap exists between the type of energy used for cooking and different geographical locations within the study area. In order to understand the cause of that difference, the next section will examine the impact of respondents' socio-economic status on energy for cooking.

4.3 Socio-economic Variables and Energy for Cooking Class

This section explores the association between the independent variables (household characteristics) and the dependent variables (household energy classes). This is achieved using Chi square tests and Cramer's V technique. Leach (1992) previously observed that transition to modern energy is a response to changes in household socio-economic status. Thus, the purpose of this section is to investigate how socio-economic variables determine the energy class (traditional, transitional and modern) used for cooking in a particular household or zone of the study area.

The aim of this section is to explore the strength of the relationship between the household's socio-economic status and 3 energy classes used for cooking. This goes beyond traditional approaches that rely on tests of significance only.

Hypothesis statement ($p = 0.05$):

H_0: The energy class used for cooking is not associated with households' social status.

H_1: The energy class used for cooking is associated with household's social status.

The null hypothesis (**H_0**) in this study assumes that differences in social status have no impact on type of energy used for cooking. So, if the calculated p value is less than the p value (0.05), the null hypothesis will be rejected and accept the alternative hypothesis (**H_1**).

4.3.1 Household Income versus Type of Energy Class for Cooking

Table 4.4 shows household income divided into 3 groups: <N18,000, <N55,000 and >N55,000 and 3 classes of energy for cooking, namely traditional, transitional and modern.

Table 4. 4: Income vs Type of Energy Class for Cooking

LGA Location	Class of Energy for Cooking	Income (Monthly)			
		<N18000	**<N55000**	**>N55000**	**Total**
Metropolitan	Traditional	84	124	44	**252**
		74%	59%	42%	**59%**
	Transitional	12	30	12	**54**
		11%	14%	12%	**13%**
	Modern	17	57	48	**122**
		15%	27%	46%	**29%**
	Total	**113**	**211**	**104**	**428**
		100%	**100%**	**100%**	**100%**
Non-Metropolitan	Traditional	149	246	49	**444**
		99%	94%	79%	**94%**
	Transitional	1	1	0	**2**
		1%	0%	0%	**0%**
	Modern	1	14	13	**28**
		1%	5%	21%	**6%**
	Total	**151**	**261**	**62**	**474**
		100%	**100%**	**100%**	**100%**

Independent Variables	LGA Zones	Energy for Cooking Class		
		X^2 value	**p-value**	**Cramer's V value**
Income (monthly)	Metropolitan	29.030[a]	0.000	.184
	Non-metropolitan	28.473[b]	0.000	.187

[a] Pearson's value

[b] Likelihood value

As indicated in Table 4.4, the majority of low income (<N18,000) groups rely on the traditional energy class for cooking in both metropolitan and non-metropolitan households. Likewise, 59% and 94% of households earning <N55,000 rely on traditional energy for cooking in the metropolitan and non-metropolitan zones respectively. In contrast, 42% and 79% of households earning >N55,000 rely on traditional energy for cooking in the metropolitan and non-metropolitan zones respectively. Households from this high income group are therefore more likely to use modern energy for cooking than households in other income groups.

Overall, these results are significant for two reasons. Firstly, they suggest that low income households are more reliant on the traditional energy class for cooking than high income households. Conversely, higher income households are more reliant on modern energy classes for cooking than lower income households. Secondly, households in the both metropolitan and the non-metropolitan zones may share the same income group, but use very different sources of energy for cooking. For instance, 27% of middle income households in the metropolitan zones use modern energy for cooking compared to only 5% in non-metropolitan households. In other words, more than half of all the households in both metropolitan and non-metropolitan zones depend on traditional energy for cooking irrespective of income status. These two findings require statistical analysis to determine whether these differences are significant or have occurred by chance.

The relationship between classes of energy for cooking and household income was tested and found to be highly statistically significant. In other words, there are significant differences in energy use for cooking at different income levels. The strength of this relationship, however, is weak (metropolitan: $p<0.000$ and Cramer's value: 0.184; non-metropolitan: $p<0.000$ and Cramer's value: 0.187). This finding suggests that energy transition is in part dependent on a households level of income in both metropolitan and non-metropolitan areas.

As has been revealed in section 4.3.1, generally, higher income households are more likely to adopt modern energy classes for cooking. This has been confirmed by other researchers including Hosier & Dowd (1987), El-katiri (2011), Baiyegunhi & Hassan (2014), Mensah & Adu (2015) and Bisu et al., (2016). Whilst income is not the only factor influencing household energy transition, it is commonly considered the fundamental factor, as represented by the energy ladder model (Leach, 1992). Indeed, this finding vindicates part of the energy ladder's assumptions regarding influence of income on energy transition.

4.3.2 Household Occupation versus Type of Energy Class for Cooking

Table 4.5 shows three major categories of occupation: civil servant, business and farmer. The 'other' category has been created by grouping more than 20 other occupations found in the study area. These include shoemaker, tailor, driver, carpenter and painter. The 'other' group tends to have the lowest frequency compared to the aforementioned occupations.

Table 4.5 reveals that those who identified themselves as civil servants are more likely to use modern energy for cooking than other occupational groups in both metropolitan (39%) and non-metropolitan (18%) zones. In contrast, the majority of those who identified themselves as farmers are more likely to use traditional energy for cooking in both metropolitan (80%) and non-metropolitan (99%) zones. Transitional energy use was found to be very low across the occupational groups in both zones.

Table 4. 5: Household Occupation vs Type of Energy Class for Cooking

LGA Location	Class of Energy for Cooking	Civil Servant	Business	Farmer	Others	Total
Metropolitan	Traditional	57	110	8	77	**252**
		54%	57%	80%	66%	**59%**
	Transitional	7	27	0	19	**53**
		7%	14%	0%	16%	**13%**
	Modern	41	57	2	20	**120**
		39%	29%	20%	17%	**28%**
	Total	**105**	**194**	**10**	**116**	**425**
		100%	**100%**	**100%**	**100%**	**100%**
Non-Metropolitan	Traditional	92	81	188	70	**431**
		82%	94%	99%	99%	**94%**
	Transitional	0	0	1	1	**2**
		0%	0%	1%	1%	**0%**
	Modern	20	5	1	0	**26**
		18%	6%	1%	0%	**6%**
	Total	**112**	**86**	**190**	**71**	**459**
		100%	**100%**	**100%**	**100%**	**100%**

Independent Variables	LGA Zones	Energy for Cooking Class		
		X^2 value	p-value (2-sided)	Cramer's V value
Major occupation	Metropolitan	17.843[a]	0.007	.145
	Non-metropolitan	46.553[b]	0.000	.226

[a] Pearson's value

[b] Likelihood value

Overall, these findings highlight that civil servant households use less traditional energy for their cooking than businesspersons or farmers. Likewise, the civil servants use more modern energy for cooking than any other occupational group in both zones. Kersten et al. (1998) and Sadath & Acharya (2017) came to similar conclusions in their studies of Nigeria and India respectively. The use of transitional energy for cooking is very low across the range of occupations compared to traditional and modern energy classes.

There are wide differences in the use of modern energy for cooking within the same occupation group between metropolitan and non-metropolitan zones. For example, 20%

of those engaged in farming in the metropolitan zone use modern energy compared to only 1% in the non-metropolitan zone.

The relationship between household occupation and type of energy class was tested and found to be statistically significant and moderately strong in the non-metropolitan zone ($p<0.000$ and Cramer's value: .226). In contrast, this relationship was found not to be significant in the metropolitan zone ($p<0.007$). This suggests that the type of energy class is not dependent on household occupation in this zone. However within the occupational groups in this zone, civil servant households show a greater potential of using modern energy among the metropolitan householders.

4.3.3 Family Size versus Type of Energy Class for Cooking

Table 4.6 indicates that 54% of households in the metropolitan zone with a family of 2 rely on traditional energy for cooking whilst 78% of households with families of 8 or more rely on traditional energy for cooking. In contrast, in the non-metropolitan zone, 81% of households with a family of 2 and 97% of households with families of >8 depend on traditional energy for cooking. These figures suggest that there is clear distinction between the two family groups in terms of use of traditional energy for cooking. Although the table shows only few households use transitional energy for cooking, the result indicates less significant variation among the families within the metropolitan zone. Smaller families tend to use more transitional energy for cooking in the non-metropolitan zone.

Table 4. 6: Family Size vs Type of Energy Class for Cooking

LGA Location	Types of Cooking Energy	Family size					
		2	**3-4**	**5-6**	**7-8**	**>8**	**Total**
Metropolitan	Traditional	32	57	57	44	65	**255**
		54%	48%	61%	67%	78%	**60%**
	Transitional	7	14	12	9	7	**49**
		12%	12%	13%	14%	8%	**12%**
	Modern	20	49	25	13	11	**118**
		34%	41%	27%	20%	13%	**28%**
	Total	**59**	**120**	**94**	**66**	**83**	**422**
		100 %	**100%**	**100%**	**100 %**	**100 %**	**100 %**
Non-Metropolitan	Traditional	21	86	94	50	159	**410**
		81%	96%	93%	88%	97%	**94%**
	Transitional	1	1	0	0	0	**2**
		4%	1%	0%	0%	0%	**1%**
	Modern	4	3	7	7	5	**26**
		15%	3%	7%	12%	3%	**6%**
	Total	**26**	**90**	**101**	**57**	**164**	**438**
		100 %	**100%**	**100%**	**100 %**	**100 %**	**100 %**

Independent Variables	LGA Zones	Energy for Cooking Class		
		X^2 value	**p-value (2-sided)**	**Cramer's V value**
Family size	Metropolitan	25.530[a]	0.001	.174
	Non-metropolitan	16.809[b]	0.032	.155

[a] Pearson's value

[b] Likelihood value

Table 4.6 shows that there is higher usage of modern energy for cooking in households with smaller families than large ones, with 34% of households with small families (2) in the metropolitan zone relying on modern energy for cooking whilst only 13% of households with large families (>8) rely on modern energy for cooking. Likewise, in the non-metropolitan zone more than 15% of households with small families (2) and only 6% of households with large families (>8) depend on modern energy for cooking.

Overall, these results suggest that households with a large number of family members tend to rely more on traditional energy for cooking in both metropolitan and non-metropolitan zones. Conversely, households with a smaller number of family members showed a higher proportion of users of modern energy in both metropolitan and non-metropolitan zones. This has been confirmed by Ouedraogo, (2006) in Ouagadougou, Burkina Faso. Mensah & Adu (2015) also found that traditional energy tended to be used for cooking with larger family sizes. This, like other findings in this chapter suggests that household energy transition in the study area cannot simply be explained by household income alone, as family size also plays a crucial role in household energy transition, especially in the developing countries.

The relationship between family size and class of energy class used for cooking was found to be highly statistically significant although the strength of the relationship is weak in the metropolitan area ($p<0.001$ and Cramer's value: .174). In contrast, the relationship was not significant in the case of the non-metropolitan households ($p>0.032$). This suggests that family size matters more when considering the transition to modern energy for cooking in metropolitan areas where there are wide range of energy carriers. This shows that the choice of energy for cooking in the metropolitan zone is dependent upon the size of household. In contrast, family size has no impact on the type of energy used for cooking in the non-metropolitan zone. This might be explained by the scarcity of non-traditional energy carriers effectively limiting household energy choice in the non-metropolitan zone.

4.3.4 Mode of Housing Ownership versus Type of Energy Class for Cooking

Table 4.7 shows that there are no striking differences between categories of housing ownership in relation to energy poverty and transition, however, there is difference between the two geographical zones as shown in the table.

Table 4. 7: Mode of Housing Ownership vs Type of Energy Class for Cooking

LGA Location	Types of Cooking Energy	Mode of housing ownership			Total
		Self-ownership	Tenant	Family House	
Metropolitan	Traditional	160	95	21	**276**
		57%	70%	70%	**62%**
	Transitional	39	11	4	**54**
		14%	8%	13%	**12%**
	Modern	81	30	5	**116**
		29%	22%	17%	**26%**
	Total	**280**	**136**	**30**	**446**
		100%	**100%**	**100%**	**100%**
Non-Metropolitan	Traditional	292	88	51	**431**
		91%	98%	100%	**94%**
	Transitional	1	1	0	**2**
		0%	1%	0%	**0%**
	Modern	27	1	0	**28**
		8%	1%	0%	**6%**
	Total	**320**	**90**	**51**	**461**
		100%	**100%**	**100%**	**100%**

Independent Variables	LGA Zones	Energy for Cooking Class		
		X^2 value	p-value (2-sided)	Cramer's V value
Mode of Housing Ownership	Metropolitan	8.091[a]	0.088	.095
	Non-metropolitan	16.151[b]	0.003	.112

[a] Pearson's value

[b] Likelihood value

In the case of modern energy for cooking, Table 4.7 shows 'self-owner' householders tend to have a higher proportion of modern energy users than other categories. For example, 29% of self-owner households in the metropolitan zones and 8% of self-owner households in the non-metropolitan zone use modern energy for cooking, whereas 22% and 1% of tenant households use modern energy for cooking in the metropolitan and the non-metropolitan zones respectively. Only 17% of 'family homes' use modern energy for cooking in the metropolitan zone, whilst none of the households in the non-metropolitan zone use modern energy for cooking. This is not surprising in respect to 'family homes' in the non-metropolitan zone. This could affect their energy situation due to large family size. Table 4.8 reveals that 100% of 'family homes' rely on traditional energy for cooking in the non-metropolitan zone.

The relationship between mode of housing ownership and energy class for cooking was not statistically significant in the metropolitan zone ($p>0.088$). In other words, there is no evidence of any association between mode of housing ownership and class of energy use or potential of possible transition to modern energy in the metropolitan households. Ironically, despite the higher number of households that use modern energy in the metropolitan zone, there was no evidence to suggest any relationship between mode of housing ownership and type of energy class used for cooking.

In contrast, this association is significant in the non-metropolitan zone, however, it is very weak ($p<0.003$ and Cramer's value: .122). This means that self-owner householders in the non-metropolitan zones have more potential to adopt modern energy carriers than tenants and family householders. Bisu et al., (2016) report contrasting findings in Bauchi State, Nigeria where tenants use more modern energy for cooking than self-owned householders. Likewise, this finding contradicts what was observed in Ouagadougou, Burkina Faso by Ouedraogo (2006) where occupants of self-owned households tend to use more traditional energy than the tenants.

4.3.5 Number of Rooms versus Type of Energy Class for Cooking

Table 4.8 shows that there is no apparent variation in terms of number of rooms across the zones of the study area and use of traditional energy for cooking. However, there is clear difference in the number of rooms in the metropolitan and non-metropolitan zones in relation to use of traditional energy. As shown in the table, the households with >5 rooms use more modern energy for cooking than those with just 2 rooms. For example, in the metropolitan zone 19% households with 2 rooms use modern energy while 26% of households with >5 rooms use the same type of energy. On the other hand, in the non-metropolitan zone, only 1% of households with 2 rooms use modern energy and about 6% of households with >5 rooms use the same energy.

Table 4. 8: Number of rooms vs Type of Energy Class for Cooking

LGA Location	Types of Cooking Energy	Number of rooms					Total
		2	3	4	5	>5	
Metropolitan	Traditional	52	75	60	43	51	**281**
		70%	64%	56%	59%	58%	**61%**
	Transitional	8	8	14	11	14	**55**
		11%	7%	13%	15%	16%	**12%**
	Modern	14	34	34	19	23	**124**
		19%	29%	32%	26%	26%	**27%**
	Total	**74**	**117**	**108**	**73**	**88**	**460**
		100 %	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**
Non-Metropolitan	Traditional	71	108	87	69	102	**437**
		99%	96%	96%	87%	94%	**94%**
	Transitional	0	1	0	1	0	**2**
		0%	1%	0%	1%	0%	**0%**
	Modern	1	4	4	9	7	**25**
		1%	4%	4%	11%	6%	**5%**
	Total	**72**	**113**	**91**	**79**	**109**	**464**
		100 %	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**

Independent Variables	LGA Zones	Energy for Cooking Class		
		X^2 value	**p-value (2-sided)**	**Cramer's V value**
Number of rooms	Metropolitan	9.244[a]	0.322	.100
	Non-metropolitan	12.426[b]	0.133	.114

[a] Pearson's value

[b] Likelihood value

As indicated in Table 4.8, the relationship between type of energy class for cooking and number of rooms was found not to be statistically significant (p>0.322) for either metropolitan or non-metropolitan zones. Number of rooms is not a good determinant when evaluating household energy transition for cooking; however, it might be of value when considering energy for lighting (See chapter 5).

4.3.6 Education versus Type of Energy Class for Cooking

Table 4.9 reveals that the level of the head of household's education impacts upon the type energy class used for cooking. Householders who have experienced higher education in the metropolitan zone are less likely to use traditional energy for cooking than those with Islamic secondary or primary education. Likewise, householders who have experienced higher education in the non-metropolitan zone show lower usage of traditional energy for cooking. Excluding higher education, more than 82% of the remaining categories rely on traditional energy as their primary energy for cooking.

Table 4. 9: Education versus Type of Energy Class for Cooking

LGA Location	Types of Cooking Energy	Education				Total
		Primary	Secondary	Higher	Islamic	
Metropolitan	Traditional	20	82	105	74	**281**
		59%	65%	50%	80%	**61%**
	Transitional	8	19	17	11	**55**
		24%	15%	8%	12%	**12%**
	Modern	6	26	87	7	**126**
		18%	21%	42%	8%	**27%**
	Total	**34**	**127**	**209**	**92**	**462**
		100%	**100%**	**100%**	**100%**	**100%**
Non-Metropolitan	Traditional	43	101	97	206	**447**
		100%	97%	82%	98%	**94%**
	Transitional	0	0	1	1	**2**
		0%	0%	1%	1%	**0%**
	Modern	0	3	20	4	**27**
		0%	3%	17%	2%	**6%**
	Total	**43**	**104**	**118**	**211**	**476**
		100%	**100%**	**100%**	**100%**	**100%**

Independent Variables	LGA Zones	Energy for Cooking Class		
		X^2 value	**p-value (2-sided)**	**Cramer's V value**
Education	Metropolitan	49.476[a]	0.000	.231
	Non-metropolitan	34.988[b]	0.000	.203

[a] Pearson's value

[b] Likelihood value

Householders who have experienced higher education and Islamic education in the metropolitan zone show least use of transitional energy (8% and 12% respectively). Ironically, those with primary and secondary education show higher use of transitional energy (24% and 15% respectively). In contrast, very few households in the non-metropolitan zone use transitional energy as their primary energy class for cooking. Householders who have experienced higher education in both metropolitan and non-metropolitan zones are more likely to use modern energy for cooking than any other type of education. As shown from the table, about 42% (metropolitan) and 17% (non-metropolitan) of those with higher education use modern energy for cooking.

As indicated in Table 4.9, the relationship between the type of education and energy for cooking was found to be highly statistically significant with the strength of the relationship moderate in both metropolitan ($p<0.000$ and Cramer's value: .231) and non-metropolitan ($p<0.000$ and Cramer's value: .203) zones. This implies that heads of households with higher levels of education are more reliant on modern energy in both metropolitan and non-metropolitan zones. These findings contradict those of Naibbi & Healey (2014) who found no relationship between households level of education and use of traditional energy such as fuelwood.

Overall, these results suggest that type of education is crucial in understanding residential energy poverty and likelihood of transition to the modern energy class. Furthermore, it reveals how the impact that the head of household has on choice of energy class for cooking varies. Similar findings have been found in Ouagadougou, Burkina Faso by Ouedraogo, (2006). Baiyegunhi & Hassan, (2014) and Bisu et al., (2016) found a significant relationship between head of household's education and use of modern energy in Kaduna State and Bauchi State, Nigeria respectively. The results from this section clearly illustrate how education can play an important role in transitioning from traditional to modern use of energy for cooking in the study area.

4.3.7 Age versus Type of Energy Class for Cooking

Table 4. 10: Age vs Type of Energy Class for Cooking

LGA Location	**Types of Cooking Energy**	**Age**					**Total**
		20-30	**31-40**	**41-50**	**51-60**	**>60years**	
Metropolitan	Traditional	48	102	65	50	24	**289**
		54%	55%	60%	81%	75%	**61%**
	Transitional	9	23	17	3	4	**56**
		10%	12%	16%	5%	13%	**12%**
	Modern	32	60	26	9	4	**131**
		36%	32%	24%	15%	13%	**28%**
	Total	**89**	**185**	**108**	**62**	**32**	**476**
		100%	**100%**	**100%**	**100%**	**100%**	**100%**
Non-Metropolitan	Traditional	87	175	103	61	23	**449**
		95%	97%	93%	85%	100%	**94%**
	Transitional	1	0	1	0	0	**2**
		1%	0%	1%	0%	0%	**0%**
	Modern	4	5	7	11	0	**27**
		4%	3%	6%	15%	0%	**6%**
	Total	**92**	**180**	**111**	**72**	**23**	**478**
		100%	**100%**	**100%**	**100%**	**100%**	**100%**

Independent Variables	**LGA Zones**	**Energy for Cooking Class**		
		X^2 value	**p-value (2-sided)**	**Cramer's V value**
Age	Metropolitan	21.852[a]	0.005	.152
	Non-metropolitan	18.669[b]	0.017	.144

[a] Pearson's value

[b] Likelihood value

Table 4.10 shows that younger people (aged 20-30 years) in the metropolitan zone are less likely to use traditional energy than older people aged (51-60 years and >60 years). Conversely, both younger and older people in the non-metropolitan zone show high reliance on traditional energy for cooking.

Conversely, younger people in the metropolitan zone (aged 20-30 years) are more likely to use modern energy for cooking than older householders. This suggest that the probability of ascending the energy ladder is higher among the younger householders. In contrast, in the non-metropolitan areas, younger people tend to use less modern energy for cooking than older people (with exception of those >60 years where none of this age group use modern energy for cooking). For example, Table 4.4.7 shows only 4% of age group 20-30 use modern energy compared to 15% of householders aged 51-60.

The relationship between the age of the head of the household and type of energy used for cooking was found to be statistically significant, but weak, in the metropolitan zone ($p<0.005$ and Cramer's value: .152). This relationship is not significant in the non-metropolitan zone ($p>0.017$). Overall, these results suggest that a householders' age is more important in metropolitan households than non-metropolitan households. A similar finding has been reported for Ghana by Mensah & Adu (2015). They suggested that the reason behind that was 'conservatism' on the part of older householders. Nevertheless, the findings from the non-metropolitan zone suggest otherwise. It could be as a result of different family sizes and geographical settings as already highlighted (see:4.4.3 and 4.6.3). Conversely, Rahut et al. (2016) found that older householders in Ethiopia and Tanzania were less dependent on traditional energy for cooking. Interestingly, this is similar to the findings for non-metropolitan zone in this study.

4.3.8 Summary

Taken in entirety, household income has been hypothesised as the leading factor contributing towards household energy choice and influencing transition to modern energy usage. However, the findings from section 4.3 suggest otherwise. The head of household's level of education is more important in determining the use of modern energy and potential transition than income in both metropolitan and non-metropolitan zones.

This suggests that transitions to higher levels of education could expedite transitions to the use of modern energy in the study area. Other socio-economic variables such as occupation, family size, mode of housing ownership and age of the head of the households have also been found to have varied effects on households' energy types and transition between metropolitan and non-metropolitan zones.

The findings from this section suggest that a number of socio-economic variables are significant in determining the proportion of different energy classes used at the household scale. However, these findings suggest that this geographical location played an important role in this relationship. Indeed, this section has illustrated the effect of a particular variable on different geographical settings. In addition, as already revealed in this section, a single variable produces different outcomes between households in different geographical zones with, for example, the same level of income and education (see 4.3.1 and 4.3.6 respectively). Hence, this implies that apart from the socio-economic impact on household energy transition, geographical differences are equally important in energy poverty and transition studies.

Finally, the overall picture of the energy use in the study area suggests that a transition to modern energy is taking place in the metropolitan zone. In sharp contrast, transition to modern energy in the non-metropolitan zones is at best minimal and at worst absent. This finding corroborates Leach's observation that " In many developing countries, anecdotal evidence and household energy surveys suggest that in urban areas the transition is well under way but is progressing slowly, if at all, in rural areas" (1992, p.116).

In order to provide plausible explanations regarding the causes behind such variation in terms of types of energy use for cooking, section 4.5 will explore barriers of access to modern energy for both metropolitan and non-metropolitan zones.

4.4 Energy Satisfaction and Type of Energy Class for Cooking

This section compares household energy class and satisfaction with energy use for cooking. Table 4.11 shows 3 energy classes for cooking and the levels of satisfaction for both metropolitan and non-metropolitan zones.

This section does not consider household energy consumption thresholds, that is the amount of energy required by a particular household (González-Eguino, 2015). Rather, it explores the relationships between the type of energy for cooking and satisfaction from the respondents' viewpoints. Findings from this section can help us to evaluate the householders' readiness to transition to modern energy services for cooking.

Table 4. 11: Energy for cooking satisfaction vs Type of Energy Class for Cooking

LGA Location			**Traditional cooking energy**	**Transitional cooking energy**	**Modern cooking energy**	**Total**
Metropolitan	Energy for cooking satisfaction	Yes	164	35	105	**304**
			57%	64%	80%	**64%**
		No	121	20	26	**167**
			43%	36%	20%	**36%**
	Total		**285**	**55**	**131**	**471**
			100%	100%	100%	**100%**
Non-Metropolitan	Energy for cooking satisfaction	Yes	356	2	27	**385**
			79%	100%	96%	**80%**
		No	96	0	1	**97**
			21%	0%	4%	**20%**
	Total		**452**	**2**	**28**	**482**
			100%	**100%**	**100%**	**100%**

Independent Variables	**LGA Zones**	**Satisfaction**		
		X^2 value	**p-value (2-sided)**	**Cramer's V value**
Types of Cooking Energy Class	Metropolitan	20.069[a]	0.000	.206
	Non-metropolitan	7.955[b]	0.019	.108

[a] Pearson's value

[b] Likelihood value

Table 4.11 indicates that 80% of modern energy users in the metropolitan zone are satisfied with their energy situation and 96% of modern energy users in the non-metropolitan zone are similarly happy with their energy for cooking. In contrast, 20% and 4% of modern energy users are dissatisfied with their current energy situation in the metropolitan in non-metropolitan zones respectively. Feelings of dissatisfaction with modern energy services might stem from high costs or unreliability of supply. Other factors that might contribute to energy dissatisfaction in the metropolitan zone may include high energy cost, which culminates in poverty. It is worth stating here that the data for this study was collected during a period of financial recession in Nigeria.

Table 4.11 shows a total of 55 of the households in metropolitan zone use transitional energy carriers for their cooking. Approximately 64% of these households are satisfied with their energy situation. This is not surprising, because transitional energy (kerosene) is not the preferred energy carrier for cooking in this area as previously reported by Hyman (1994) and Maconachie et al. (2009). Also, its scarcity could be a source of householders dissatisfaction. Naibbi & Healey (2013) found an inequality of fossil fuel distribution between the south and north of Nigeria. Moreover, there have been reports of fossil fuel smuggling to neighbouring countries that share the border with northern Nigeria (Odihi, 2003; Maconachie et al., 2009). Consequently, the kerosene supply in the study area is likely to be limited. In addition, there is the negative impact of 'black market' vendors to consider, which also creates sporadic artificial scarcity (Hyman, 1994; Odihi, 2003). Undoubtedly, these factors will make kerosene a less favourable energy choice for cooking in the study area.

Table 4.11 shows that 57% of traditional energy users in the metropolitan zone are satisfied with their energy supply. In contrast, 79% of traditional energy users in the non-metropolitan zone are satisfied with their energy for cooking. This is a surprising outcome, suggesting that large numbers of households depend on traditional energy class for cooking, yet are satisfied with their energy situation. Their satisfaction may be as a result of cultural heritage like, ‘we thank God’ and ‘I cannot complain’. This type of attitude is more common among non-metropolitan dwellers.

The results show that regardless of energy source, non-metropolitan householders express more satisfaction than their metropolitan counter parts. One possible explanation for this may be that the traditional energy system is more reliable than the modern energy system in the study area, particularly in the non-metropolitan zone.

The relationship between household type of energy use for cooking and satisfaction was tested and found to be highly statistically significant in the metropolitan zone. In contrast, there was no evidence of any relationship between the household type of energy class and satisfaction in the non-metropolitan zone. This suggests that unreliability of modern energy supply might have led to the absence of relationship in non-metropolitan zone.

Overall, the findings from this section reveal that the householders in the metropolitan zone are more dissatisfied with traditional energy class for cooking than their counterparts in the non-metropolitan zone. The findings also suggest that irrespective of geographical or social setting, people are happier to use modern energy carriers than traditional carriers for their cooking. In other words, the majority of the householders in the study area showed preference to use modern energy for cooking. This corroborates Naibbi’s findings (2013) who found that the majority of householders in Yobe State, northern Nigeria were in favour of using modern energy for cooking. Earlier, Onyebuchi (1989) found that despite the severity of energy poverty in rural areas of Nigeria, a large proportion of the rural population preferred to use modern energy for cooking.

4.5 Major Barriers for Household Energy for Cooking Transitions

This section considers major barriers preventing traditional energy users from transitioning to modern energy classes as identified by the heads of households in both metropolitan and non-metropolitan zones. Table 4.6 indicates that 221 (46%) and 401 (83%) households in the metropolitan and the non-metropolitan zones respectively face difficulties in making the transition to modern energy. Causes of this are discussed below.

Table 4. 12: Traditional Energy Class for Cooking and Major Barriers

Barrier	Number of Households (Metropolitan)	%	Number of Households (Non-metropolitan)	%
Cost of energy source and appliance	97	44%	154	38%
Tradition and Safety	49	22%	55	14%
Large family	17	8%	47	12%
Govt. policy and Scarcity	7	3%	57	14%
Low income	51	23%	88	22%
Total	**221**	**100%**	**401**	**100%**

Source: Author's Fieldwork

4.5.1 Cost of Energy sources and Appliances

Table 4.12 indicates that about 44% of households in the metropolitan zone and 38% of households in the non-metropolitan zone reveal that the cost of modern energy (such as gas and electricity) and cost of modern energy appliances (such as cooker gas/gas stove and electric stove) are major obstacles to transition. There are clear differences between the households in metropolitan and non-metropolitan zones.

The ‘cost’ barrier is the largest of the barriers. Odihi (2003) observes that the cost of energy in Nigeria has been increasing ‘substantially’ for decades. This could be associated with frequent subsidy withdrawals that have been witnessed for many years (Hyman, 1994; Naibbi & Healey, 2015). Cost of modern energy appliances has been identified as the major barrier to transition in developing countries (Leach, 1992). Odihi (ibid) also observed that the cost of modern appliances for cooking increased by 3000% in 2003. Under such circumstances, the likelihood of transition to modern energy is negligible.

Maconachie et al. (2009) found the high and rising price of energy to be the major barrier to the use of modern energy class for cooking in Kano State. They also indicated that this has more effect on householders with low income, and that this issue is not restricted to energy price, but also includes the acquisition of modern appliances which are key components in the transition to modern energy. Further, coincidentally, these barriers are specifically associated with the households using traditional energy for cooking as indicated in Table 4.7. As also revealed by the table, these barriers affect more households in the non-metropolitan zone than the metropolitan zone.

4.5.2 Tradition and Safety Concerns

Table 4.12 shows that a combination of ‘tradition’ and ‘safety concerns’ affect 22% of households in the metropolitan zone and 14% of households the non-metropolitan zone. Tradition in the context of the study area implies that households prefer to use traditional energy sources such as fuelwood, charcoal and crop residues for cooking. Safety concerns relate to the fear of fire outbreak as a result of using modern energy carriers (such as gas, and electricity) and transitional carriers (kerosene).

Most people in the study area use traditional energy for cooking because of its effectiveness in giving a good taste to local food. Furthermore, family size is also considered a traditional factor affecting household type of energy class used for cooking.

For example, it is part of the tradition in the study area to cook '*tuwo*' for dinner. This traditional food requires a lot of energy to cook and is mainly served to an extended family. It is commonly cooked with a source of traditional energy such as fuelwood. Maconachie et al. (2009) reported that the majority of households in Kano State preferred using fuelwood to cook tuwo. Maconachie et al. (ibid), also found that those who cooked with kerosene were perceived as being ungenerous, not wanting to share their food with others. This implies that households' socio-cultural preference have a great impact on household's energy transition.

On safety concerns, some respondents avoid using modern and transitional energy carriers such as kerosene and LPG because of their potential to cause a fire. Maconachie et al., (2009) noted that some people did not use kerosene due to safety concerns. In addition, households with extended families tend to avoid using LPG stoves. This could be as a result of the incompatibility with their cooking requirements or because of safety concerns for their young children. Schlag & Zuzarte (2008) observed that such incompatibility poses a serious challenge to household energy transition in sub-Saharan Africa.

Additionally, Naibbi & Healey (2014) argue regarding the household's choice of energy for cooking in northern Nigeria, even if there is availability of modern energy supply, the full transition to higher quality energy carriers cannot be guaranteed owing to cultural factors attached to the household cooking needs.

4.5.3 Large Family Size

Table 4.12 shows that only 8% of households in the metropolitan zone identified large family size as a barrier to using modern energy for cooking. In contrast, 12% of households in the non-metropolitan zone revealed this to be an issue. This is not surprising, because the findings of this work have already shown that family sizes are larger in the non-metropolitan zone than the metropolitan zone. Furthermore, the findings reveal that there is less usage of traditional energy for cooking in households with smaller families than larger ones (see section 4.3.3).

It has been observed that the extended family structure in the north affects its ability transition to the use of modern energy for cooking (Odihi, 2003; Maconachie et al., 2009; Naibbi & Healey, 2014).

Although, 'large family' is not considered a major obstacle to transition to modern energy in both metropolitan and non-metropolitan zones, it links directly to the traditional barrier in the study area which affects the choice of energy for cooking.

4.5.4 Government Policy and Scarcity

Table 4.13 reveals how government policy and scarcity of modern energy supplies affect energy transition for cooking in both metropolitan and non-metropolitan zones. As indicated in Table 4.12, only 3% of households in the metropolitan zone identified government policy and scarcity of modern energy as major barriers to transition to modern energy class. In contrast, about 14% of households in the non-metropolitan zone identified these as major barriers. The table also show a clear distinction between the two zones in terms of distribution of these barriers.

As indicated earlier in section 4.5.1, cost of energy is the major barrier to transition. However, it has been observed that government policy on domestic energy price such as kerosene and gas contributes to the scarcity of these energy supplies (Na'ibb in:Tomei & Gent, 2015). This situation is not only linked to the country's policy makers, but also to global drivers where household energy poverty for cooking receive less attention (OECD/IEA, 2006). Consequently, this will have negative impact on household energy transition for years to come. Another policy problem concerns the inequality of domestic energy supplies between the northern and southern parts of Nigeria. It has been noted earlier that the North has been receiving less energy than its southern counterpart (Naibbi & Healey, 2014). This give rise to scarcity of domestic energy in the most parts of the north and thereby reduces the likelihood of transition.

4.5.5 Low Income

Table 4.12 reveals that low income prevents more than 20% of households from using modern energy for cooking in metropolitan and non-metropolitan zones respectively. The table shows that low income is the second major barrier after the cost of energy carriers and appliances in both metropolitan and non-metropolitan zones. Furthermore, section 4.4.1 reveals that low income households tend to use more traditional energy for cooking than high income households in both metropolitan and non-metropolitan zones. Maconachie et al. (2009) has previously noted that a combination of low income and high energy price hinder transition to modern energy usage.

Overall, this result indicates the importance of finance (cost and income) in removing barriers preventing household energy transition in developing countries. There are also other barriers (socio-economic, socio-cultural, socio-political to socio-technical) to consider, and the impact of socio-geographical factors in shaping those barriers is obvious. Thus, this chapter reveals the complexity of the household energy barriers in the study area, which are multifaceted in nature. In order to address these barriers there should be an adjustment in both energy policy and social-cultural paradigms, particular education and awareness. However, findings from this section illustrate those socio-cultural barriers that hinder transition will remain the most challenging ones to address in the foreseeable future.

4.6 Chapter Summary

The results from this chapter have revealed a clear distinction between the energy classes adopted for cooking in relation to household's socio-economic status. The findings show that the energy profile for cooking in Kano State is characterised by the following: high use of traditional energy and a large amount of stacking in both metropolitan and non-metropolitan zones. Many authors have reported similar findings. In addition, this chapter has shown that a sizeable proportion of households in the non-metropolitan zone and a few in the metropolitan zone use only a single traditional type of energy. This observation has not previously been reported in the available literature. Nonetheless, this chapter confirms that the majority of energy profiles in both metropolitan and non-metropolitan households support the underlying assumptions of the energy stacking model. Moreover, the results have also revealed that there is more stacking of modern energy in the metropolitan zone than in the non-metropolitan zone, due to the wider availability of more modern energy carriers.

The chapter also examined the impact of the head of household's socioeconomic status on types of energy class used for cooking. The results revealed that level of education and income are the most significant variables shaping the household energy profile in both metropolitan and non-metropolitan zones. Other significant impacts include the head household's occupation, family size, mode of housing ownership and age. Unsurprisingly, number of rooms per household does not explain types of energy for cooking and transition to the use of modern energy in the study area.

This study found that the household's social status is important in determining the energy class used for cooking as well as in predicting possibility of transition. However, the wide gap observed between the metropolitan and the non-metropolitan zones in terms of using modern energy cannot be explained by socio-economic indices alone as highlighted in section 4.3. Therefore, this chapter suggests that such differences could be as a result of geographical variation.

Moreover, this chapter has revealed that the most challenging barriers preventing a transition to adopting modern energy for cooking are (i) combination of cost of energy carriers and appliances and (ii) low income. However, these are just some of the barriers. Others include tradition and safety, government policy and energy scarcity and family size. Further, as observed in this chapter, the lack of compatibility between household cooking needs and cooking appliances is also a potential barrier for using transitional energy. This suggests that the barriers preventing transition in the study area are multifaceted and not restricted only to income.

This chapter make both theoretical and empirical contributions in the field of energy transition. Theoretically, the findings from this chapter highlight that the integration of energy ladder and the energy stacking frameworks provides better understanding of both household and particularly regional energy systems. Conversely, the majority of empirical studies that are in favour of the energy ladder ignore the existence of stacking practice for the majority of households in their respective study areas (see works of Hosier & Dowd, 1987 and Lay et. al, 2013). In contrast, proponents of energy stacking are more concerned with a generalized view of the energy situation (for example see: Hiemstra-van der Horst & Hovorka, 2008; Baiyegunhi & Hassan, 2014; Bisu et al., 2016).

Empirically, both the energy ladder and stacking models place more emphasis on household income in making energy choice. However, this study found that the household level of education is the most important parameter in promoting energy transition to modern energy. This chapter also highlights that this relationship may not be identical in the two different socio-geographical areas. The empirical evidence from this study reveals that the impact of socio-economic variables is largely dependent on a particular geographical context. In other words, the theories of energy model should be conceived according to a particular geographical context when studying the household energy transition in the developing countries.

Moreover, relationships between the so-called family home and informal religious education and class of energy used for cooking add to the literature of household energy poverty and transition. Also, energy satisfaction does not necessarily mean use of modern energy as revealed in this chapter. The findings from this chapter suggest that availability of energy is more important to the majority of households than the quality of energy used for cooking.

4.7 Conclusion

Findings from this chapter support the view that a combined energy stack-ladder model better represents the characteristics of energy used for cooking than either the energy ladder or the energy stacking model in isolation. This challenges the rationale of generalizing the applicability or dismissal of application of the energy ladder or energy stacking models. The chapter reveals that among the households' socioeconomic variables that determine the energy transition, education is the most important variable followed by income. This suggests that a transition towards higher levels of education could represent a first step towards transition to modern energy as highlighted in this chapter. The chapter has also revealed that there is a wide difference between the households in metropolitan and non-metropolitan zones in terms of using modern energy. This chapter concludes that this cannot be explained solely by their socioeconomic status; rather, this difference is a reflection of their geographical differences.

The next chapter moves on to examine energy for lighting transition in the study area using the energy ladder-stacking framework.

Chapter 5: Household Energy for Lighting and Barriers to Transition

5.1 Introduction

One of the salient issues observed in this thesis is that household energy for lighting has been neglected in the hypotheses and frameworks of both the energy ladder and energy stacking models. Most research in developing countries is focussed on energy for cooking (Sathaye & Tyler, 1991). Recently, Rahut et. al, (2017) attempted to use the energy ladder framework to investigate energy for lighting in some sub-Saharan African countries, however, their work was limited to factors that determine the use of modern energy in Ethiopia, Tanzania and Malawi. This chapter sets out, for the first time, an evaluation of household energy for lighting and uses an integrated framework of the energy ladder and energy stacking model to examine characteristics of household energy poverty for lighting and barriers to transition in Kano State, Nigeria.

It is worth stating from the outset that the authors cited in this chapter did not classify or analyse their results by class of energy use (traditional, transitional and modern) as presented in this study.

This chapter is organised as follows: section 5.2 explores the characteristics of household energy for lighting. Section 5.3 examines the relationship between households' socio-economic status and energy for lighting class. Section 5.4 presents respondents energy for lighting satisfaction and Section 5.5 presents the relationship between power duration and energy for lighting class. Section 5.6 examines the major barriers to use of modern energy, Section 5.7 presents chapter summary and Section 5.8 provides a synthesis of Chapter 4 and Chapter 5.

5.2 Characteristics and Proportions of Household Energy Classes for Lighting

Based on the proposed energy ladder-stacking framework, Table 5.2 shows that energy for lighting can be classified as traditional (kerosene/paraffin oil wick lamp and candle); transitional: lanterns (battery or solar powered); and modern: the national grid, solar electricity and small scale generators. The energy stack can contain 2-4 carriers as shown in the table. As already indicated in chapter 3, this classification was derived based on the quality of energy end-use (light) and sophistication of electrical appliances. Thus, these classes will be used to explore the characteristics of household energy for lighting in the metropolitan and the non-metropolitan zones in the subsequent sections.

5.2.1 Traditional Energy for Lighting

Table 5.1 and Figures 5.1 and 5.2 show that 15% and 28% of households use traditional energy carriers for lighting in the metropolitan and the non-metropolitan zones respectively. This result suggests two things. Firstly, that there is a clear difference between the two geographical zones in terms of using this class of energy, with fewer households depending on this energy carrier in the metropolitan zone, a finding confirmed by Rahut et al., (2017) in some sub-Saharan countries. This suggests that most households in the metropolitan have abandoned the use of traditional energy carriers for lighting. Secondly, that despite the lack of access to the national grid, most rural households in both metropolitan and non-metropolitan zones use less traditional energy carriers than other classes of energy for lighting. This suggests that the majority of households in both metropolitan and non-metropolitan zones are not energy poor, because use of traditional energy as a primary energy source for lighting implies an energy poverty situation (Bazilian & Nussbaumer, 2010).

Table 5. 1: Traditional Energy Class for Lighting

No. of carriers	Metropolitan	Metropolitan (%)	Non-Metropolitan	Non-metropolitan (%)
1	2	0.5%	11	2%
2	14	3%	27	6%
3	49	10%	97	20%
4	5	1%	0	0%
		15%		**28%**

In addition, the table indicates more stacking of traditional energy carriers in the non-metropolitan zone than the metropolitan zone. Use of a single traditional energy carrier is limited in both metropolitan and non-metropolitan zones.

Plate 5.1: Kerosene wick lamp

Source: Author's Fieldwork

5.2.2 Transitional Energy for Lighting

As shown in Table 5.2, households transitional energy carrier characteristics reflect the assumptions of both the energy ladder and stacking models. For example, 23% and 1% of households in non-metropolitan and metropolitan zones respectively use only a single energy carrier. In contrast, the majority of transitional energy carriers stack with other energy carriers for lighting in both metropolitan and non-metropolitan zones.

Table 5. 2: Transitional Energy Class for Lighting

No. of carriers	Metropolitan	Metropolitan (%)	Non-Metropolitan	Non-metropolitan (%)
1	4	1%	109	23%
2	93	19%	112	23%
3	46	10%	68	14%
		30%		**60%**

Table 5.2 shows that 60% of households in the non-metropolitan zone primarily on transitional carriers (lanterns) for their energy for lighting (see Figure 5.1). For the purpose of this research, lanterns have been classified as transitional energy carriers. In contrast, only 30% of households in the metropolitan zone used transitional energy carriers for lighting (see Figure 5.2). This result suggests that the majority of the non-metropolitan householders have abandoned traditional energy carriers for lighting (such as kerosene) in favour of transitional ones. These findings contradict those noted by Sambo (2005) who found that the majority of rural households in Nigeria used traditional energy for lighting, kerosene oil in particular. In a similar study, Bhattacharyya (2006) also found more than half of Indian rural householders used traditional energy (kerosene) for lighting.

These differences may be due to the penetration of lantern technology in most developing countries. The cost of transitional energy appliances has been declining; making it more affordable and accessible to large numbers of people in developing countries (Newsom, 2012 and Power for All, 2014). Another possible explanation for increased uptake could be the persistent scarcity of kerosene supplies in northern Nigeria, which is the main energy carrier for kerosene wick lamps, as has been highlighted in Chapter 4.

Plate 5.2: A Lantern (battery)

Source: Author’s Fieldwork

Further, these results suggest that the bottom rung of the energy ladder-stacking model for lighting will diminish in near future. The use of traditional energy is rapidly declining in most sub-Saharan countries (Bensch et al., 2015). The traditional energy carriers in rural Malawi have been replaced by transitional energy carriers (Adkins et al., 2010). They found that transitional energy carriers were less expensive and more efficient than traditional alternatives.

Finally, the results from this section (5.2.2) suggests that a transition is underway, especially in the non-metropolitan zone. Further, this transition may be occurring out of necessity as the majority of households in the non-metropolitan zone are not connected to the national grid (see section 5.5).

5.2.3 Modern Energy for Lighting

The findings show that the majority of the households use multiple energy carriers for lighting in both metropolitan and non-metropolitan zones, with up to four carriers being used in total. However, the table reveals more stacking in the metropolitan zone than the non-metropolitan zone. Only 4% and 1% of modern energy users use a single lighting energy carrier in the metropolitan and non-metropolitan zones respectively.

Table 5. 3: Modern Energy Class for Lighting

No. of carriers	Metropolitan	Metropolitan (%)	Non-Metropolitan	Non-metropolitan (%)
1	21	4%	4	1%
2	130	27%	14	3%
3	112	23%	33	7%
4	4	1%	4	1%
		55%		**12%**

As indicated earlier in this section, the modern energy for lighting class is not restricted to national grid electricity, rather it comprises other sources including solar and independent generation (generator). The modern energy class is the main energy source for lighting in the metropolitan zone (see Table 5.12). Apart from providing lighting, this energy class also provides other additional energy services.

Plate 5.3: Electric generator

Source: Author's Fieldwork

Table 5.3 and Figure 5.1 show that more than half (55%) of the households in the metropolitan zone used modern energy carriers for lighting in contrast to 12% of households in the non-metropolitan zone. As shown in Table 5.3, this represents the biggest difference in energy in energy use for lighting between the two zones. Similarly, Bhattacharyya (2006) observed that, in India, more than 87% of urban households used modern energy for lighting compared to less than 44% of rural households. The differences of using modern energy between urban and rural areas is the widest in sub-Saharan countries and South Asia (Saghir, 2005).

Further, use of modern energy as a primary energy class for lighting is higher in the metropolitan zone than any other energy class. Likewise, Sathaye & Tyler, (1991) found only a few households using traditional energy for lighting in most cities in Asia.

5.2.4 Conclusion

Generally, the findings from this section confirm that the characteristics of number of energy carriers reflect the combined characteristics of the energy ladder and energy stacking models. In addition, the findings reveal that there are more households using multiple carriers (stacking) for lighting compared to those using a single carrier (ladder). Both single and multiple carriers were evidently found across the 3 classes of energy for lighting.

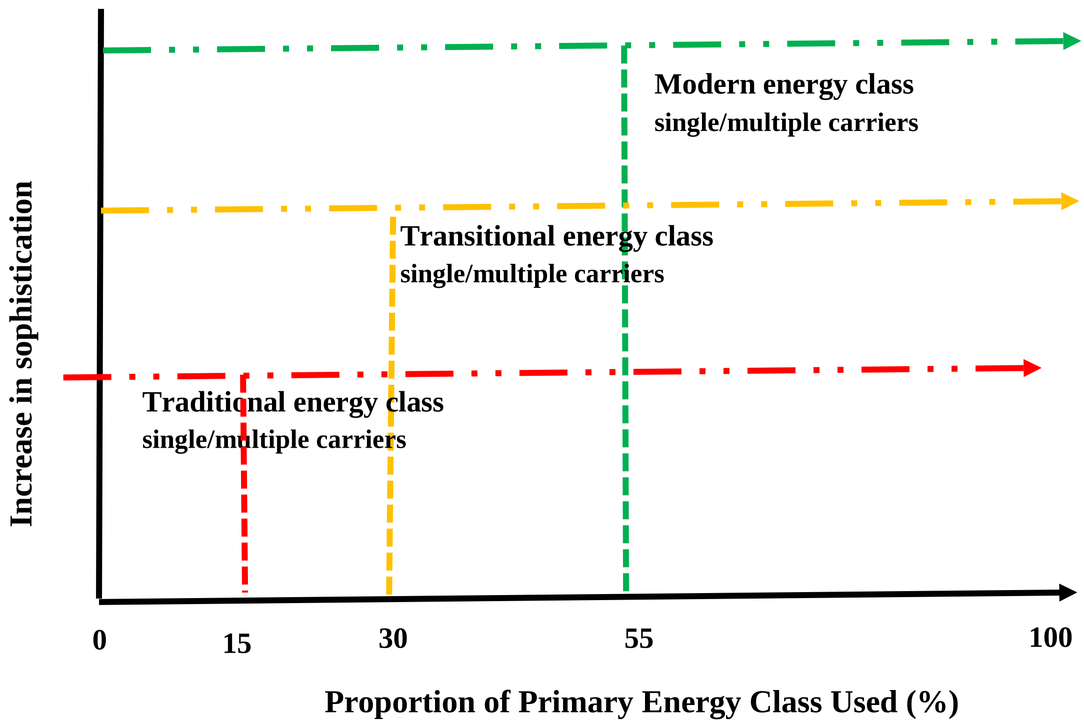

Figure 5. 1: An Integrated Energy Stack-Ladder for Lighting (Metropolitan zone)

The energy information presented in Figure 5.1 represents a perfect ladder with the proportion of transitional and modern energy classes outpacing the traditional one. However, this is not surprising considering the level of urbanisation the metropolitan zone has experienced, which includes more infrastructure and more power than the non-metropolitan zone. Nevertheless, Figure 5.2 also indicates that the proportion of transitional energy used for lighting is higher than that of the traditional energy.

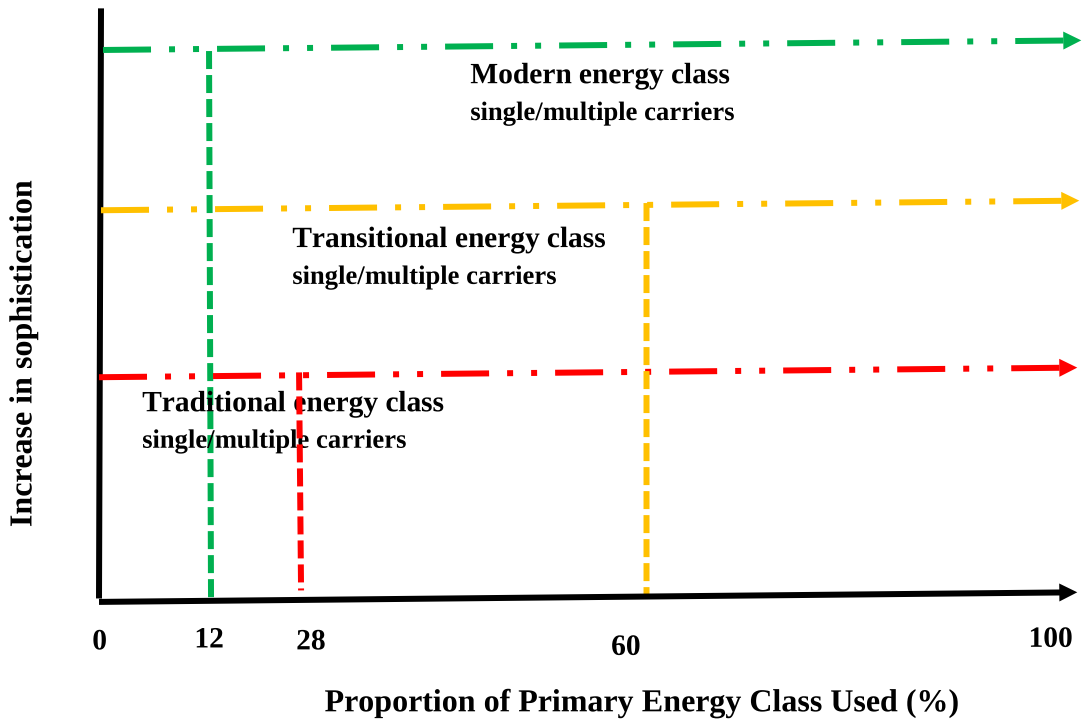

Figure 5. 2: An Integrated Energy Stack-Ladder for Lighting (Non-metropolitan zone)

The majority of households in the metropolitan zone used one of the modern energy classes as their primary energy carrier along with one or more carriers from modern or other classes. In contrast, the majority of households in the non-metropolitan zone used transitional energy carriers as their primary class for lighting followed by other energy classes, mostly from the traditional energy class. This reflects the gross disparity in relation to primary energy for lighting between the two zones of the study area.

Interestingly, the use of traditional energy for lighting is relatively low in both metropolitan and non-metropolitan zones. This suggests that a transition towards modern energy for lighting is underway. Much of the transition in the non-metropolitan households has nothing to do with government policy, rather, it is borne out of government failure in the power sector (see section 1.1.3) and the latest developments in the transitional energy market in most developing countries as highlighted earlier in this section.   Similar observations have been made in rural parts of Africa by Bensch et al.

(2015) who observed that the transition from traditional to transitional energy carriers was largely down to the individual householder's commitment.

Taken together, the findings from section 5.2 provide important insights into the latest trends in household energy poverty for lighting and energy transition in developing countries. The current trends indicate that transitional energy classes are replacing traditional classes in the non-metropolitan zone. The next section will look at impacts of household's socio-economic status on the three energy classes presented in Figures 5.1.and 5.2 in both the metropolitan and non-metropolitan zones.

5.3 Socio-economic Status and Types of Energy Class for Lighting

This section sets out to examine how the head of households' socio-economic status determines the class of energy use for lighting. The socio-economic status includes household monthly income, occupation, family size, mode of housing, number of rooms, education and age. The Chi square test and Cramer's V technique were used to assess levels of significance and strength of relationships between head of households' socio-economic status and class of energy use for lighting respectively. Outcomes from this analysis can be used to influence policies addressing household energy poverty for lighting in both zones.

The null hypothesis (**H_0**) states that the class of energy used for lighting is independent of head of households' socio-economic status. The alternative hypothesis (**H_1**) states that the class of energy used for lighting is dependent on head of households' socio-economic status. The significant level is 0.05.

It worth stating here that, in practice, there is one null/alternative hypothesis for each socio-economic variable.

5.3.1 Household Income versus Types of Energy Class for Lighting

The findings from Table 5.4 suggest that as the household income increases, the chances of adopting sophisticated energy classes for lighting also increase. This indicates that the wealthy households are more likely to adopt modern classes than poor households. As shown in the Table 5.4, 48% and 6% of lower income households (<N18000) are found using modern energy for lighting in the metropolitan and non-metropolitan zones respectively. In contrast, 63% and 37% of high income households (>N55,000) are found using modern energy carriers for lighting in the metropolitan and non-metropolitan zones respectively. Table 5.4 also indicates that more than half of the households in the metropolitan zone rely on modern energy for lighting, whereas more than half of the households in the non-metropolitan zone rely on the transitional energy class.

Table 5. 4: Energy Class vs Income (Monthly) Cross-tabulation

Location	Class of Lighting Energy	<N18000	<N55000	>N55000	Total
Metropolitan	Traditional	21	20	29	**70**
		19%	10%	28%	**16%**
	Transitional	38	69	10	**117**
		34%	33%	10%	**27%**
	Modern	54	122	65	**241**
		48%	58%	63%	**56%**
	Total	113	211	104	**428**
		100%	100%	100%	**100%**
Non-Metropolitan	Traditional	55	53	20	**128**
		36%	20%	32%	**27%**
	Transitional	87	180	19	**286**
		58%	69%	31%	**60%**
	Modern	9	28	23	**60**
		6%	11%	37%	**13%**
	Total	151	261	62	**474**
		100%	100%	100%	**100%**

Independent Variables	LGA Zones	Types of Energy Class for Lighting		
		X^2 value	**p-value (2-sided)**	**Cramer's V value**
Income (monthly)	Metropolitan	32.953[a]	0.000	.196
	Non-metropolitan	57.769[a]	0.000	.247

[a] Pearson's value

The relationship between head of households' income and type of energy class for lighting were tested and found statistically significant. The strength of the relationship was weak in the metropolitan zones ($p<0.000$; Cramer's Value: 0.194) and moderate in the non-metropolitan zones ($p<0.000$; Cramer's Value: 0.247).

The results of this section are consistent with those of Rahut et al., (2017) who found that wealthy householders in Tanzania and Ethiopia tended to use more modern energy classes for lighting than the poor householders. However, in their work they used proxies of wealth such as car and TV ownership. This study intentionally used householder's monthly income in order to assess its relationship with the energy class for lighting. Rahut et al., (2014) also found use of traditional energy for lighting (kerosene oil) decreased with increased household income in Bhutan.

5.3.2 Household Major Occupation versus Types of Energy Class for Lighting

Table 5.5 shows the 3 major occupations in both metropolitan and non-metropolitan zones. All other minor occupations were grouped together into the class 'other' (for more details see 4.3.2).

Table 5.5 shows that civil servants and businesspersons tend to predominantly use (64% and 62% respectively) modern energy carriers for lighting in the metropolitan areas. Likewise, in the non-metropolitan zone, civil servants tend to use more (28%) modern energy carriers for lighting than other occupational groups. On the other hand, as shown in Table 5.6, householders engaged in civil service and business occupations are found using more transitional energy than those engaged in farming and 'other' occupations in the metropolitan zone. In contrast, householders engaged in farming and 'other' occupations are found using more transitional energy for lighting than civil servants and businesspersons.

Table 5. 5: Energy Class vs Major Occupation Cross-tabulation

LGA Location	Types of Lighting Energy	Civil Servant	Business	Farmer	Other	Total
Metropolitan	Traditional	4	14	4	35	**57**
		4%	7%	40%	30%	**13%**
	Transitional	34	59	2	28	**123**
		32%	30%	20%	24%	**29%**
	Modern	67	121	4	53	**245**
		64%	62%	40%	46%	**58%**
	Total	**105**	**194**	**10**	**116**	**425**
		100%	100%	100%	100%	**100%**
Non-Metropolitan	Traditional	34	29	50	14	**127**
		30%	34%	26%	20%	**28%**
	Transitional	47	49	130	49	**275**
		42%	57%	68%	69%	**60%**
	Modern	31	8	10	8	**57**
		28%	9%	5%	11%	**12%**
	Total	**112**	**86**	**190**	**71**	**459**
		100%	100%	100%	100%	**100%**

Independent Variables	LGA Zones	Types of Energy Class for Lighting		
		X^2 value	p-value (2-sided)	Cramer's V value
Major Occupation	Metropolitan	48.974[a]	0.000	.240
	Non-metropolitan	42.186[a]	0.000	.214

[a] Pearson's value

The findings from the metropolitan zone reveal that traditional energy is less commonly used for lighting in households engaged in civil service and business occupations compared to farmers and 'others' occupations. In contrast, the findings from the non-metropolitan zone indicate that civil servants and businesspersons used slightly more traditional energy for lighting than farmers or those involved in other occupations.

While the findings from Table 5.5 reveal that householders engaged in civil service occupations use more modern energy carriers for lighting in both metropolitan and non-metropolitan zones, the relationship between the head of household's occupation and other energy classes varies. This relationship was tested and found statistically significant in both the metropolitan and non-metropolitan zones (metropolitan: $p<0.000$ and Cramer's value: 0.240; non-metropolitan: $p<0.000$ and Cramer's value: 0.214). The strength of both relationships were moderate.

5.3.3 Family size versus Types of Energy Class for Lighting

Table 5. 6: Types of Lighting Energy vs Family size Cross-tabulation

LGA Location	Types of Lighting Energy	2	3-4	5-6	7-8	>8	Total
Metropolitan	Traditional	9	13	14	15	12	**63**
		15%	11%	15%	23%	15%	**15%**
	Transitional	16	37	26	18	20	**117**
		27%	31%	28%	27%	24%	**28%**
	Modern	34	70	54	33	51	**242**
		58%	58%	57%	50%	61%	**57%**
	Total	**59**	**120**	**94**	**66**	**83**	**422**
		100%	100%	100%	100%	100%	**100%**
Non-Metropolitan	Traditional	11	29	32	14	27	**113**
		42%	32%	32%	25%	17%	**26%**
	Transitional	8	50	51	37	120	**266**
		31%	56%	51%	65%	73%	**61%**
	Modern	7	11	18	6	17	**59**
		27%	12%	18%	11%	10%	**14%**
	Total	**26**	**90**	**101**	**57**	**164**	**438**
		100%	100%	100%	100%	100%	**100%**

Independent Variables	LGA Zones	Types of Energy Class for Lighting		
		X^2 value	p-value (2-sided)	Cramer's V value
Family Size	Metropolitan	5.764[a]	0.674	.083
	Non-metropolitan	27.998[a]	0.000	.179

[a] Pearson's value

Table 5.6 indicates that there are slight differences between family size and energy class used for lighting in the metropolitan areas. Coincidently, the result from Chi square test showed no evidence of relationship between the household family size and energy class used for lighting in metropolitan zone (metropolitan: p>0.674).

In contrast, households with larger families were found to be using more transitional energy than households with smaller families in the non-metropolitan zone. Surprisingly, the smaller households were found to be using more traditional and modern energy classes for lighting than the larger households. As shown in the table, the relationship between household's family size and class energy used for lighting is significant, but weak in the non-metropolitan areas ($p<0.000$; Cramer's Value: .179). This suggests that the relationship between household's family size and type of energy class for lighting is more important in the non-metropolitan zone than in the metropolitan zone. This might be due lack of infrastructure for modern energy for lighting in most parts of the non-metropolitan zone. Secondly, findings from section 5.2 reveal that transitional energy forms the dominant energy carriers for lighting in the non-metropolitan zone.

5.3.4 Mode of Housing Ownership versus Types of Energy for Lighting

Table 5. 7: Types of Lighting Energy vs Mode of housing ownership Cross-tabulation

LGA Location	Types of Lighting Energy	Self-ownership	Tenant	Family House	Total
Metropolitan	Traditional	36	25	3	**64**
		13%	18%	10%	**14%**
	Transitional	84	46	3	**133**
		30%	34%	10%	**30%**
	Modern	160	65	24	**249**
		57%	48%	80%	**56%**
	Total	**280**	**136**	**30**	**446**
		100%	100%	100%	**100%**
Non-Metropolitan	Traditional	105	11	7	**123**
		33%	12%	14%	**27%**
	Transitional	169	69	40	**278**
		53%	77%	78%	**60%**
	Modern	46	10	4	**60**
		14%	11%	8%	**13%**
	Total	**320**	**90**	**51**	**461**
		100%	100%	100%	**100%**

Independent Variables	LGA Zones	Types of Energy Class for Lighting		
		X^2 value	p-value (2-sided)	Cramer's V value
Mode of Housing	Metropolitan	11.856[a]	0.018	.115
	Non-metropolitan	26.276[a]	0.000	.169

[a] Pearson's value

Table 5.7 reveals that tenants (18%) and self-owned (33%) householders tend to use more traditional energy for lighting in both metropolitan and non-metropolitan zones respectively. The table also reveals that those who live in family homes are more likely to use modern energy (80%) than self-owners (57%) and tenants (48%) in the metropolitan zones.

In contrast, Table 5.7 shows that the majority of households in the non-metropolitan zone used transitional energy for lighting. The table shows that usage is higher for those living in rented accommodation (77%) and family houses (78%) in this zone.

The relationship between household mode of accommodation and class of energy use for lighting was tested. In other words, there was no relationship between mode of accommodation and energy class used for lighting in the metropolitan zone. In contrast, this relationship was found to be statistically significant, but weak, in the non-metropolitan zone ($p<0.000$ and Cramer's value: 0.169).

5.3.5 Number of Rooms versus Types of Energy Class for Lighting

Surprisingly, the results from Table 5.8 reveal no evidence of relationship between the number of rooms per household and class of energy use for lighting in either metropolitan or non-metropolitan zones. Coincidently, the findings from the household energy for cooking survey also show no relationship between this variable and energy class used for cooking.

Table 5. 8: Types of Lighting Energy vs No. of rooms Cross-tabulation

LGA Location	Types of Lighting Energy	2	3	4	5	>5	Total
Metropolitan	Traditional	14	16	11	15	12	**68**
		19%	14%	10%	21%	14%	**15%**
	Transitional	26	44	26	15	22	**133**
		35%	38%	24%	21%	25%	**29%**
	Modern	34	57	71	43	54	**259**
		46%	49%	66%	59%	61%	**56%**
	Total	**74**	**117**	**108**	**73**	**88**	**460**
		100%	100%	100%	100%	100%	**100%**
Non-Metropolitan	Traditional	7	35	30	25	32	**129**
		10%	31%	33%	32%	29%	**28%**
	Transitional	57	67	48	42	65	**279**
		79%	59%	53%	53%	60%	**60%**
	Modern	8	11	13	12	12	**56**
		11%	10%	14%	15%	11%	**12%**
	Total	**72**	**113**	**91**	**79**	**109**	**464**
		100%	100%	100%	100%	100%	**100%**

Independent Variables	**LGA Zones**	**Types of Energy Class for Lighting**		
		X^2 value	**p-value (2-sided)**	**Cramer's V value**
Number of Rooms	Metropolitan	16.176[a]	0.040	.133
	Non-metropolitan	17.756[a]	0.023	.138

[a] Pearson's value

5.3.6 Education versus Types of Energy Class for Lighting

Table 5.9 shows the relationship between the head of household's level of education and energy class used for lighting. It is worth clarifying here that the ranking of household educational level is limited to formal primary, secondary and higher education. Islamic education in the context of this study area refers to informal Islamic schools run by volunteer teachers without any government support.

Table 5. 9: Education vs Types of Lighting Energy Cross-tabulation

LGA Location	Types of Lighting Energy	Islamic	Primary	Secondary	Higher	Total
Metropolitan	Traditional	24	10	18	17	**69**
		26%	29%	14%	8%	**15%**
	Transitional	33	6	41	52	**132**
		36%	18%	32%	25%	**29%**
	Modern	35	18	68	140	**261**
		38%	53%	54%	67%	**57%**
	Total	**92**	**34**	**127**	**209**	**462**
		100%	100%	100%	100%	**100%**
Non-Metropolitan	Traditional	44	12	36	40	**132**
		21%	28%	35%	34%	**28%**
	Transitional	152	31	56	44	**283**
		72%	72%	54%	37%	**60%**
	Modern	15	0	12	34	**61**
		7%	0%	12%	29%	**13%**
	Total	**211**	**43**	**104**	**118**	**476**
		100%	100%	100%	100%	**100%**

Independent Variables	LGA Zones	Types of Energy Class for Lighting		
		X^2 value	p-value (2-sided)	Cramer's V value
Education	Metropolitan	33.586[a]	0.000	.191
	Non-metropolitan	58.644[a]	0.000	.248

[a] Pearson’s value

Heads of households who experienced primary (29%) or Islamic (26%) education used more traditional energy for lighting than heads of households who experienced higher (8%) or secondary (14%) education in the metropolitan zone. In contrast, heads of households who experienced Islamic (21%) or primary (28%) education used less traditional energy for lighting than those who had experienced higher (34%) and secondary (35%) education in the non-metropolitan zone.

Table 5.9 reveals heads of households who had experienced Islamic education (36%) used more transitional energy for lighting in the metropolitan zone. Similarly, households with Islamic (72%) and primary (72%) education are found using more transitional energy than the other types of education in the non-metropolitan zone. In addition, Table 5.10

shows that households with higher and secondary education are found more likely to use modern energy carriers for lighting than other types of education in both metropolitan and non-metropolitan zones. For example, 67% and 29% of households who had experienced higher education used modern energy carriers in metropolitan and non-metropolitan zones respectively. In contrast, only 38% and 7% of those with Islamic education are found using the same class of energy for lighting.

The results from this section were tested and found statistically significant ($p<0.000$) in both metropolitan and non-metropolitan zones. The strength of the relationship was found weak (Cramer's Value: .191) in the metropolitan and moderately strong (Cramer's Value: .248) in the non-metropolitan zone. This suggests that energy class used for lighting is dependent on heads of household's type of education. Further, the result suggests that the higher the level of education the more sophisticated the use of lighting energy class in both metropolitan and non-metropolitan zones. This finding is in agreement with Rahut et al., (2017) and Rahut et al., (2014) who showed that heads of households with higher level of education tended to use more modern energy carriers.

5.3.7 Age versus Types of Energy Class for Lighting

Table 5.10 indicates that households with older occupants, aged >60 (25%) are more likely to use more traditional energy for lighting than the households with younger occupants, aged 20-30 (18%), 31-40 (10%), 41-50 (16%) and 51-60 (13%), in the metropolitan zone. In contrast, households with older occupants use less (22%) traditional energy for lighting than younger householders, aged 20-30 (28%), 31-40 (26%), 41-50 (32%) and 51-60 (26%), in non-metropolitan zones.

Table 5.10 also reveals that older householders used less transitional energy for lighting than the younger householders in the metropolitan zone. In contrast, older householders are found using more transitional energy for lighting than the younger householders in the non-metropolitan zone.

Table 5. 10: Age vs Types of Lighting Energy Cross-tabulation

LGA Location	Types of Lighting Energy	20-30	31-40	41-50	51-60	>60years	Total
Metropolitan	Traditional	16	19	17	8	8	**68**
		18%	10%	16%	13%	25%	**14%**
	Transitional	16	53	39	28	6	**142**
		18%	29%	36%	45%	19%	**30%**
	Modern	57	113	52	26	18	**266**
		64%	61%	48%	42%	56%	**56%**
	Total	**89**	**185**	**108**	**62**	**32**	**476**
		100%	100%	100%	100%	100%	**100%**
Non-Metropolitan	Traditional	26	46	36	19	5	**132**
		28%	26%	32%	26%	22%	**28%**
	Transitional	52	115	58	44	17	**286**
		57%	64%	52%	61%	74%	**60%**
	Modern	14	19	17	9	1	**60**
		15%	11%	15%	13%	4%	**13%**
	Total	**92**	**180**	**111**	**72**	**23**	**478**
		100%	100%	100%	100%	100%	**100%**

Independent Variables	**LGA Zones**	**Types of Energy Class for Lighting**		
		X^2 value	**p-value (2-sided)**	**Cramer's V value**
Age	Metropolitan	22.930[a]	0.003	.155
	Non-metropolitan	7.062[a]	0.530	.086

[a] Pearson's value

Further, Table 5.10 indicates that younger householders are more likely to use modern energy for lighting than older householders in both the metropolitan and non-metropolitan zones. This result, to some extent, corroborates the findings of Rahut et al., (2017) who found that older householders tended to use more traditional energy carriers and less modern and transitional energy carriers in sub-Saharan Africa. In contrast, older householders tended to use more modern energy for lighting than younger ones in South Asia, Bhutan (Rahut et al., 2014).

These results were tested and found statistically significant in the metropolitan zone ($p<0.003$), although the strength of the relationship was very weak (Cramer's Value: .155). In contrast, despite obvious variations found among different age groups, there was no evidence of any relationship between the age of the head of household age and energy class use for lighting in the non-metropolitan zone.

5.3.8 Conclusion

The findings from this section have revealed that head of household level of education, income and occupation determined the type of energy class used for lighting in both parts of the study area. In addition, those householders with higher education, income or better job were less reliant on traditional energy carriers for lighting such as kerosene wick lamps. Moreover, these householders are anticipated to be more modernised then the rest. Consequently, this would increase more demand on energy in order to satisfy their life style.

Looking at other factors surrounding modern energy access in the study area, the next section will investigate whether those households that are less vulnerable to energy poverty for lighting are more satisfied with their energy situation in both the metropolitan and non-metropolitan zones.

5.4 Energy for Lighting Satisfaction vs Types of Energy Class for Lighting

Table 5.11 shows that only 55% of modern energy users in the metropolitan zone expressed satisfaction with their energy situation. In contrast, the majority of households in the non-metropolitan zone were satisfied with their energy situations. The table also indicates that most of the traditional energy users in both the metropolitan (66%) and non-metropolitan (54%) zones were dissatisfied with their energy situation.

Table 5. 11: Energy for lighting satisfaction vs Types of Energy Class

		Types of Lighting Energy			
LGA Location	**Energy for lighting satisfaction**	**Traditional lighting energy**	**Transitional lighting energy**	**Modern lighting energy**	**Total**
Metropolitan	Yes	23	47	139	209
		34%	34%	55%	46%
	No	44	93	112	249
		66%	66%	45%	54%
	Total	67	140	251	458
		100%	100%	100%	100%
Non-Metropolitan	Yes	60	252	47	359
		46%	88%	81%	75%
	No	71	36	11	118
		54%	12%	19%	25%
	Total	131	288	58	477
		100%	100%	100%	100%

Independent Variables	**LGA Zones**	**Types of Energy Class for Lighting**		
		X^2 value	p-value (2-sided)	Cramer's V value
Satisfaction	Metropolitan	21.270[a]	0.000	.215
	Non-metropolitan	85.273[a]	0.000	.423

[a] Pearson’s value

As shown in Table 5.11, the level of dissatisfaction with the energy situation, irrespective of energy class, is more obvious in the metropolitan zone than in the non-metropolitan zone. The relationship between class of energy for lighting and level of satisfaction was tested and found to be statistically significant ($p<0.000$) in both the metropolitan and non-metropolitan zones. The strength of this relationship was found to be moderate (Cramer’s Value: .215) in the metropolitan zone and very strong (Cramer’s Value: .423) in the non-metropolitan zone.

What is striking from Table 5.11 is that despite low levels of connection and limited hours of electricity, residents in the non-metropolitan zones were more satisfied with their energy provision than residents in metropolitan zones who experience greater access to the grid and larger periods of connection (for details about power duration see Table 5.12

in the next section). This differs from Aklin's et al. (2016) finding that power duration has the most significant impact on household lighting satisfaction in India, with dissatisfaction related to power scarcity. Adkins et al., (2010) found high satisfaction by householders switched from traditional to transitional energy carriers in rural Malawi. Interestingly, their findings are largely replicated in this study, with the non-metropolitan households showing high satisfaction with transitional energy carriers.

The findings from this study suggest that those who rely on transitional energy carriers for lighting are more satisfied than those who rely on the national grid. A possible explanation for this could be that there is narrow scope for energy end use (such as lighting, communication and charging phones) in the non-metropolitan zone, whereas the metropolitan households have a broader spectrum of uses including lighting, IT, communication, heating, washing, cooking, and so on. In other words, most of households' activities in the metropolitan zone are largely dependent on modern energy services.

5.5 Power Duration and Types of Energy Class for Lighting

Before examining the relationship between duration of electricity supply and types of energy used for lighting, it is necessary to give an overview of findings presented in Table 5.12. Table 5.12 reveals that a sizeable proportion (238 households) of non-metropolitan households are not connected to the national grid. In contrast, only 16 households in the metropolitan zone are not connected to national grid. In terms of duration of supply, Table 5.12 indicates that more than half of the households (237 households) in the metropolitan zone received less than 5 hours of electricity a day from the national grid, whereas the majority of households in the non-metropolitan zone who are connected to national grid receive less 3hrs of electricity in a day.

This indicates a wide gap between the metropolitan and the non-metropolitan zones in terms of access to electricity. A similar observation was made by Rahut et al., (2017) who found a wide discrepancy in electricity access between urban and rural zones in four African countries. Such discrepancy (of poor connection and supply) in the current study area may necessitate the use of alternative energy carriers such as LEDs lanterns (solar/battery) as highlighted earlier in section 5.2.2. Kumar (2015) also found that poor levels of access to the national grid incentivized use of both transitional and traditional energy classes in rural areas of Bihar, India.

Table 5. 12: Types of Energy Class vs Electricity duration from National grid Cross-tabulation

LGA Location	Types of Lighting Energy	Not connected	<3hrs	3-5hrs	6-7hrs	8-10hrs	>10hrs	Total
Metropolitan	Traditional lighting energy	9	6	26	13	10	1	65
		56%	15%	11%	11%	18%	7%	14%
	Transitional lighting energy	3	11	86	32	11	0	143
		19%	28%	36%	28%	19%	0%	30%
	Modern lighting energy	4	23	125	69	35	14	270
		25%	57%	53%	61%	63%	93%	56%
	Total	**16**	**40**	**237**	**114**	**56**	**15**	**478**
		100%	100%	100%	100%	100%	100%	100%
Non-Metropolitan	Traditional lighting energy	71	47	16	0	0	0	134
		30%	41%	21%	0%	0%	0%	28%
	Transitional lighting energy	146	56	50	15	5	16	288
		61%	48%	68%	54%	56%	100%	60%
	Modern lighting energy	21	13	8	13	4	0	59
		9%	11%	11%	46%	44%	0%	12%
	Total	**238**	**116**	**74**	**28**	**9**	**16**	**481**
		100%	100%	100%	100%	100%	100%	100%

Independent Variables	LGA Zones	Types of Energy Class for Lighting		
		X^2 value	**p-value (2-sided)**	**Cramer's V value**
National grid Duration	Metropolitan	42.597[a]	0.000	.211
	Non-metropolitan	69.477[a]	0.000	.269

[a] Pearson’s value

Although the figures of non-electrified households seems very high, the percentage of those connected, even in the non-metropolitan zone, contradicts previous figures supplied by other organisations such as FMPS (2006). This suggests that there has been a tendency to exaggerate these figures. Therefore, what is obvious from these findings is that more than half of the households only receive power for a short period of time. In addition, the supply is quite unreliable and poor quality at times. This situation as highlighted in the literature (Chapter 2) is one of the main drivers for considering for alternatives energy sources in the study area.

The relationship between lighting duration and the energy class used for lighting was tested and found to be statistically significant in both metropolitan and non-metropolitan zones ($p<0.000$). The strength of relationship was found to be moderately strong in the non-metropolitan zone (Cramer's Value: .269) and moderate in the metropolitan zone (Cramer's Value: .211).

Thus, findings from this section suggest that apart from socio-economic determinants of household energy for lighting, these two contradicting pictures shown in Table 5.13 are also critical in determining the class of energy use in both metropolitan and non-metropolitan zones. In other words, the table has shown the geographical differences in terms of power duration and levels of access to the national grid between the two zones.

5.6 Major Barriers Preventing Energy for Lighting Transition

Table 5.13 shows that 77% (372 households) of households in the non-metropolitan zone are facing barriers preventing transition to modern energy class for lighting. About 29% (140 households) of households in the metropolitan zone face similar barriers.

Table 5. 13: Major Barriers for Traditional & Transitional Lighting Energy Users

Barrier	Number of Households & % (Metropolitan)		Number of Households & % (Non-metropolitan)	
Cost of energy source and appliance	24	17%	111	30%
Tradition and Safety	31	22%	53	14%
Large family	11	8%	38	10%
Govt. policy and Scarcity	18	13%	59	16%
Low income	56	40%	111	30%
Total	140	100%	372	100%

Source: Author's Field Survey, 2017

As shown in Table 5.13, there are differences in the major barriers preventing transition to use modern energy for lighting in the metropolitan and non-metropolitan zones. Major barriers in the metropolitan zone include low income, tradition and safety and the cost of energy and appliances. Major barriers in the non-metropolitan zone include cost of energy and appliances, low income and a combination of government policy and scarcity.

5.6.1 Cost of Energy Appliances

Table 5.13 indicates that the impact of cost of energy appliances is more severe in the non-metropolitan zone (30%) than the metropolitan zone (17%). This suggests that this variation may be due to income differences between the two zones of the study areas as highlighted previously in section 3.3.11.1.

5.6.2 Low income

Table 5.13 reveals that low household income is the most important barrier (40%) preventing use of modern energy for lighting in the metropolitan zone. Similarly, about 30% of households in the non-metropolitan zone are unable to transition to modern energy for lighting because of low income. The table also indicates that a sizable proportion of households in the non-metropolitan and metropolitan zones are facing problems of low income when transitioning to modern energy services respectively. Income poverty has been identified as one of leading barriers preventing use of modern energy services in Yemen (El-katiri, 2011).

5.6.3 Other Barriers

Other key barriers include tradition/safety and government policy/scarcity metropolitan and non-metropolitan zones respectively. Ironically, the majority of households in the metropolitan zone were connected to the national grid, but concerns around tradition and safety might be preventing them from using alternative sources of modern energy for lighting. Tradition in this context means ‘conservatism’ or sticking to what has been used in the past. Another possible explanation is that they perceive their current energy classes (traditional and transitional) to be more reliable than the conventional grid. This suggests that despite poor quality of lighting provide by their energy carriers, most of these householders prefer to use them as their primary energy class.

Table 5.13 indicates that poor government policy and scarcity of modern energy infrastructures prevent about 16% and 13% of households in the non-metropolitan and metropolitan zones respectively from transitioning to modern energy services. As shown in Table 5.13 earlier, this problem is more severe in the non-metropolitan zone. This suggests that this barrier is largely caused by failure of policy makers to provide adequate power, particularly in the non-metropolitan parts of the country (see: 1.1.3). This finding raises a question of energy justice, particularly, in the non-metropolitan areas. A further exploration with more focus on energy justice in the non-metropolitan areas is therefore recommended. As highlighted earlier in section 5.5, the lack of grid connection in the non-metropolitan zone could be the most critical barrier to adoption of modern energy services. Lack of connection to the grid has been identified as one of the leading barriers preventing transition to modern energy use for lighting in most rural parts of sub-Saharan Africa (Kojima et al., 2016).

5.7 Summary and Conclusion

This chapter has explored the status of energy for lighting in the study area and controlling effects of socio-economic status. The results have shown that the majority of households in the metropolitan zone rely on modern energy for lighting whereas the majority of households in the non-metropolitan depend on transitional sources. The use of traditional energy for lighting in both metropolitan and non-metropolitan zones was found low. This suggests that the energy transition for lighting is clearly underway in the context of the study area.

The results from this chapter have indicated that a householder income, occupation and level of education are significant in determining class of energy use for lighting in both metropolitan and non-metropolitan zones. However, the strength of these relationships were not strong as shown by the Cramer's V results.

As highlighted in this work, geographical difference is not necessarily an excuse for restricting access to modern energy for lighting in rural parts of developing countries. As reported earlier in this chapter, electrified rural communities in Bhutan used less traditional energy carriers for lighting services. This suggests that the failure to transition to modern energy for lighting in the non-metropolitan zone could be largely due to poor energy policy.

The findings from this chapter contribute to the literature of household energy poverty and transition by expanding its scope to include the component of energy for lighting. As highlighted earlier, this component has been neglected in most household energy studies that use either the energy ladder or energy stacking model. This chapter has defined and explored characteristics of household energy transition in the study area.

Further, the findings from this chapter can also contribute to the field of energy policy. The findings can help policy makers when searching for an alternative to the national grid (particularly in the non-metropolitan areas) and should not focus on fossil fuel sources such as kerosene. As highlighted in this chapter, the majority of householders have abandoned traditional energy sources for lighting such as kerosene. This is because the government programme for household kerosene (HHK) distribution has been counterproductive (Naibbi & Healey, 2014) with limited geographical coverage (Odihi, 2003). This suggests that solar-based energy carriers may provide a credible alternative, especially in the non-metropolitan zone.

Therefore, the next chapter will explore solar energy and its potential to address household energy poverty for lighting in the study area. The major themes of this chapter include solar RET drivers, barrier and sustainable solutions for solar transition.

5.8 Synthesis of Chapter 4 and 5

This section distils the key findings from chapters 4 and 5. It is evident from these chapters that the two energy services under investigation share some similarities and differences. Thus, synthesising such characteristics could shed more light on the current trends of energy poverty and energy transition for both energy for cooking and lighting in the context of the study area.

5.8.1 Models and Characteristics of Household Energy for Cooking and Lighting

Analysis of the survey results revealed sizeable proportions of households in both metropolitan and non-metropolitan zones using only a single energy carrier for cooking and lighting. The use of one energy carrier (irrespective of its class) reflects one of the core tenets of the energy ladder (van der Kroon et al., 2013). However, the results from chapters 4 and 5 reveal that there were more single energy carrier users in the traditional class in the non-metropolitan zone than the metropolitan zone. The findings from the household energy for lighting survey shows that nearly a quarter of the non-metropolitan's households rely on transitional energy carriers for their lighting services. In contrast, only 1% of the metropolitan households were found using this energy carrier.

The findings from the household energy for cooking and lighting survey revealed that there were a few users of a single modern energy carrier. The majority of these users live in the metropolitan zone.

In contrast, the findings from both chapters indicate that the majority of households in both metropolitan and non-metropolitan zones were found to be using multiple energy carriers for cooking and lighting. Use of multiple energy carriers underlines the central assumption of the energy stacking model (Masera et al., 2000). As found in chapter 4, the majority of the households in both metropolitan and non-metropolitan zones were using energy stacking for cooking with a traditional energy carrier as the primary source. This is more evident in the non-metropolitan zone. In contrast, the use of multiple energy carriers for cooking with a modern energy carrier as a primary carrier is higher in the metropolitan zone.

For household energy for lighting, the results reveal that more than half of households in the metropolitan zone rely on multiple energy carriers for lighting with modern energy source as their primary energy carrier. In contrast, transitional energy is the primary carrier for lighting in the non-metropolitan zone, with stacking of other carriers in this zone. Possible explanations for this were discussed in in sections 5.2.2 and 5.5.

To this end, these findings reveal that there were more households in the non-metropolitan zone that rely on a single traditional energy carrier for both cooking and lighting. In contrast, use of energy stacking for both cooking and lighting with a modern energy carrier as a primary carrier was higher in the metropolitan zone.

This study has revealed that there is more use of modern energy for both cooking and lighting in the metropolitan zone than in the non-metropolitan zone. In the context of lighting, most households have abandoned the traditional carriers in favour of transitional carriers in the non-metropolitan zone. Similar trends have been reported in other SSA countries (Bensch et al., 2015). In addition, this study has revealed that the majority of households practice energy stacking for both cooking and lighting. Use of multiple energy classes does not necessarily mean using them for a single purpose, rather, they provide multiple energy services (Enslev et al. 2018). In contrast, a handful of households continue to use single energy carriers for both cooking and lighting. This mirrors trends in other developing countries, where households use different energy carriers for lighting.

5.8.2 Hypothesis

The two chapters explore hypothetical relationships between household socio-economic status and energy class used for cooking and lighting. The results for energy for cooking in Chapter 4 reveal that the household level of income and education have highly significant relationships in both metropolitan and non-metropolitan zones. In contrast, income, occupation and education were found to have a cross-zonal effects on household energy for lighting in both metropolitan and non-metropolitan zones. However, the strength of these relationships varied according to Cramer’s V tests.

Findings from both chapters have revealed that some of the socio-economic indicators have opposing effects on energy classes for cooking and lighting. Only education and income have similar effects on the choice of energy for cooking and lighting. The findings have illustrated that education and income are the most critical socio-economic indices that determine household energy class for cooking and lighting in the metropolitan and the non-metropolitan zones.

This study draws on two conclusions from these findings:

- Since the relationship between householders' level of education and energy class used for cooking are little stronger than other variables, this suggests that the use of modern energy for cooking is more or less a reflection of transition to 'modernity' in regard of a particular household. As earlier revealed in Chapter 4, those who have experienced higher levels of education tend to use more modern energy carriers for cooking in both metropolitan and non-metropolitan zones. Nevertheless, this study recommends further research to explore how level of modernization determines use of modern energy for cooking in the study area.
- The findings from household energy for lighting indicates that effect of 3 variables (income, occupation and education) across the study area for using a particular energy class. Moreover, the findings suggest that a causal link exists between these 3 variables in relation to increase use of modern energy carriers for lighting. For example, householders that belong to: higher income groups (N>55,000); are mostly engaged in civil service occupation and have experienced higher education are found to use more modern energy class for lighting in both metropolitan and non-metropolitan than zones other householders without these qualities. This suggests that these householders have more awareness of alternative energy carriers for lighting, and can afford the cost of modern appliances aside from the national grid.

Finally, although the findings from these chapters indicate that there are differences in terms of relationships between the household socio-economic status and energy class used, it has been observed that these variations are well moderated by locational differences between the two zones in the study area. This suggests that the energy stack-ladder of a particular context are highly influence by locational properties as similarly observed by Hosier & Dowd (1987) and Nansoir et al. (2013) in their studies for the energy ladder and energy stacking in Zimbabwe and Thailand respectively.

5.8.3 Satisfaction

Regarding energy satisfaction, householders of both the metropolitan and non-metropolitan zones expressed more satisfaction with modern energy for cooking. Surprisingly, the majority of these households were found using traditional energy classes for cooking. In contrast, the majority of households in the non-metropolitan showed more satisfaction with transitional energy carriers for lighting than those using modern energy carriers. Overall, the findings suggest that, irrespective of energy class, availability of energy has profound implications on energy satisfaction. However, this relationship between energy availability and satisfaction requires further, in-depth investigation.

5.8.4 Barriers

As revealed from the two chapters, the major barriers preventing transition to modern energy classes were cost of energy and low income. In addition, an important insight gained from the two chapters is that socio-cultural barriers (such cooking preference and extended family) are critical in choice household energy for cooking and affect virtually all households in both the metropolitan and non-metropolitan zones. In contrast, government failure to extend the national grid to remote areas largely affects the non-metropolitan zone.

Comparing the outcomes of the two chapters, it is obvious that a lighting energy transition is taking place, and at faster pace than it is for cooking. The findings from chapters 4 and 5 suggest that energy transition for lighting could be more likely than the energy for cooking, because the system of energy for cooking is more complex and less formal. Hence, this can curtail the effort of policy makers in realizing a full transition in sub-Saharan Africa (Sokona et. al, 2012). Consequently, the next chapter will explore the possibilities of transitioning to solar RETs to alleviate household energy poverty for lighting.

Chapter 6: Energy Transition: Exploring Solar Energy as a Solution to Lighting Energy Poverty and Barriers to Uptake

6.1 Chapter Overview

As has been highlighted in chapter 5, energy for lighting has received less attention than energy for cooking in academic circles. Furthermore, Van der Kroon et.al (2013) observe that the vast majority of the literature in the field of energy transition neglects renewables options in their discourse. This chapter adopts the framework of the energy stack-ladder to explore drivers for solar renewable energy technologies (RETs) for lighting and barriers preventing their uptake. This chapter addresses objectives 3 and 4 of the thesis: *To explore drivers and barriers to the uptake of solar RETs for lighting; and to evaluate whether and how these technologies can help alleviate energy poverty (for lighting) at household level.*

Although the objective indicates that the main focus is on the household, it should be acknowledged that household energy systems cannot be disentangled from large scale energy systems for power generation. Hence this chapter focuses on drivers and barriers affecting both small scale solar appliances and large scale solar RETs.

The results from this chapter were gathered from solar RETs stakeholders. As has already identified in chapter 3, these include:

- Federal government stakeholders: these are stakeholders representing federal government for energy management nationwide. This study conducted interviews with the Federal Ministry of Power and Steel (FMPS) and the Energy Commission of Nigeria (ECN).
- State government stakeholders: these are representatives from the state Rural Electrification Board (REB) and office of the Sectary to the State Government (SSG).

- Vendors' stakeholders: these stakeholders include solar RETs vendors and private companies that participate in solar business. They range from small shops to well-established companies, occasionally with multinational ties.
- NGOs stakeholders: these are NGOs promoting use of alternative energy sources for lighting in the study area. Some of these NGOs promote, for example, solar power for rural water supply or irrigation.

In addition, this chapter uses a selection of responses from the open-ended and closed-ended questionnaire issued to households in the metropolitan and non-metropolitan zones.

Thematic analysis was employed to analyse the data generated from the semi-structured interviews with solar stakeholders. This was conducted in a hybrid manner, involving both inductive and deductive approaches (Fereday & Muir-Cochrane, 2006). The outcomes from thematic coding produced the following major themes: Drivers for solar RETs adoption: 'push' and 'pull' drivers; Barriers to solar RETs adoption: socio-economic, socio-technical and market and socio-political barriers; and Barrier removal measures for solar RETs transition: socio-economic, sociotechnical and socio-political and financial interventions (see Appendix IV).

The chapter is organised around the following themes: Section 6.1 presents an overview of the chapter. Section 6.2 explores the drivers for solar RETs uptake. Section 6.3 examines the major barriers impeding this uptake. Section 6.4 explores how barriers may be removed, to promote solar RETs adoption and alleviate household energy poverty for lighting. Finally, section 6.5 presents a model for solar RETs uptake.

6.2 Drivers for Household Solar RETs Transition

The findings of the interviews with multiple stakeholders indicate ‘push’ and ‘pull’ factors in relation to solar RETs adoption. Push factors include power shortages, high electricity tariffs and the high cost of running generators. In contrast, pull factors include availability of resource, solar RETs market expansion and ongoing awareness.

6.2.1 Push Factors

Push factors are borne out of less favourable conditions that necessitate adoption of alternative energy carriers including solar RETs. These include power shortages, high electricity tariffs and costs of operating and maintaining generators.

6.2.1.1 Power Shortages and Coverage

The majority of the stakeholders stated that power shortages were the most important driver for solar RETs uptake. One government official lamented:

> “With our population of almost 200 million we are still talking about less than 4000MW stable electricity. For our population we should be talking of at least 100,000 MW. So, there is large gap between demand and supply of electricity in the country. And so many individuals are trying to solve that problem, that is why people are going into RETs to solve their energy needs” (Federal Government Stakeholder 01).

Apart from power shortages, another issue prompting the use of solar RETs in Nigeria is poor coverage of the national grid, especially in the non-metropolitan zones. As already highlighted in Chapter 5, the majority of households in the non-metropolitan zones are not connected to the national grid. One of the energy experts in the energy research centre commented on this:

> “We do not also have enough [electricity] to go round, particularly those in the rural areas where this the grid did not even reached. So we advocate the use of RE as an alternative” (Energy Expert).

Acute power shortages have been identified as one of the major factors influencing transition to solar RETs in Nigeria (Ohunakin et al. 2014; Mas’ud et al., 2016). This problem is exacerbated in non-metropolitan zones where the majority of households have no access to electricity (Oparaku, 2002). This implies that the motivation for adopting solar RETs for electricity in the metropolitan zones is to find a viable alternative to the grid, whilst in the non-metropolitan zones this is seen as the only means of obtaining reliable electricity. Sokona et al., (2012), suggest that due to the scattered nature of households in most parts of non-metropolitan Africa, solar RETs could provide a more cost effective means of supply electricity to these areas than extending gridlines.

6.2.1.2 High Electricity Tariff

Another driver for solar RETs uptake is the recent increase in the electricity tariff in Nigeria. Ironically, despite poor supply of electricity by the national grid, there has been a significant hike in price of electricity. Tariffs have increased by 142 % over the last ten years as reported by the Vanguard newspaper (Vanguard, 2017). One of the solar vendors felt that the recent increase in electricity bills makes solar RETs more attractive than ever before:

> “…….now people are going for it [solar], you see the type of bills NEPA are bringing, people are complaining. So, people are going into it [solar] because they know the benefits of it” (Vendor 2).

Although, solar energy was widely found to be used as a backup energy source in the metropolitan zone, some stakeholders claimed (interviewed) that they had already disconnected from the national grid lines in favour of solar RETs for their households' energy services.

6.2.1.3 High Cost of Maintaining Generators

Use of diesel or petrol generating sets for electricity is a common place in Nigeria (Ohimain, 2013). As observed during the fieldwork, this was very visible in many households, commercial centres, health centres, schools and government offices. Ironically, only recently the Federal Ministry of Power signed a contract to install solar RETs at its headquarters in Abuja. However, current policy in the energy sector, which marked the end of subsidy for fossil fuels, has forced energy prices up. Two of the solar RETs vendors commented on this issue as follows:

> "Before, people used generators, due to increased price of fuel, price keep increasing, so people they have looked for an alternative" (Vendor 8).

> "So, everybody is looking for alternatives, the main alternative we have is generator sets which is increasing in cost because of increase of price in fuel" (Vendor 9).

The views from these vendors suggest they are happy with the removal of subsidy from fossil fuels, which makes the use of generators more expensive and solar RETs more competitive in the market place. In addition, the upfront price of generators has increased due to high inflation and the on-going currency crisis in Nigeria.

6.2.2 Pull Factors

In contrast to 'push factors', the pull factors are types of drivers that are borne out of the anticipated benefits of solar adoption. Major themes include availability of resource, solar RETs market expansion and ongoing awareness.

6.2.2.1 Resource Availability:

The study area has significant resource potential (see section 2.4.4 and Figure 2.5). Some of the stakeholders felt this potential was being wasted and should be utilized to address the long-standing problem of energy poverty.

> "When you say solar, you are talking about sun, this the fundamental source. In fact, we have it in abundance here. I want to believe that is very important. Availability is there 100%" (State Government Stakeholder-01).

And also:

> "Solar is renewable and sustainable. I think it is our best bet in Northern Nigeria where we have high solar intensity. Why in Northern Nigeria? Because it is hotter compared to the southern and eastern Nigeria. So in northern Nigeria, we should focus on [it]" (NGO-01).

Nigeria is endowed with an abundance of solar energy to power generation all year round (Mas'ud et al., 2016). It has been estimated that only 0.1% of the total solar potential on Nigeria's landmass needs to be exploited to address the country's energy poverty (Bugaje, 2006b). Significantly, northern Nigeria's solar resource potential is considered to economically and socially viable for solar electrification (Ley et al. 2015). If the solar potential is to be harnessed effectively in the northern part of the country, the electricity gap between the north and south could be closed.

6.2.2.2 Ongoing Awareness and Market Expansion:

Ongoing awareness and the market expansion of solar RETs are some of the factors driving the diffusion and adoption of solar RETs. However, there are contradictory views on this theme:

> "I think the first thing in terms of acceptability we need to look at the awareness of the solar technology which is very low if you take away the elite class or the educated category of the population of Kano State" (NGO-04).

As observed from this stakeholder's perspective, awareness is mainly limited to those that are well-educated or upper class among society. Level of education has previously been identified as a key factor motivating use of modern energy in developing countries (Rahut et al. 2017). However, this notion of "exclusive awareness" has been challenged by one of the solar RET vendors who claimed that the awareness is growing among householders in the study area:

> "Demand has been increasing, with the growing awareness demand has been increasing. Virtually you now see people from the villages coming to buy small solar appliances like solar lamps with one or two bulbs, solar torch lights [lanterns] are very much in demand" (Vendor 09).

The views of these stakeholders is interesting in the sense that NGO 4 is commenting on solar home systems, which are quite large and unaffordable for the majority of the householders in the study area. In contrast, Vendor 9 is commenting on smaller scale solar appliances for lighting, which are now more common in the non-metropolitan zone in the form of solar lamps and lanterns. Lanterns and other solar devices are now being used for household lighting in most SSA countries (Grimm et al., 2014; Bensch et al., 2015).

From personal encounters and observations during the fieldwork, it was obvious that there are numerous solar marketers in the metropolitan zone of the study area. These range from small shops to international companies, mostly from China. This gives rise to expansion of solar RETs businesses and diffusion of solar products in the study area.

In addition, there has been a campaign organised by foreign organizations in conjunction with the Federal Government.

> "Presently we have Nigerian Energy Support Programme (NESP), this is funded by GIZ (Germany) and European Union. Under this, a lot of awareness been created through meetings, flyers and leaflets to create the awareness that RE is the way to go. So currently, they are helping us to propagate the news. Looking at Nigeria as a very large and disperse country, obviously, we need to do more in terms of on encouraging the use of RE and also more of information sharing" (Federal Government Stakeholder- 01).

It is obvious from this view that the level of these campaigns is not sufficient to create the required awareness for wider diffusion and adoption. In addition, views from section 6.3.1.2 reinforce this observation.

In summary, the drivers for transition to solar RETs transition include power shortages, poor coverage of remote areas and high costs of maintaining generators which have been the main alternative to the national grid. It is apparent from the findings that none of these drivers are motivated by environmental concern such as carbon reduction or climate change mitigation. Equally, there are no clear signs of government encouragement for solar RETs adoption. This section has demonstrated that solar RETs have the potential to alleviate household energy poverty for lighting, however, these drivers coincide with barriers obstructing solar RETs uptake as discussed in the next section.

6.3 Barriers to Solar RETs Adoption

Table 6.1 shows major barriers preventing solar RETs uptake at household level. As indicated in the table, initial cost of solar RETs was the most significant barrier in both the metropolitan and non-metropolitan zones. Other significant barriers include lack of awareness, large family size and lack of quality.

Table 6. 1: Major Barriers Preventing Solar Adoption

Barriers	**Metropolitan Zone (No. of HH)**	**%**	**Non-Metropolitan Zone (No. of HH)**	**%**	**Total**
Family size	34	10%	59	15%	93
Initial Cost	217	62%	194	51%	411
Lack of Awareness	53	15%	51	13%	104
Lack of Quality	36	10%	14	4%	50
Others (including combination of the above)	11	3%	66	17%	77
Total	**351**	**100%**	**384**	**100%**	**735**

Source: Author's Field Survey, 2017

In addition, when conceiving this topic, societal acceptance was considered a barrier to solar RETs adoption. However, this was not the case as many householders were accepting of the technology and testified on their good prospects in the near future. In addition, when asked about levels of acceptance by the general public, solar vendors stated that public acceptance was not an issue:

> "Acceptability I can say is almost 100%, because we are in a situation whereby the grid is not available. When it comes on sometimes it is erratic, sometimes get your appliances burnt, high voltage and what have view. So, everybody is looking for alternatives". (Vendor 09).

Despite the drivers identified earlier in this chapter and the level of acceptance of solar RETs by the consumers, the solar stakeholders claimed that there were major barriers to be overcome before solar RETs could be fully adopted in the study area. Interviews with key solar stakeholders revealed 3 major barriers: socio-economic, socio-technical and socio-political.

6.3.1 Socio-economic Barriers to Solar RETs Adoption

Socio-economic barriers are associated with householders' socio-economic status. There are two major barriers under this theme: initial cost and low income and lack of awareness.

6.3.1.1 Initial Cost and Low Income

The household energy survey revealed that the main barrier to solar RETs adoption was initial cost in both metropolitan and non-metropolitan zones of the study area (see Table 6.1). Likewise, interviews revealed that there was consensus among all stakeholders that initial cost and low income were the fundamental barriers to solar adoption in the study area.

> "The major obstacles that is preventing this solar product not moving very fast in the market is the financial aspect of it [solar], the price is very high" (Vendor 5).

One of the participants commented further on this:

> "The barrier is one and only one: the economic constraint. The price of the goods [solar appliances] is very high, and then income, people's income…… there is austerity generally, poverty. The price of this solar installation is high [initial cost and low purchasing power]. Because if you want to enjoy solar installation, at least you need N150, 000." (Vendor 08).

Initial cost of solar RETs and low income are identified as the key socio-economic barriers preventing household energy transition in many developing countries (Reddy & Painuly, 2004; Lay et al., 2013; Pode, 2013). The findings from this study reinforce this view in respect of individual householders.

6.3.1.2 Lack of Awareness

Although the solar markets in the study area are expanding, particularly in the metropolitan zone, it was evident from interaction with the solar vendors that there are still a reasonable number of householders that are not aware of its long term benefits. One of the solar vendors argued that there were rich householders who did not appreciate the benefit of adopting solar RETs:

> "The major thing is problem of awareness. Because there are some people who have enough money, but they don't have knowledge or information about that products [solar], but once they get, they may buy it." (Vendor 10).

This view contradicts previous findings on cost and low income barriers. It demonstrates that lack of knowledge is also a crucial factor in solar RETs uptake. It has been documented that there has been poor awareness regarding socio-economic benefits that can be derived from adopting solar RETS in Nigeria (Ohunakin et al., 2014). Furthermore, lack of awareness on proper usage of solar RETs by householders impedes their gaining the full benefits from using solar RETs (D'Agostino et al., 2011).

6.3.2 Socio-technical and Market Barriers

Socio-technical barriers relate to issues of confidence in the quality of solar RETs and the challenges faced by unqualified technicians. In other words, some stakeholders consider technical knowledge and understanding to be more of a barrier to adoption than cost, income or awareness. Moreover, the stakeholders lamented on frequent use of substandard solar RETs and intrusion of unqualified solar technicians into solar design and installation. All these combined to erode confidence of householders in these technologies.

6.3.2.1 Lack of Confidence

There has been some literature on the use of low quality solar components in developing countries. These include storage and panel components (Müggenburg et al., 2012; Ohunakin et al., 2014; Karakaya & Sriwannawit, 2015). Some batteries have short lifespans and panels can be of substandard quality. The majority of solar modules are obtained from markets. Small solar RETs in some developing countries are perceived as low quality products (Müggenburg et al., 2012). This has been identified as a source of major concern in relation to uptake. One solar vendor commented:

> "the availability of fake products in the market is what affecting majority of the people not to partake in it." (Vendor 05).

In contrast, one of the solar vendors argued that householders did not express much concern over the quality of solar products:

> "People mostly don't worry about quality products; they only worry about the cost. As long as something is cheap, they will accept it. ……. So mostly, people accept something which is cheaper; they don't care about how quality that thing is". (Vendor 07).

This view reveals that there is a dilemma between cost and quality. This could be particularly true for the low-income householders in the study area. It might be linked to their low socio-economic status and their desperate needs for energy alternatives. In contrast, findings from Ethiopia revealed that householders' dissatisfaction with Chinese products led them to opt for more expensive high quality solar RETs (Müggenburg et al., 2012).

The findings from the interviews indicate that the use of substandard solar RETs goes beyond the household level in the study area. It extends to solar projects meant for community utilization. Some of these problems are onsite, such as use of substandard materials in solar projects. This affects the lifespan of solar modules and their efficiency. Most of these community projects are in the form of solar streetlights and for productive use such as rural water supply.

The success of a solar RETs project depends on the quality of solar RET components. Stakeholders from Government and Research Centres have commented on this issue.

> "So because of the huge substandard materials and lack of knowledge of proper sizing of the systems…… perhaps a poor design, you have also a poor system, it will not operate adequately. That is why mainly the failure is due to the use of substandard materials and poor design. These are the main factors. Particularly the streetlights that are being used in Nigeria, the failure rate of this system is very high. This is usually due to substandard materials" (Energy Expert).

> "We have a lot fake materials here, especially the solar panels; these substandard ones that are brought from China. People do bring them because of gain ….for financial this thing [profits]" (Federal Government Stakeholder-02).

There are a few standard solar RETs in the market. However, because of the nature of contract in Nigeria that involves lots of selfish interests that is why quality of large solar RETs in many projects has been compromised. This lack of transparency affects solar RETs projects adversely as posited by one respondent:

> "…… You know recently in Nigeria, if you want to give a contract, you will give it to politician who have to maximize profit, so by trying to maximize profit you will use substandard materials also. So that is the problem and the engineers, the supervising engineers compromise, and that is corruption" (Energy Expert).

From personal interaction with different stakeholders, it was obvious that the majority of solar RETs components were imported from China. In addition, there was a negative perception of Chinese products among the householders as well as vendors. However, one may argue that this blame cannot put on Chinese manufacturers alone, rather it is connivance between the two parties: Nigeria's solar dealers and Chinese manufactures.

6.3.2.2 Unqualified Technicians

Another sociotechnical problem lies in engaging the services of unqualified technicians for solar RETs installation. During the fieldwork exercise it was observed that the majority of the solar vendors take part in installation services in addition to their normal business ventures. There was also evidence of independent technicians at work who install the solar components once purchased from the vendors. Most of these technicians do not understand the basic requirements for successful installation and connection:

> "…there are people who are not very qualified of handling of solar and they have gone into the business and they have caused tears to some people" (Vendor 09).

This view is not only shared among solar vendors, but public officials and experts alike:

> "We have so many 'quacks' and non-professionals [technicians] in the system. And even in these days, people still doubt the possibility of powering their homes and businesses using solar energy. Because they have seen more failed projects than ones that work" (Federal Government Stakeholder-01).

These views reveal an existential threat to future solar RETs uptake in the study area. Unless government take this threat seriously, many householders will be discouraged from adopting this technology. The problem of unqualified technicians preventing solar RETs transition has not been documented in other studies.

6.3.3 Socio-Political Barriers: Policy & Finance

The barriers identified under this theme include: lack of financial incentives, poor monitoring of imported materials and lack of government commitment. These barriers have overarching impacts on the other two barriers (socio-economic and socio-technical).

6.3.3.1 Lack of Financial Incentives

One of the key issues affecting solar RETs uptake in Nigeria is policy and regulation. It is worth stating here that there is no RE policy at the state level as revealed by one public official. In contrast, there are RE policies at federal level, particular for solar RETs adoption. However, such polices have not been promoted in many respects as revealed through the interviews with federal government stakeholders. For example, a solar RETs subsidy to householders has not been traced during the data gathering of this work (for both survey and interviews). Some solar stakeholders commented on this view:

> "As I said earlier we are trying policy for now, the waivers and the 'tax holidays' have not been fully implemented" (Federal Government Stakeholder-01).

Neither federal government nor state government give incentives for solar RETs adoption. Absence of incentives in terms of tax waivers to potential investors and importers poses a serious challenge to solar RETs for community projects. Likewise, lack of subsidy deters widespread adoption by individual householders. Moreover, none of the solar vendors or householders interviewed stated they had received any incentive from the government. One Federal Government Official disclosed that the policy of providing incentives is underway but they were waiting for a response from the government:

> "No as of now, we don't give for now. But we have written to the govt., I think they are going to act on it. That is not yet ready" (Federal Government Stakeholder-02).

Unfortunately, the initial cost of solar RETs has been identified as the major barrier to their adoption in the study area. Indeed, without subsidizing the price of solar RETs, the transition to solar power at household level will be kept on hold, particularly for low income households.

6.3.3.2 Poor Monitoring of Imported Materials

Another dimension of government policy failure relates to reports of many of substandard solar RETs modules being imported into the country, from China in particular (Ohunakin et al., 2014). There have been reports of disputes between solar vendors/technicians and their customers. This study reveals that there has been no restriction on imports of such materials which carry no seal of quality from any safeguarding organisation under the federal government. In most cases, solar vendors/technicians have to rely on a brand's reputation before they buy, as stated by one vendor:

> "Well, from my experience, from where we buy these [products], I have never seen any standard quality code. Because the way things are going on, one can easily go to China and say please I need these so, so products because of the demand by the public. So they go ahead, you know, people just import any how panels without any code or following due process like that. Like SON [Standard Organisation of Nigeria] which I know are the governing body of all these consumable items. So can hardly find a product like this solar system, you hardly find this 'logo' of SON. You hardly see it there! That is to tell you that people do go and import whatever they want. For us here, [at company level] I use my own way of assessing all these solar products and whatever. If I buy this I know which is good, which one is bad. You know if you go to the market you can find different brands……… which if you buy them at the end of the day you end up maybe losing your money or may be you will end up in the police station." (Vendor 05).

This shows that a quality watchdog organisation does exist, but is ineffective. This illustrates a fundamental institutional failure of government (Ohunakin et al., 2014). It implies from what this stakeholder has commented, that the use of substandard solar RETs causes many conflicts between solar vendors and their clients.

6.3.3.3 Is Government committed to Solar RETs Uptake?

There are contradictory views regarding the government's commitment to solar RETs uptake. Some stakeholders felt that the government was not doing enough to promote the solar sector. They accuse the government of lack of commitment for transition to solar RETs at both state and federal level.

> "You know the problem we have is that we don't have committed government toward solar energy, because if you look at most of the govt. buildings like institutions, federal and state institutions, you can barely find solar system functioning in that institution, which is very bad. That's to tell you that govt. is not even encouraging these solar system in the society. Because they are supposed to be number one and they should be the first example" (Vendor 05).

An NGO participant added:

> "Actually, government to me as we are talking at the state level, I don't think they are committed. To me they are not entirely. Because you go to our street now, they are trying very hard to light up the street, spending a lot of money on diesel, why? If they are committed solar is there, they can handle it, they can do it. And if you go to the government house they are always consuming diesel. So they are not committed in any way" (NGO 02).

In contrast, there are some stakeholders who feel that both state and federal government are committed toward solar RETs adoption:

> "Government [state government] is committed because at times even the government officials give us and confirmed [contracts]….some of their appliances like solar street lights the government are good in it, they buy from us at times" (Vendor 05).

> "I think the government is much committed. I was fortunate to attend a meeting with the vice president. They called it solar round table meeting. It was very interesting and the federal government showed commitment to RE in general, but solar energy in particular, the Ministry of Science and Technology, Energy Commission of Nigeria (ECN) and Transmission Company of Nigeria (TCN) was very much involved. We all gathered there to see how we can improve energy supply in Nigeria through solar particularly solar energy. National Electricity Regulation Commission (NERC) was there. NERC was the same commission that launched the mini-grid regulation. The mini-grid regulation as I said earlier is enforced now and the federal govt. is ready to give licence to anybody generate electricity through RE including solar energy anywhere in Nigeria as long as if is going to generate less than 1 MW. If you are generating more than 1MW meaning you have to go to the existing grid" (NGO 03).

This latest development indicates a clear shift from the federal government towards a promoting solar electricity. However, these policies have been there, written on papers. Without proper implementation, the situation will remain the same as earlier commented by NGO 2.

Another stakeholder from the federal government claimed that government is always committed towards solar transition, but the problem is a lack of commitment and readiness of potential investors:

> "because from what I have noticed from interacting with them, they are too afraid to take that business decision. They believe the risk factor is high and they are making too many demands from the country: [they] want tax holiday, security guarantee, finance guarantee, free land….[laugh]. There are so many requests investors are making. I believe as business men they should be able to take that risk and …. Hope for the best" (Federal Government Stakeholder-01).

Another contentious issue related to the government's lack of commitment to solar RETs projects is security of the components. This problem is more peculiar to developing countries where there is abject poverty. One government official commented:

> "we have a problem of theft, and vandals. Most of the streetlights that we have are vandalised. Some thieves stole all the solar batteries and panels" (State government stakeholder 02).

This stakeholder further argued that the insecurity of solar RETs components necessitate the use of diesel generators by the state government to power the streetlights. However, the majority of the solar stakeholders outside government (including vendors and NGOs) criticize the use of diesel to power streetlights, because they feel the government intention behind this is to entice political allies and promote corruption practice.

In summary, from the discussion above, it is clear that the barriers preventing solar RETs transition at household level in the study area are multifaceted, ranging from socio-economic, socio-technical to socio-political. The socio-political barriers are related to the other two barriers in various ways. This reinforces the argument that the energy for lighting transition is largely the responsibility of public officials. In other words, policy interventions are required to remove the barriers to adoption.

6.4 Barrier Removal Measures for Solar RETs Transition

Previous sections have illustrated that there are drivers for a solar transition, but at the same time there are multifaceted barriers blocking transition in the study area. This section examines some of the ways transition can be made a reality, using outcomes from the interviews with the key stakeholders.

6.4.1 Socio-economic Intervention for Solar RETs Transition

Section 6.3.1 discussed the major socio-economic barriers affecting householders from adopting solar RETs for energy for lighting. These socio-economic barriers could be addressed through the following solutions:

6.4.1.1 Subsidy

It is apparent from the demographic data of each household that a sizeable proportion of them are low-income earners (see section 3.3.11.1). In addition, it has been found that the majority of these low-income householders rely on traditional energy for lighting (5.3.1). In other words, this suggests that the majority of these households cannot afford the price of modern energy, including solar RETs without government or external intervention. On this view, one participant commented:

> "there should be subsidy, In view of cost, the high cost of installations, if there is subsidy, I can assure you that RE system will be embraced". (Energy Expert).

This view corroborates the majority views shared among householders during the household energy survey. However, not all householders that participated in the survey shared this view, there are some few that opined that government full participation would be a failure as in the case of the power sector.

In addition, householders living in the non-metropolitan zone are more disadvantaged than those living in the metropolitan zone; they are less connected to the national grid and less affluent (see 5.5 & 3.3.11.1). Furthermore, the fossil fuels subsidies have been removed. Thus, government may need to redirect such subsidies towards solar power projects especially in the non-metropolitan zones and other remote parts of the country.

6.4.1.2 Awareness

Despite rapid expansion of solar RETs markets in the study area, there is a pressing need to initiate a large scale awareness campaign on the benefits of solar RETs. As presented earlier, there are some households that can afford solar RETs but due to lack of awareness they are yet to adopt them. When asked how the solar RETs' barriers could be removed? One NGO stakeholder responded:

> "The most appropriate ways are by creating awareness… I do not know where this research is going to reach, but I can say wherever it reaches, I want this people [researchers] to take awareness strongly." (NGO 02).

Another dimension of public awareness is that there is a need for public to understand the importance of solar projects in their communities. They should not allow any act of vandalism.

> "We have to undertake awareness programmes to let them know this project is for their own benefits. We have to keep 24hrs surveillance to disrupt thefts for these materials" (State Government Stakeholder-02).

There is clearly a need for individuals and the community as a whole to be made more aware of solar RETs. This may require the participation of NGOs in creating awareness through demonstrating the productive use of these technologies. The householders living in the non-metropolitan zone are in more urgent need of awareness in order to demystify the barriers of adopting solar RETs for lighting services than their counterparts. Moreover, there is need for more awareness to rebuild public confidence in use of solar RETs for power generation.

6.4.2 Socio-technical Intervention for Solar RETs Transition

Two major challenges have been highlighted as major socio-technical barriers to solar RETs adoption: quality of components and unqualified technicians. This problem is interconnected between solar RETs business bases and technicians engaged in installation. These barriers can be removed in the followings ways:

6.4.2.1 Professional Certification for Technicians

Unqualified technicians play a major role in discouraging people from adopting solar RETs. In order to address this challenge, there is a need for them to undergo professional training for solar design and installation to gain certification in the industry. One of the solar vendors suggested that:

> "We need accreditation: the govt. should set up a system whereby people will be certified to be in this business [certification]" (Vendor 09).

Ideally, government intervention should extend beyond solar certification for business, to include all aspects of solar installation. In addition, householders should be advised to engage only with services of technicians or companies with good reputations.

6.4.2.2 Quality Warranty

As has already been highlighted in section 6.3.1, the problem with the solar RETs market is one of quality and transparency of solar products. Thus, the solar vendors or companies should provide a warranty for their products. In an exceptional case, a communication company give a 5 year warranty for their products.

> "…..you see if you look at our product, it is different from the commercial solar. Because we give the system [solar] like a 'lease', the people are paying the remaining balance gradually through an MTN account. So, if we produce the

> product with low quality, the people may have complained about it" (Vendor 11).

This could be a useful model for rebuilding householders' confidence in solar RETs work and has the potential to alleviate longstanding energy poverty. Thus, if other business organizations can emulate this model, it could help many householders make transition to solar energy for lighting.

It was observed during the fieldwork that most of the solar products in the market have no standard quality code, with solar vendors relying on their personal experience and company's reputation to purchase the solar products as commented by solar vendors:

> "Generally, what we do, we go through the company's reputation, you know there are companies that have good reputation, so we just follow that reputation" (Vendor 08).

6.4.3 Socio-Political and Financial Interventions for Solar RETs Transition

The major themes under this section deal with policies to provide incentives, law enforcement and financial support.

6.4.3.1 Incentives

There are two broad kinds of incentives subsidies for householders (consumers) and tax waivers for importers and investors. This is known as cross-subsidy. Subsidy has been highlighted as a way forward for solar RETs adoption by householders. The majority of the participants or stakeholders stated that they could only make the transition to solar power if subsidised. Thus, the Federal Government should implement some form of policy of subsidy at household level. However, one-sided incentives cannot reduce the price of solar RETs if the there is no cross-subsidy in place. In other words, the solar importers and investors (developers) cannot sustain their business without significant percentage of their tax being waived. On this point, some stakeholders commented:

> "…in Nigeria we have this master plan for RE applications which was established by the Ministry of Power and ECN. Now in this…we suggested incentives that there should be incentives for those who want actually to use RE systems in their domestic applications. So that we can now bring down the cost of that initial cost. So actually what we were able to get out of that master plan most of the importation, the goods are even imported should be duty free" (Energy Expert).

> "There are a lot of measures: we have already written to the NASS about RE Master Plan, Govt. should give incentives to people bringing [importing] this kind of technologies [solar appliances] here, in Nigeria. On custom duties, on PV materials they should remove custom duties, or waivers; they should give waivers to the people who bring this kind of technologies into Nigeria" (Federal Government Stakeholder-02).

The views from these stakeholders capture the basic concept of cross-subsidy for solar RETs, namely incentives to consumers (householders) and incentives to importers.

6.4.3.2 Active Quality Assurance Law

Enforcement of existing quality assurance laws on any solar component should be the first step of addressing quality challenges in the solar business and adoption as a whole. This may help to regain householders' confidence in solar RETs. One of the stakeholders commented:

> "The key recommendations for the government is actually to ensure that quality materials are imported, only quality materials are imported in the country" (Energy expert).

Likewise, another stakeholder commented:

> "The appropriate way is that the govt. should look into it in terms of importations and verifying if these products they are supplying to the masses are genuine [monitoring standards], so that anybody can beat his chest and believe that this product is working" (Vendor 05).

These similar views reinforce the idea of empowering quality assurance organizations such as SON and the consumer protection agency to carry out their work diligently. Enforcement of quality assurance laws is a primary responsibility of the Federal Government.

6.4.3.3 New Financial Model

A new financial model has been suggested to fast track solar RETs adoption. This kind of model is run by private companies in some developing countries (Lay et al., 2013). Conversely, some vendors recommended financial loans to householders working under government.

> "In addition to that, we need a situation whereby people can pay over time, just like what is happening in other countries especially Kenya. Though, it has started coming to Nigeria and we are also participating in that whereby you will pay solar based on use. If you need solar energy [power] in your place, we will set it up for you and you will be paying a service. We called it: 'energy as a service'. Or a hire purchase system whereby we will set up solar system for you then you will pay over 2-3 years" (Vendor 09).

> "That finance, if govt. can assist poor masses on this solar, everything will be ok. If they can give loan, there are some people working under government but their salary is very low, at times they will not receive their salary in time. But if government can give a loan for people that have an interest in it and continue to deduct the money monthly from their salary, this issue of finance would be reduced". (Vendor 02).

These vendors proposed solutions to the challenges of initial cost of solar RETs through provision of government loans. As these stakeholder suggested, it has been reported that the Kenyan employers in conjunction with solar companies arranged for a hire purchase for their employees. This will be deducted from their monthly salary (Pode, 2013). However, this proposed solution excludes householders outside the civil service.

6.5 Discussion

As already highlighted in this chapter, the drivers for solar RETs transition can broadly be classified into push and pull factors. The push factors seems to be the overwhelming factors influencing adoption of solar RETs. Similar findings suggest that solar adoption in the study area is due to poor supply of the national grid (FMPS, 2006). Likewise, the removal of subsidies from fossil fuels help to make solar RETs more competitive in the market than ever before. It has been observed that government subsidy on fossil fuels impedes solar RETs uptake in some developing countries (Karakaya & Sriwannawit, 2015). These drivers substantially demonstrate that there is motivation for solar RETs adoption uptake in the study area. This addressed the question of whether solar RETs can alleviate household energy poverty for lighting in the context of the study area. None of these drivers are related to government policy toward solar RETs uptake.

However, numerous barriers have been identified preventing solar RETs uptake. The major socio-economic barrier highlighted is initial cost of solar RETs and low income household. Other barriers include lack of confidence in solar RETs (based on cheap imports) and challenges posed by unqualified technicians. Another dimension of solar RETs barriers for uptake is ineffective policies that have adverse impacts on the socio-economic and the socio-technical barriers. These include lack of policy of incentives that can address the initial cost, poor monitoring of imported solar RETs and lack of serious commitment from government. Obviously, the findings from this chapter suggest that barriers to energy transition or causes of energy poverty extended beyond household income and cost of energy appliances as observed in Chapter 5.

6.6 Solar RETs Transition Model for Energy for Lighting: Ascending the Energy Stack-Ladder

This model attempts to harmonize the views from the stakeholders in order to find out a sustainable framework for solar RETs transition across the study area. As Reddy & Painuly (2004) suggest: "*the perceptions on barriers and barrier-removal measures vary across the stakeholders and unless these are harmonised, policies devised may not work.*" *(p.1432).*

However, perceptions of stakeholders alone are insufficient when removing multidimensional of barriers preventing solar RETs. Equally, identifying their various roles is crucial in making solar RETs transition. One of the participants commented:

> "…identify the roles and assign each role to a particular stakeholder. For instance, government have to come in, solar companies, NGOs have to come in to create awareness, also donor organisations can even come in to subsidize the cost of the solar. So if all the stakeholders come in and take responsibilities, those barriers could be eliminated." (NGO 04).

Figure 6.1 shows strategies for implementing a policy framework for solar RETs transition for lighting. This framework is designed to accommodate both small and large scale solar RETs at household or community level.

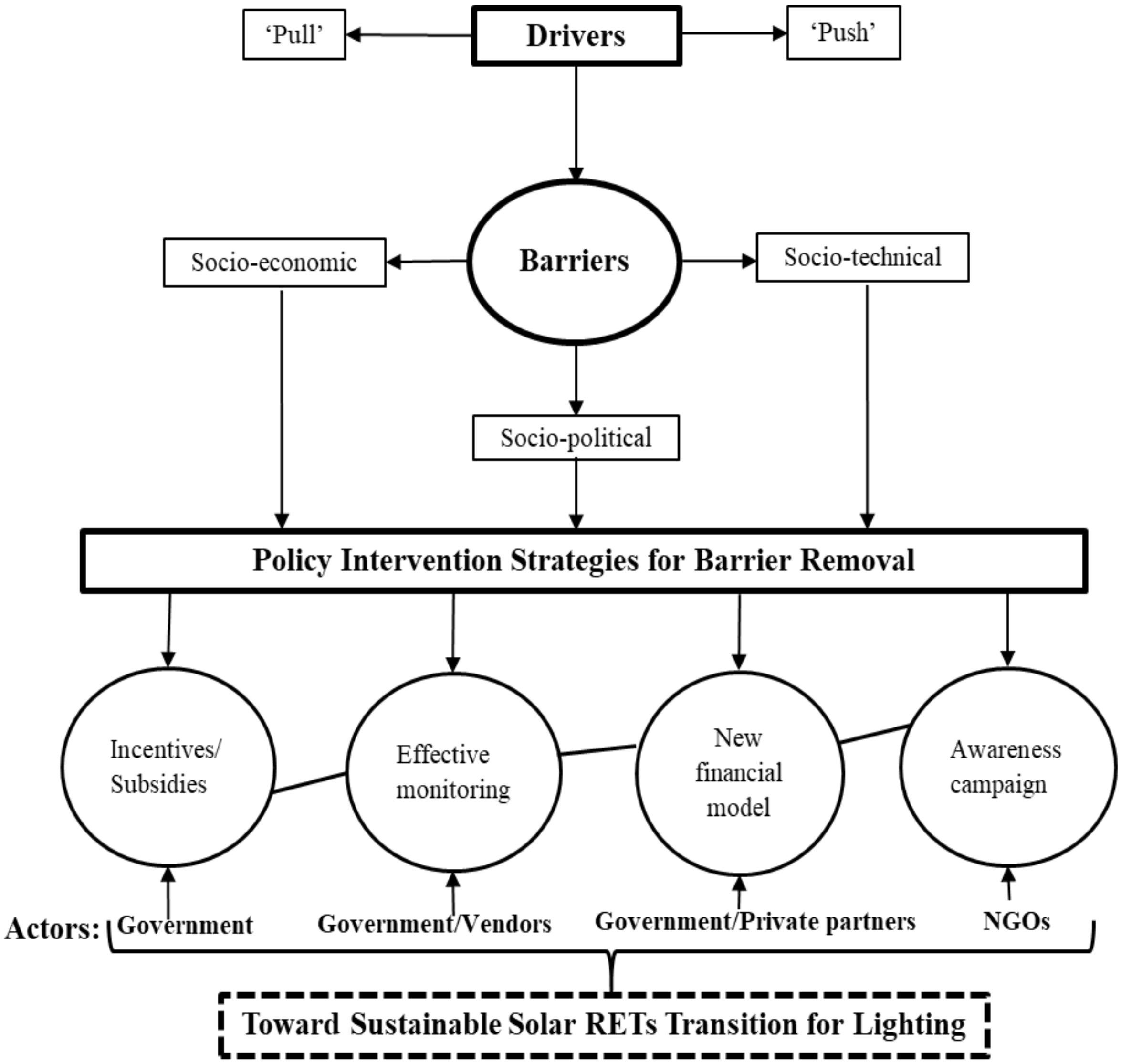

Figure 6. 1: A Policy Framework for Solar RETs Transition for Lighting

The first step is to investigate types of drivers for solar RETs transition in a particular context. As found in the previous chapter (Chapter 5), energy for lighting is not sufficient in the metropolitan zone and most parts of the non-metropolitan zone are not connected to the national grid. As discussed earlier in this chapter, poor energy supply is classified as one of the push drivers for solar RETs transition. The findings from this chapter revealed that these drivers have been obscure with multidimensional barriers, which, include socio-economic, socio-technical and socio-political barriers dimensions.

Thirdly, based on the findings from this chapter, this study combined the stakeholders' view to proffer the following polices for sustainable solar RETs:

- ✓ Policy of providing incentives and subsidies: this requires full government participation at national, state and local level. Fortunately, the federal government of Nigeria phased out fossil fuels subsidies in 2016. According to the Department of Petroleum Resources, DPR, the country has saved over N1.4 trillion (Naira) in the first year. This money has been invested into the revitalization of oil and gas infrastructure (DPR, 2016). However, part of this money should be reallocated to the solar subsidy programme to improve the power sector in the country.
- ✓ Policy of effective monitoring of solar RETs at ports and market centres: An effective monitoring scheme should be introduced between the government and solar RETs vendors organizations at local levels. Foley (1995) suggests that in absence of such an organization, the government should help to initiate them.
- ✓ Policy of introducing new financial models for soft loans: this should be implemented by government and members of solar RETs vendors' organizations. In addition, this policy should be underpinned by a dedicated financial institution to provide loans to householders. In addition, donor organizations such as GIZ should be requested to participate in this scheme. Similar efforts has been reported in some developing countries (REN21, 2016).
- ✓ Awareness of the benefits of adopting solar: this is largely function of NGOs in disseminating information regarding the benefits that can be derived from using solar RETs, particularly in the rural areas. This may help to break the cultural barriers preventing householders from adopting modern energy appliances such solar RETs.

This chapter contributed to the field of household energy transition in developing countries. Firstly, it has made an empirical contribution by classifying the drivers of solar RETs uptake into ‘push’ and ‘pull’ factors. This can be extended to incorporate all other components of household energy services as push and pull factors influencing transition. Secondly, it has identified the problem of unqualified technicians, which has not been reported in the past. The cost and quality of solar RETs receives more attention in academic circles than issues of personnel. This study found that public confidence in solar RETs was eroded through a combination of poor quality, unqualified technicians.

6.7 Conclusions

The results from this chapter suggest that the bulk of the work of addressing barriers associated with solar RETs uptake rests with developing and implementing effective policy. That is, policy for incentives, quality assurance and new financial schemes for loan provision. Others have documented that solar RETs transition requires effective policy (Karakaya & Sriwannawit, 2015). This does not mean that the responsibility of making the transition to solar RETs lies solely with the policy makers, rather, that the complexity of the barriers highlighted in this study requires participation of all stakeholders.

Working together, stakeholders can address the socio-economic, socio-technical and socio-political challenges. This implies that household solar RETs transition for lighting requires the active participation of different actors and that household energy transition is beyond the socio-economic status the household as posited by proponents of the energy ladder (Hosier & Dowd, 1987; Leach, 1992).

Chapter 7: Summary and Conclusion

7.1 Introduction

This chapter presents a synthesis of the main results and draws conclusions in relation to the stated aims and objectives of this study. The aim of this study was to examine the key factors affecting household energy poverty in Kano State, Nigeria and explore potential solutions using solar RETs technologies and associated uptake mechanisms. The aim and objectives were achieved by exploring the key models of household energy poverty and transition in the developing countries in relation to energy for cooking and lighting. Opportunities to enhance energy transition using solar RETs in order to alleviate household energy poverty for lighting were then explored.

This chapter also summarises the major contributions of this thesis. It also presents the policy implications of this research for addressing household energy poverty and transition to modern energy classes. Finally, the chapter presents the limitations encountered during the research process and suggests avenues for further studies.

7.2 Summary and Critical Reflection on the Research Objectives

The following sections summarises the main findings of the research in relation to the objectives introduced in chapter 1.

7.2.1 Research Objective 1: To explore suitable frameworks for studying energy poverty and transition in developing countries.

This objective was achieved through an extensive literature review on household energy poverty and transition models in developing countries. The review revealed that the energy ladder model dominates the discourse of household energy poverty and transition in developing countries and sub-Saharan Africa in particular (Muller & Yan, 2018). However, this model has been widely criticized by many energy experts in this field (Masera et al., 2000). This paved way to the adoption of an alternative model of energy stacking which acknowledges use of multiple energy carriers at the same time without abandoning the previous ones (Muller & Yan, 2018). This study suggests that that these two models can be further integrated to study household/community energy situations and transitions at the same time.

This study argues that by combining elements of the energy ladder and stacking models, better understanding of the characteristics of household energy poverty and complexity of different energy systems can be achieved. In addition, this approach has the potential to identify precise areas that need urgent policy intervention in order to address aspects of household energy poverty, as presented in chapters 5 and 6 for energy for lighting.

7.2.2 Research objective 2: To examine Characteristics of Household Energy Poverty and Barriers to Transition for Cooking

This objective was fulfilled through examining household energy for cooking in both metropolitan and non-metropolitan zones of the study area. This study concludes that the number of energy carriers used for cooking confirmed the assumptions of both the energy ladder and energy stacking models. The results revealed that a large proportion of households used multiple energy carriers at the same time, consistent with the assumptions of the energy stacking model. However, there were also a reasonable number of households that relied on a single energy carrier, consistent with the assumptions of the energy ladder model.

The findings from the household energy survey for cooking revealed that the majority of households in both the metropolitan zone and the non-metropolitan zones were characterized by significant dependence on traditional energy carriers for cooking such as fuelwood, charcoal, animal dung and crop residues. This finding corroborates previous research. Furthermore, the householders in the non-metropolitan zone were found to be more reliant on this energy carrier than those in the metropolitan zone. In contrast, the householders in the metropolitan zone were found to be using more modern energy carriers for cooking than their counterparts in the non-metropolitan zone.

In addition, this study examined the relationships between the householder's socio-economic status and class of energy used for both cooking and lighting. The strength of these relationships were tested using Cramer's V method. The findings revealed that householder's income and educational level were significant factors in both parts of the study area. However, the relationship is stronger with householder's level of education and modern class of energy than with income in both metropolitan and non-metropolitan zones.

The findings presented in chapter 4 suggest that the cost of energy and appliances and low levels of household income were major barriers (irrespective of geographical zone) to the use of modern energy carriers for cooking.

7.2.3 Research objective 3: To examine the Characteristics of Household Energy Poverty and Barriers to Transition for Lighting

Household energy for lighting has received much less attention in the energy poverty literature. Similar to the findings for household energy for cooking, the findings presented in chapter 5 regarding lighting also revealed a significant number of households were reliant on a single energy carrier, whilst at the same time, the majority of households used multiple energy carriers for lighting. The former is consistent with the assumption of the energy ladder model, whereas the latter affirms the assumptions of the energy stacking model.

The study confirmed that the majority of households in the metropolitan zone were characterized by the use of modern energy carriers, such as the national grid, solar electricity and generators for lighting. In contrast, the majority of the households in the non-metropolitan zone were found to be using transitional energy carriers for lighting (lanterns). The findings from chapter 5 suggest that this reliance on transitional energy can be explained by the fact that the non-metropolitan zone is less connected to the national grid than the metropolitan zone. Despite this, the majority of these households were not using traditional energy carriers for lighting as in the other sub-Saharan countries (Bensch and Peters, 2015). This study also concluded that transition from traditional to transitional energy carriers for lighting is occurring in parts of the non-metropolitan zone of the study area.

Ironically, this study found that those householders who relied upon transitional energy carriers for lighting in the non-metropolitan zone were more satisfied with their energy service than those who reliant upon more modern energy carriers in the metropolitan zone. The findings presented in chapter 5 confirm that low income was the most common barrier obstructing the use of modern energy for lighting at the household scale in both the metropolitan and non-metropolitan zones.

This study concludes that household energy transition for lighting could be achieved through adoption of solar RETs. However, this may require participation from external actors in addition to householders. Therefore, chapter 5 recommended exploration of drivers and barriers for viable solar RETs transition in the study area.

7.2.4 Research objective 4: To explore drivers and barriers to the uptake of solar RETs for lighting.

This objective explored the key drivers and barriers for solar RETs for household energy transition in the study area in relation to the wider national context. This objective was achieved through conducting interviews with a variety of solar RETs stakeholders and some respondents from the household energy survey. Major drivers for solar RETs adoption can be classified into 'push' and 'pull' factors. The 'push' factors include power shortages, high electricity tariffs and high costs of running and maintaining generators. In contrast, the 'pull' factors include availability of solar resource, on-going awareness and solar RETs market expansion. However, as was highlighted in section 6.7 the push factors have more influence on the uptake of solar RETs in the study area than the pull factors.

Barriers preventing solar RETs transition/uptake were discussed in detail in chapter 6. The major themes identified include socio-economic barriers, including initial cost of solar RETs and lack of awareness; socio-technical barriers, including lack of confidence in solar RETs and unqualified technicians; and socio-political barriers, including lack of financial incentives, poor monitoring of imported solar RETs and lack of government commitment in solar uptake. This study concluded that more understanding of solar RETs barriers is needed when looking for effective interventions.

7.2.5 Research objective 5: To evaluate whether and how solar RETs can help alleviate energy poverty (for lighting) at household level.

The findings from chapter 6 revealed that solar RETs transition could be enhanced through a combination of the following types of intervention: socio-economic, socio-technical and socio-political. The findings suggest that socio-political interventions could have an overarching effect on both the socio-economic and socio-technical components. As discussed in chapter 6, the latter components were found to be intricately connected to government interventions through robust regulatory and institutional monitoring and implementation. This study provides a new framework for sustainable solar RETs uptake. Thus, this study concludes that policy makers and other key stakeholders could work together to address the household energy poverty for lighting in the study area.

7.3 Contributions of this research

This research has made numerous theoretical, empirical and methodological contributions in the field of household energy poverty and transition in developing countries.

7.3.1 Theoretical Contribution

Firstly, the findings from chapter 5 have made a significant contribution to the model of the energy ladder. This model has been widely adopted to study, explicitly, household energy for cooking (Hosier and Dowd, 1987; Nansaior et al., 2011; Maconachie et al., 2009), but little attention has been paid to components of household energy for lighting. This research has taken energy for lighting into consideration using the three broad classes defined by the energy ladder model: traditional, transitional and modern.

Secondly, this research has also shown for the first time that neither the energy ladder nor the energy stacking model captures the precise profile of household energy systems in developing countries as claimed by other researchers. For the first time, this study has combined these models to explore household energy for cooking and lighting in the context of the study area. This integrated model better presented the characteristics of household energy poverty and relationships between the energy classes and household socioeconomic status and energy satisfaction. Moreover, the aim of this study is to explore contextual challenges of household energy poverty using the integrated energy stack-ladder model introduced in Chapter 2. However, the findings from chapter 4 and 5 suggest that this model can be applied to study wider contexts of energy poverty in developing countries, particularly in SSA.

This study also conceptualized the drivers for solar RETs uptake into 'push' and 'pull' factors. This has been discussed in greater detail in chapter 6. Such conceptualization can allow us to construe motivations behind energy transition in most developing countries that experience energy poverty.

7.3.2 Empirical

Like previous researchers, this study suggests that householder income is crucial in determining household energy choice/class for cooking. Moreover, this research found that the higher the educational status (higher education), statistically, the more significant the impact on determining the use of modern energy class for cooking. Moreover, this study suggests that the relationship between householder's socio-economic status and class of energy use is dependent on location (see 4.6). The majority of studies that apply the energy model pay less attention to the influence of geographical differences on household energy class. Finally, this study strongly argues that the transition to the use of modern energy, particularly for cooking, in the context of this study area is more or less a function of ‘modernization’. This was evident from the influence of householder’s higher educational status and use of more modern energy in both metropolitan and non-metropolitan zones.

Another empirical contribution from chapter 6 is that barriers to solar RETs transition in the context of the study area are in different social dimensions: socio-economic, socio-technical and socio-political. The intervention measures also reflect these social dimensions, however, the findings from this study confirm that the socio-political dimension is of most importance.

7.3.3 Methodological

Firstly, this research contributes to the methodological aspect of the implementation of the energy ladder and stacking models. This was achieved by recoding the values of energy carriers into 3 classes as asserted by the energy ladder model. For the first time, this study employed this technique in order to concisely rank a household’s energy profile in the study area. Previous studies were limited to presenting only households’ energy inventories (for example see: Hosier & Dowd, 1987; Baiyegunhi & Hassan, 2014; Bisu et al., 2016; Zhang et al., 2016). Secondly, recruitment of multiple solar RETs stakeholders provides a comprehensive account regarding both small and large scale solar RETs’ drivers, barriers, and possible solutions for its uptake. This approach provides a novel conclusion for formulating a sound policy towards transition to solar RETs in a contextual manner.

7.4 Policy Implications of the Research

The findings from this study have significant policy implications in the context of the study area and sub-Saharan Africa as a whole.

The approach employed in this research has the potential to identify the energy poor and visualize their geographical differences. Consequently, this can provide policy makers with an opportunity to formulate different policies for addressing household energy poverty in different contexts. Additionally, the findings from this research and the wider literature confirm that there is wide gap between household energy demand and supply in Nigeria (Naibbi & Healey, 2014). This situation is more exacerbated in the non-metropolitan zones, the remote areas with little or no coverage of the national grid (Sambo, 2005). Thus, this research proposes a solar RETs model for policy consideration. This model proposes a 'relocation concept' be incorporated, that is, the withdrawn fossil fuel subsidy fund should be redistributed towards solar RETs investment which can help to improve energy access, particularly in remote parts in the country.

Another policy implication of this research is that the findings from chapter 6 have highlighted the shortcomings of government agencies responsible for quality assurance of imported solar products. This study suggests that apart from the existing government agencies there is a pressing need to come up with strong institutional and regulatory frameworks dedicated to solar RETs' businesses.

Also, access to higher education proved to be one of the influential factors behind transition to modern energy for cooking in both parts of the study area. Thus, government should embark on a large campaign to enhance the higher educational status of its people and break cultural barriers preventing use of modern energy for cooking. Moreover, income equality, and expansion of public sector can help to facilitate transition to modern energy usage. Finally, this research concludes that effective policy on subsidies and incentives could form the first step towards initiating and sustaining household energy transition for cooking and particularly energy for lighting.

7.5 Limitations and Further Research

Despite the research achievements, there are some limitations, as highlighted in the previous chapters. Thus, this final section suggests avenues for further research and improvements in the future. This study acknowledges a methodological oversight in relation to the design of the open-ended questions. The open-ended household energy survey did not yield as much insight into householders views to RETs adoption as anticipated. Thus, this study recommends use of an exploratory mixed-method approach for data collection in future research. In addition, the proposed study should map the zones of the study area in terms of access to energy for lighting. This will provide an opportunity to evaluate the proposed solar RETs model at both community and household levels. Also, further research is recommended to evaluate the influence of solar RETs stakeholders for sustainable solar power transition as proposed in Chapter 6.

Another methodological limitation is that the householders were not asked about reasons for using single or multiple energy carriers during the household energy survey. This should be explored fully in future works; since it may yield more insight into the assumptions of the energy ladder and energy stacking models. Also, it has already acknowledged that both the researcher and field assistants had not got chance to talk directly to female members of the households during the survey. Indeed, this could have generated more comprehensive results, particularly in relations to barriers to modern energy and level of satisfaction with the different energy classes. However, these limitations did not undermine the goals set to achieve in this study.

As also highlighted in chapter 4, the relationship between household energy class for cooking and geographical differences requires further exploration. This may necessitate adopting the concept of ‘energy justice’ in relation to these distinctive geographical settings.

In addition, this study also highlighted the concept of ‘modernization’ in relation to modern energy transition. However, this is beyond the scope of this study. Finally, it is obvious that all the recommendations related to household energy for cooking transitions in this thesis were based on fossil fuels sources. However, with regard to RE transition, this study suggests a further investigation into prospect of using biogas for cooking in study area. This might help to alleviate the longstanding challenges of household energy poverty for cooking in near future.

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Appendices

Appendix I: Household Energy Survey (Closed-ended Questionnaire)

HOUSEHOLD ENERGY SURVEY

Lancaster University

I am a PhD student based in Lancaster Environment Centre, Lancaster University, UK. I am working on energy poverty at the household level and the potential of solar energy technologies to address levels of poverty. The focus of this survey is to find out key factors affecting energy for lighting and cooking. Also it seeks to determine opportunities and constraints of using solar energy in your home or community as a whole. This survey will take 20-30 minutes. You have the right to withdraw from this research at any time. Information will remain anonymous as your name is not required in this survey. There is no financial benefit for taking part in this survey. All data will be secured safely and only be used for academic purposes.

Declaration:

I confirm that I understand the information provided above and I agree to take part in this survey. ☐

…………………………………………… ………………………………………………

Signature Date

SECTION A: HOUSEHOLD (Head of household unit) BASIC INFORMATION:

GPS: Latitude……………………. Longitude……………………

(Please tick the box (es) that is applicable and fill in the blank spaces where necessary)

1. **Ward Name**…………………………………………………………………………………….
2. **Local Government Area**………………………………………………………………..
3. **Age:** a) 20-30 yrs [ ] b) 31-40yrs [ ] c) 41-50yrs [ ] d) 51-60yrs [ ] e) above 60yrs [ ]
4. **Family Size:** a) 2 [ ] b) 3-4 [ ] c) 5-6 [ ] d) 7-8 [ ] e) Above 8 [ ]
5. **Mode of housing ownership:** a) Self ownership [ ] b) Tenants [ ] c) Other (specify)...
6. **No. of rooms:** a) 2 [ ] b) 3 [ ] c) 4 [ ] d) 5 [ ] e) Above 5 [ ]
7. **Educational attainment:** a) Primary education [ ] b) Secondary education [ ] c) Higher education [ ] d) Islamic education [ ] d) Other (specify)…………………
8. **Occupation:** ………………………………………..
9. **Monthly earning (Naira):** a) <N18, 000[ ] b) N18, 000-N54, 999[ ] c) N55, 000-N108,999 [ ] d) N109, 000-N163, 999 [ ] e) Other (specify)………………………………

SECTION B: HOUSEHOLD ENERGY FOR COOKING:

1. **Do you have enough energy for cooking?**
   a) Yes [ ] b) No [ ]

2. **Please rank the energy sources you use for cooking by how often you use them (e.g. 1, 2, 3, etc.):**

a) Charcoal [ ]

b) Gas [ ]

c) Fuelwood [ ]

d) Electricity [ ]

e) Kerosene [ ]

f) Other (specify)……………………………………………

3. Please choose (✓) which factor(s) influenced your first choice in Q2 above:

Factors	**Degree of influence (choice no. 1 above)**			
	High	**Moderate**	**Low**	**I don't know**
Tradition/Custom				
Income/cost				
Government policy on energy price				
Seasonal change				
Availability/reliability of energy supply				
More efficient				
Availability of modern appliances				
Family size				

Other (specify)……………………………………………………………………………

4. Monthly expenditure on energy for cooking (one or more energy sources).

Tick appropriate box:

a) <N500 [ ]

b) N500-N999 [ ]

c) N1,000-N1,999 [ ]

d) N2,000-N2,999 [ ]

e) N3,000-N5,000

f) Above N5,0000 [ ], specify……………………………………………………

g) Don't know [ ]

5. Major energy source for cooking that you listed as first choice in Q2 above:

Class	**Energy Source for Cooking**	**Yes**	**No**
5a: Modern	**Electricity, Gas and Kerosene**		
5b:Traditional	**Fuelwood, Charcoal and Animal Dung**		

6. **If the answer to 5a above is No, and you are not using 'modern' energy sources, (kerosene, LPG-gas, electricity), then what is the major barrier preventing you doing so?**

a) Cost of energy source [ ] b) Cost of Appliances e.g. cooker [ ] c) Tradition [ ]

d) Safety concerns [ ] e) Large family size [ ] f) Scarcity [ ] g) Low income [ ]

h) Govt. policy [ ] i) Not applicable [ ] j) Other (specify)

……………………………

7. **What type of appliance are you using for cooking? (Please rank your response accordingly e.g. 1 = most important, 2 = less important, 3 = least important, etc.):**

a) Three-stone [ ] b) Kerosene stove [ ] c) Improved stove [ ]

d) Electric stove [ ] e) Cooker gas [ ] f) Other (specify)……………………..

8. **Why are you using the cooking appliances (first choice) above?**

a) Tradition [ ]
b) Less cost [ ]
c) Family size [ ]
d) Efficiency [ ]
e) Availability [ ]
f) Other (specify)………………………………………………….

SECTION C: HOUSEHOLD ENERGY FOR LIGHTING:

1. **Do you have enough energy for lighting?**

a) Yes [ ] b) No [ ]

2. **Please rank the energy sources you use for lighting by how often you use them (e.g. 1, 2, 3, etc.):**

a) Candle [ ]
b) Generator [ ]
c) Solar Electricity [ ]
d) National Grid electricity [ ]
e) Lantern (solar/battery) [ ]
f) Kerosene/paraffin wick lamp [ ]
g) Other (specify)………………………………………………………………………

3. **Please choose (✓) what factor(s) influenced your first choice in Q2 above:**

Factors	**Degree of influence (choice no. 1 above)**			
	High	**Moderate**	**Low**	**I don't know**
Tradition/Custom				
Income/cost				
Government policy on energy price				
Seasonal change				
Availability/reliability of energy supply				
More efficient				
Availability of modern appliances				
Family size				

Other (specify)…………………………………………………………………………

4. **How many hours a day do you receive electricity from the National Grid?**
   a) <3hrs [ ] b) 3-5hrs [ ] c) 6-7hrs [ ] d) 8-10hrs [ ] e) > 10hrs
   f) Other (specify)…………………………………………………………………………
   g) Not connected [ ]

5. **Monthly expenditure on energy for lighting (one or more energy sources). Tick appropriate box.**
   a) <N1,000 [ ]
   b) N1000-N2,999 [ ]
   c) N3000-N3, 999 [ ]
   d) N4,000-4, 999 [ ]
   e) Above N5, 000 [ ], specify…………………………………….

6. **Major energy source for Lighting that you listed as first choice in Q2 above:**

Class	**Energy Source for Lighting**	**Yes**	**No**
6a: Modern	**National grid electricity, Solar electricity, Generator**		
6b:Traditional	**Candle, Kerosene lamp, Lantern touch**		

7. **If 6a above is 'No', and you are not using 'modern' energy sources (e.g. solar electricity etc.), then what is the major barrier preventing you doing so?**

a) Cost Appliances e.g. solar panels [ ] b) Tradition [ ] c) Safety concerns [ ] d) Large family size [ ] e) Scarcity [ ] f) Low income [ ] g) Govt. policy [ ] h) Not applicable [ ] i) Other (specify)
…………………………………………………

8. **What type of lighting appliance (technologies) are you using? Please rank your response accordingly (e.g. 1 = most important, 2 = less important, 3 = least important, etc.):**

a) Candle [ ] b) Generator [ ] c) Lantern [ ]
d) Kerosene lamp [ ] e) Solar panels [ ] f) Other (specify)……………………..

9. **Why are you using the lighting appliances (first choice) above?**

a) Tradition [ ]
b) Less cost [ ]
c) Family size [ ]
d) Efficiency [ ]
e) Availability [ ]
f) Other (specify)……………………………………………….

SECTION D: SOLAR TECHNOLOGIES (APPLIANCES) ADOPTION AND PROSPECT

1. **Do you use any solar energy technologies for cooking or lighting in your house?**
   a) Yes [ ] b) No [ ]

   - **If the answer to 1 above is 'No' please go to Q5:**

2. **What type of solar appliance(s) do you use for lighting?**
   a) Solar Lantern/Led [ ]
   b) Solar power generator [ ]
   c) Solar Fan [ ]
   d) Solar Home lighting system [ ]
   e) Other (specify)…………………………………………………

3. **What type of solar appliance(s) do you use for cooking?**
    a) Solar Cooker [ ]
    b) Solar Oven [ ]
    c) Solar Stove [ ]
    d) Solar water heater [ ]
    e) Other (specify)…………………………………………………….

4. **Where do you get your solar appliances?**
    a) Market [ ]
    b) Solar Companies [ ]
    c) Solar NGOs [ ]
    d) Government [ ]
    e) Other (specify)………………………………….

- **If you have already answered Q2 to Q4, please go Q6to Q8**

5. **What do you think are the major barriers preventing you from using solar appliances?**
    a) Family size [ ]
    b) Initial cost [ ]
    c) Lack of awareness [ ]
    d) Lack of quality [ ]
    e) Other (specify)……………………………………

6. **Do you know of any awareness programmes on renewable energy technologies?**
    a) Yes [ ], specify the name……………………………………………………………… b) No [ ]

7. **If 'Yes', how did you get the information?**
    a) Radio b) TV [ ] b) Extension workers [ ] c) Marketers promotion [ ]
    f) Friend [ ] e) Neighbour [ ] f) Other (specify) …………………………………

8. **Do you think solar energy appliances have prospects in near future?**
    a) Yes [ ] b) No [ ] c) Don't know [ ]

Thank you very much for participating in this research

Appendix II: Household Energy Survey (Open-ended Questionnaire)

HOUSEHOLD ENERGY SURVEY

Lancaster University

I am a PhD student based in Lancaster Environment Centre, Lancaster University, UK. I am working on energy poverty at the household level and the potential of solar energy technologies to address levels of poverty. The focus of this survey is to find out key factors affecting energy for lighting and cooking. Also it seeks to determine opportunities and constraints of using solar energy in your home or community as a whole. This survey will take 20-30 minutes. You have the right to withdraw from this research at any time. Information will remain anonymous as your name is not required in this survey. There is no financial benefit for taking part in this survey. All data will be secured safely and only be used for academic purposes.

Declaration:

I confirm that I understand the information provided above and I agree to take part in this survey. ☐

…………………………………………… ……………………………………………

Signature Date

SECTION A: HOUSEHOLD (Head of household unit) BASIC INFORMATION:

GPS: Latitude……………………. Longitude……………………

(Please tick the box (es) that is applicable and fill in the blank spaces where necessary)

1. **Ward Name**………………………………………………...
2. **Local Government Area**……………………………………
3. **Age:** a) 20-30yrs [ ] b) 31-40yrs [ ] c) 41-50yrs [ ] d) 51-60yrs [ ] e) above 60yrs [ ]
4. **Family Size:** a) 2 [ ] b) 3-4 [ ] c) 5-6 [ ] d) 7-8 [ ] e) Above 8 [ ]
5. **Mode of housing ownership:** a) Self ownership [ ] b) Tenants [ ] c) Other (specify)…..................................
6. **No. of rooms:** a) 2 [ ] b) 3 [ ] c) 4 [ ] d) 5 [ ] e) Above 5 [ ]
7. **Educational attainment:** a) Primary education [ ] b) Secondary education [ ] c) Higher education [ ] d) Islamic education [ ] d) Other (specify)…………………
8. **Occupation:** …………………………………………..
9. **Monthly earning (Naira):** a) <N18, 000[ ] b) N18, 000-N54, 999[ ] c) N55, 000-N108,999 [ ] d) N109, 000-N163, 999 [ ] e) Other (specify)…………………………………….

SECTION B: HOUSEHOLD ENERGY FOR COOKING:

1. **Do you have enough energy for cooking?**
   a)Yes [ ] b) No [ ]
2. **If NO, explain why you don't have enough energy for cooking?**
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
…………

3. **What type of appliance are you using for cooking? (Please rank your response accordingly e.g. 1 = most important, 2 = less important, 3 = least important, etc.):**

   b) Three-stone [ ] b) Kerosene stove [ ] c) Improved stove [ ]
   d) Electric stove [ ] e) Cooker gas [ ] f) Other (specify)……………………..

4. **Why are you using the cooking appliances (first choice) above?**

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

5. **Please rank the energy sources you use for cooking by how often you use them (e.g. 1, 2, 3, etc.):**

a) Charcoal [ ]

b) Gas [ ]

c) Fuelwood [ ]

d) Electricity [ ]

e) Kerosene [ ]

f) Other (specify)……………………………………………………………………………

6. **Please choose (✓) which factor(s) influenced your first choice in Q5 above:**

Factors	**Degree of influence (choice no. 1 above)**			
	High	**Moderate**	**Low**	**I don't know**
Tradition/Custom				
Income/cost				
Government policy on energy price				
Seasonal change				
Availability/reliability of energy supply				
More efficient				
Availability of modern appliances				
Family size				

Other (specify)……………………………………………………………………………

7. **Monthly expenditure on energy for cooking (one or more energy sources). Tick appropriate box:**

a) <N500 [ ]

b) N500-N999 [ ]

c) N1,000-N1,999 [ ]

d) N2,000-N2,999 [ ]

e) N3,000-N5,000

f) Above N5,0000 [ ], specify………………………………………………………………

g) Don't know [ ]

8. Major energy source for cooking that you listed as first choice in Q5 above:

Class	Energy Source for Cooking	Yes	No
8a: Modern	Electricity, Gas and Kerosene		
8b:Traditional	Fuelwood, Charcoal and Animal Dung		

9. If the answer to 8a above is No, and you are not using 'modern' energy sources, (kerosene, LPG-gas, electricity), then what is the major barrier preventing you doing so?

a) Cost of energy source [ ] b) Cost of Appliances e.g. cooker [ ] c) Tradition [ ] d) Safety concerns [ ] e) Large family size [ ] f) Scarcity [ ] g) Low income [ ] h) Govt. policy [ ] i) Not applicable [ ] j) Other (specify) …………………

10. Is there anything you can do to remove the barrier?

a) No [ ] b) Yes, explain

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

SECTION C: HOUSEHOLD ENERGY FOR LIGHTING:

1. Do you have enough energy for lighting?

a) Yes [ ] b) No [ ]

2. If 'No', explain why you don't have enough energy for lighting?

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………

3. **What type of lighting appliance (technologies) are you using? Please rank your response accordingly (e.g. 1 = most important, 2 = less important, 3 = least important, etc.):**

a) Candle [ ] b) Generator [ ] c) Lantern [ ]

d) Kerosene lamp [ ] e) Solar panels [ ] f) Other (specify)……………………..

4. **Why are you using the lighting appliances (first choice) above?**
………………………………………………………………………………………
………………………………………………………………………………………
…………

5. **Please rank the energy sources you use for lighting by how often you use them (e.g. 1, 2, 3, etc.):**

a) Candle [ ]
b) Generator [ ]
c) Solar Electricity [ ]
d) National Grid electricity [ ]
e) Lantern (solar/battery) [ ]
f) Kerosene/paraffin wick lamp [ ]
g) Other (specify)…………………………………………………………………

6. **Please choose (✓) what factor(s) influenced your first choice in Q5 above:**

Factors	**Degree of influence (choice no. 1 above)**			
	High	**Moderate**	**Low**	**I don't know**
Tradition/Custom				
Income/cost				
Government policy on energy price				
Seasonal change				
Availability/reliability of energy supply				
More efficient				
Availability of modern appliances				
Family size				

Other (specify)…………………………………………………………………

7. How many hours a day do you receive electricity from the National Grid?

a) <3hrs [ ] b) 3-5hrs [ ] c) 6-7hrs [ ] d) 8-10hrs [ ] e) > 10hrs f) Other (specify)………………………………………………………………………

g) Not connected [ ]

8. Monthly expenditure on energy for lighting (one or more energy sources). Tick appropriate box.

a) <N1,000 [ ]

b) N1000-N2,999 [ ]

c) N3000-N3, 999 [ ]

d) N4,000-4, 999 [ ]

e) Above N5, 000 [ ], specify…………………………………….

9. Major energy source for Lighting that you listed as first choice in Q5 above:

Class	**Energy Source for Lighting**	**Yes**	**No**
9a: Modern	**National grid electricity, Solar electricity, Generator**		
9b:Traditional	**Candle, Kerosene lamp, Lantern touch**		

10. If 9a above is 'No', and you are not using 'modern' energy sources (e.g. solar electricity etc.), then what is the major barrier preventing you doing so?

a) Cost Appliances e.g. solar panels [ ] b) Tradition [ ] c) Safety concerns [ ] d) Large family size [ ] e) Scarcity [ ] f) Low income [ ] g) Govt. policy [ ] h) Not applicable [ ] i) Other (specify)

………………………………………………………

11. Is there anything you can do to remove the barrier?

a) No [ ] b) Yes, explain

………………………………………………………………………………

………………………………………………………………………………

SECTION D: SOLAR TECHNOLOGIES (APPLIANCES) ADOPTION AND PROSPECT

1. **Do you use any solar energy technologies for cooking or lighting in your house?**
   a) Yes [ ] b) No [ ]

➢ **If the answer to 1 above is 'No' please go to Q6 & Q7:**

2. **What type of solar appliance(s) do you use for lighting?**
   a) ……………………………………………………………..
   b) …………………………………………………………….
   c) …………………………………………………………….

3. **What type of solar appliance(s) do you use for cooking?**
   a) . ...
   b) ………………………………………
   c) ………………………………………
4. **Where do you get your solar appliances?**

   a) ………………….. b) ……………………. c) ………………….
5. **What influenced you to start using solar appliances?**
   …………………………………………………………………………………
   …………………………………………………………………………………
   …………………………………………………………………………………
   ………………

   ➢ **If you have already answered Q2 to Q5, please go Q10 to Q13**
6. **What do you think are the major barriers preventing you from using solar appliances?**

   a)…………………… b) ………………………… c) …………………………
7. **How such barriers can be removed?**

   a) ……………………………………………………………………………

   b) ……………………………………………………………………………
8. **Who do you think can remove the barriers?**

   …………………………………………………………………………………
   …
9. **Why?**
   …………………………………………………………………………………….
10. **Do you know of any awareness programmes on renewable energy technologies?**

    a) Yes [ ], specify the name…………………………………………… b) No [ ]

11. If ‘Yes’, how did you get the information?

a) Radio b) TV [ ] c) Extension workers [ ] d) Marketers promotion [ ]

e) Friend [ ] f) Neighbour [ ] g) Other (specify) …………………………

12. Do you think solar energy appliances have prospects in near future?

a) Yes [ ] b) No [ ] c) Don’t know [ ]

13. What is your recommendation to government on using solar energy in households/communities?…………………………………………………………

……………………………..…………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

……………

Thank you very much for participating in this research

Appendix III: Solar Stakeholders' Interviews Questions

SOLAR ENERGY STAKEHOLDERS

Lancaster University

Title: Energy Poverty in Kano State, Nigeria: Understanding the Problem and Finding Solutions

INTERVIEW FOR FEDERAL GOVERNMENT OFFICALS

- ✓ **Solar RETs Drivers**

1. What are the types of solar projects available in Nigeria? (Give examples)
2. What types of solar RETs available for lighting and cooking? (State)
3. What are the key drivers of solar RETs diffusion in Nigeria? (Explain)

- ✓ **Solar Development**

4. Can you describe the solar RETs development in Nigeria? (Major success and failure)
5. What is the total installation capacity of solar technologies in Nigeria so far?
6. How many local or foreign solar companies are present in Nigeria?
7. Do you think the current energy system (mix) can solve Nigeria's energy needs in near future? (Justify)
8. What are you doing to help ('fast-track') local solar industries?
9. Do have any ongoing programme for public awareness regarding solar technologies? (Give examples)
10. Do you have RE data-base at local level (Federal/States level)? (State/to provide a copy)

- ✓ **RE Policy, Solar Barriers and Barrier-Removal Measures:**

11. What are the major barriers to solar RETs diffusion?
12. What measures are you taking in removing such barriers?
13. Who should remove the barriers? (Explain)
14. Do you have renewable energy acts at national level?
15. Do you think the current government RE policy can deliver solar RETs by 2025?
16. What is your current budget for solar technologies?
17. What type of incentives is the government giving to solar technologies projects?

- ✓ **Prospect and Recommendation(s):**

18. Does solar RETs have prospect in addressing energy poverty in Nigeria? (Justify)
19. What (a specific) role you can play (as a public official) in solar products diffusion at household and community levels? (Specify)
20. What is your key recommendation(s) on solar energy transition?

Thank you very much for participating in this research

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SOLAR ENERGY STAKEHOLDERS

Title: Energy Poverty in Kano State, Nigeria: Understanding the Problem and Finding Solutions

INTERVIEW FOR STATE GOVERNMENT OFFICALS

✓ **Solar RETs Drivers**

1. What are the types of solar projects available in Kano State? (Give examples)
2. What types of solar RETs available for lighting and cooking? (State)
3. What are the key drivers of solar RETs diffusion in Kano State?

✓ **Solar Development**

4. Can you describe the solar RETs development in Kano State? (Major success and failure)
5. What is the total installation capacity of solar technologies in Kano so far?
6. What is your current budget for solar technologies?
7. Do you have RE data-base at local level (States/LGAs level)? (State)
8. How many local or foreign solar companies are present in Kano State?

✓ **RE Policy and Solar Barriers and Barrier-Removal Measures**

9. What are the major barriers to solar RETs (large scale) diffusion?
10. What measures are you taking in removing such barriers?
11. Who should remove the barriers? (Explain)
12. What type of incentives giving to solar technologies projects and local communities?
13. Do you have renewable energy policy at state level?
14. Despite a proven potential for solar uptake in Nigeria, most governments are still using diesel to power street lights. Why?
15. Do you have any ongoing programme for public awareness regarding solar technologies adoption? (Give examples)

✓ **Prospect and Recommendation(s):**

16. Does solar RETs have prospect in addressing energy poverty in rural and urban Kano centres? (Justify)
17. What (a specific) role can you play (as a public official) in solar products diffusion at household and community levels? (Specify)
18. What is your key recommendation(s) on solar energy transition?

Thank you very much for participating in this research

SOLAR ENERGY STAKEHOLDERS

Title: Energy Poverty in Kano State, Nigeria: Understanding the Problem and Finding Solutions

INTERVIEW FOR ENERGY RESEARCH CENTRE, SOKOTO STATE

✓ **Solar RETs Types and Drivers (Solar Development Household)**

1. What types of solar RETs are available for lighting and cooking? (State)
2. What are the key drivers of solar RETs diffusion in Nigeria/households? (Explain)
3. What type of solar RETs are appropriate for households for cooking and lighting in relation to our life-style? (Explain/examples?).
4. What are the major barriers to solar RETs diffusion? (List)
5. Who should remove the barriers? (Explain)

✓ **Solar- General Development**

6. Can you describe solar RETs development in Nigeria? (Major successes and failures)
7. Do you have RE data-base at local level (States/LGAs)? (State /to provide a copy)
8. Do you think the current energy system (mix) can solve Nigeria's energy needs in near future?
9. What is the knowledge gap in solar RETs in Nigeria? (Explain)

✓ **Solar Development- Industries**

10. What is the total installation capacity of solar technologies in Nigeria so far? (State)
11. How many local or foreign solar companies are present in Nigeria? (State)

✓ **Solar RETs Policies:**

12. Do have any ongoing programme for public awareness regarding solar technologies? (Give examples)
13. Do you think the current government RE policy can deliver solar RETs by 2025? (Explain)
14. Despite a proven potential for solar uptake in Nigeria, most governments are still using diesel to power street lights. Why?

✓ **Prospect and Recommendation(s):**

15. Does solar RETs have prospect in addressing energy poverty in Nigeria? (Justify)
16. What (a specific) role you can play (as a research centre) in solar products diffusion at household and community levels? (Specify)
17. What is your key recommendation(s) on solar energy transition (for both government and householders)? (State)

Thank you very much for participating in this research

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SOLAR ENERGY STAKEHOLDERS

Title: Energy Poverty in Kano State, Nigeria: Understanding the Problem and Finding Solutions

INTERVIEW FOR SOLAR ENERGY MARKETERS/COMPANIES

- ✓ **Types of solar Appliances and Public Acceptability:**

1. What are the main solar technology appliances available in the market? (List).
2. What is the level of public acceptability of solar RETs? (Explain)
3. What is your opinion on solar RETs appliances demand in Kano State in the last five years? (Explain)
4. What are the barriers preventing solar technologies in the society? (Explain)
5. What are the appropriate ways of removing such barriers**?** (Explain)
6. Who should remove the barriers? (Explain)

- ✓ **Incentive (subsidy) from Government:**

7. Do you receive any incentive from government? (Explain)
8. If yes what type of incentives? (Explain)
9. Do you believe government is committed to solar diffusion? (Explain/why?)

- ✓ **Industrial Issue:**

10. Do you have 'standardize code' (quality code) for renewable energy (including solar) technologies products at market level?
11. What are the key strategies do you follow to diffuse your products? (Explain)

- ✓ **Prospect and Recommendation(S):**

12. Do you think solar product has prospect in addressing energy access problem? (Justify)
13. What is your key recommendation(s) to government and public on adopting solar energy technologies?

Thank you very much for participating in this research

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SOLAR ENERGY STAKEHOLDERS

Title: Energy Poverty in Kano State, Nigeria: Understanding the Problem and Finding Solutions

INTERVIEW FOR SOLAR ENERGY NGOs

- ✓ **Awareness initiatives and Public Acceptability:**

1. What is the level of public acceptability of solar RETs? (Explain)
2. What is your opinion on solar RETs appliances adoption in Kano State/Nigeria? (Explain)

- ✓ **Solar Barriers and Barrier-Removal Measures:**

3. What are the barriers preventing solar technologies in the society? (Explain)
4. What are the appropriate ways of removing such barriers? (Explain)
5. Who should remove the barriers? (Explain)

- ✓ **Government Policy on Solar Diffusion**

6. Do you believe government is committed to solar diffusion? (Explain/why?)
7. Despite a proven potential for solar uptake in Nigeria, most governments are still using diesel to power street lights. Why?

- ✓ **NGOs Activities in Solar Diffusion**

8. What are the main solar technologies appliances that are you promoting/criticising? (List).
9. What are your current activities in solar RETs diffusion to society? (Explain)
10. What are the key strategies you follow to promote solar RETs diffusion at household level? (Explain)

- ✓ **Prospect and Recommendation(s):**

11. Do you think solar RETs have prospect in addressing energy poverty? (Justify)
12. Please can you specify a key role (as NGO) that you can play in solar appliances diffusion and adoption at household and community levels? (Specify)
13. What is your key recommendation(s) to government and public on adopting solar energy technologies?

Thank you very much for participating in this research

Appendix IV: Examples of Codes

Themes	Categories	Codes	Data extracts/ Comments
Drivers	**'Push' drivers**	**Power shortage**	"With our population of almost 200 million we are still talking about less than 4000MW stable electricity. For our population we should be talking of at least 100,000 MW. So, there is large gap between demand and supply of electricity in the country. And so many individuals are trying to solve that problem, that is why people are going into RETs to solve their energy needs" **(Federal Government Stakeholder 01).** "We do not also have enough [electricity] to go round, particularly those in the rural areas where this the grid did not even reached. So we advocate the use of RE as an alternative" **(Energy Expert).**
	'Pull' drivers	**Resources Availability**	"Solar is renewable and sustainable. I think it is our best bet in Northern Nigeria where we have high solar intensity. Why in Northern Nigeria? Because it is hotter compared to the southern and eastern Nigeria. So in northern Nigeria, we should focus on [it]" **(NGO-01).** "When you say solar, you are talking about sun, this the fundamental source. In fact, we have it in abundance here. I want to believe that is very important. Availability is there 100%" **(State Government Stakeholder-01).**

Themes	Categories	Codes	Data extracts/ Comments
Barriers	**Socio-economic**	**Initial cost and low income**	"The major obstacles that is preventing this solar product not moving very fast in the market is the financial aspect of it [solar], the price is very high" **(Vendor 5).** "The barrier is one and only one: the economic constraint. The price of the goods [solar appliances] is very high, and then income, people's income…… there is austerity generally, poverty. The price of this solar installation is high [initial cost and low purchasing power]. Because if you want to enjoy solar installation, at least you need N150, 000." **(Vendor 08).**
	Socio-technical and market	**Lack of confidence**	"the availability of fake products in the market is what affecting majority of the people not to partake in it." **(Vendor 05).** "So because of the huge substandard materials and lack of knowledge of proper sizing of the systems…… perhaps a poor design, you have also a poor system, it will not operate adequately. That is why mainly the failure is due to the use of substandard materials and poor design. These are the main factors. Particularly the streetlights that are being used in Nigeria, the failure rate of this system is very high. This is usually due to substandard materials" **(Energy Expert).**
		Unqualified technicians	"…there are people who are not very qualified of handling of solar and they have gone into the business and they have caused tears to some people" **(Vendor 09).**

	Socio-political barriers	**Lack of financial incentives**	"As I said earlier we are trying policy for now, the waivers and the 'tax holidays' have not been fully implemented" **(Federal Government Stakeholder-01).**
		Poor monitoring of imported materials	"Well, from my experience, from where we buy these [products], I have never seen any standard quality code. Because the way things are going on, one can easily go to China and say please I need these so, so products because of the demand by the public. So they go ahead, you know, people just import any how panels without any code or following due process like that. Like SON [Standard Organisation of Nigeria] which I know are the governing body of all these consumable items. So can hardly find a product like this solar system, you hardly find this 'logo' of SON. You hardly see it there! That is to tell you that people do go and import whatever they want. For us here, [at company level] I use my own way of assessing all these solar products and whatever. If I buy this I know which is good, which one is bad. You know if you go to the market you can find different brands……… which if you buy them at the end of the day you end up maybe losing your money or may be you will end up in the police station." **(Vendor 05).**

Themes	Categories	Codes	Data extracts/ Comments
Barriers-removal measures	**Socio-economic interventions**	**Subsidy**	"there should be subsidy in view of cost, the high cost of installations, if there is subsidy, I can assure you that RE system will be embraced". **(Energy Expert).**
		Awareness	"The most appropriate ways are by creating awareness… I do not know where this research is going to reach, but I can say wherever it reaches, I want this people [researchers] to take awareness strongly." **(NGO 02).**
	Socio-technical and market interventions	**Professional certification**	"We need accreditation: the govt. should set up a system whereby people will be certified to be in this business [certification]" **(Vendor 09).**
		Quality warranty	"…..you see if you look at our product, it is different from the commercial solar. Because we give the system [solar] like a 'lease', the people are paying the remaining balance gradually through an MTN account. So, if we produce the product with low quality, the people may have complained about it" **(Vendor 11).**
	Socio-political interventions	**Incentives**	"…in Nigeria we have this master plan for RE applications which was established by the Ministry of Power and ECN. Now in this…we suggested incentives that there should be incentives for those who want actually to use RE systems in their domestic applications. So that we can now bring down the cost of that initial cost. So actually what we were able to get out of that master plan most of the importation, the goods are even imported should be duty free" **(Energy Expert).**

			“There are a lot of measures: we have already written to the NASS about RE Master Plan, Govt. should give incentives to people bringing [importing] this kind of technologies [solar appliances] here, in Nigeria. On custom duties, on PV materials they should remove custom duties, or waivers; they should give waivers to the people who bring this kind of technologies into Nigeria” **(Federal Government Stakeholder-02).**
		Active quality assurance law	“The key recommendations for the government is actually to ensure that quality materials are imported, only quality materials are imported in the country” **(Energy expert).** “The appropriate way is that the govt. should look into it in terms of importations and verifying if these products they are supplying to the masses are genuine [monitoring standards], so that anybody can beat his chest and believe that this product is working” **(Vendor 05).**
		New financial model	“In addition to that, we need a situation whereby people can pay over time, just like what is happening in other countries especially Kenya. Though, it has started coming to Nigeria and we are also participating in that whereby you will pay solar based on use. If you need solar energy [power] in your place, we will set it up for you and you will be paying a service. We called it: 'energy as a service'. Or a hire purchase system whereby we will set up solar system for you then you will pay over 2-3 years” **(Vendor 09).** “That finance, if govt. can assist poor masses on this solar, everything will be ok. If they can give loan, there are some people working under government but their salary is very low, at times they will not receive their salary in time. But if government can give a loan for people that have an interest in it and continue to deduct the money monthly from their salary, this issue of finance would be reduced”. **(Vendor 02).**

Appendix V: Consent Form

Lancaster University

CONSENT FORM

July 24, 2017

Project Title: Energy Poverty in Kano State, Nigeria: Understanding the Problem and Finding Solutions

Name of Researchers: **Sule Muhammad Zubairu**

Supervisors: Dr Duncan Whyatt and Dr Nils Markusson

Email: **s.zubairu@lancaster.ac.uk**

Please tick each box

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, up to publication of the results. If I withdraw, my data will be removed. ☐
3. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher/s, but my personal information will not be included and I will not be identifiable. ☐
4. I understand that my name/my organisation's name will not appear in any reports, articles or presentation without my consent. ☐
5. I understand that any interviews or focus groups will be audio-recorded and transcribed and that data will be protected on encrypted devices and kept secure. ☐
6. I understand that data will be kept according to University guidelines for 10 years after the end of the study, after which data will be destroyed. ☐
7. I agree to take part in the above study. ☐

________________________	_______________	________________
Name of Participant	Date	Signature

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher /person taking the consent __________________________
Date ___________ Day/month/year

Appendix VI: Participant information sheet

Lancaster Environment Centre

I am a PhD student at Lancaster University and I would like to invite you to take part in a research study about solar Energy Technologies Diffusion and Barrier-removal Measures in Kano State Nigeria.

Please take time to read the following information carefully before you decide whether or not you wish to take part.

What is the study about?
This study aims to assess energy poverty problem and prospect of using solar energy as a potential solution. This part of the study ultimately seeks to understand solar technologies diffusion and identify possible barrier-removal measures.

Why have I been invited?
I have approached you because I am trying to find out about the solar technologies diffusion and barrier-removal measures. So, your contribution to this research will be invaluable to the understanding of solar energy utilization status through its sustainable diffusion/adoption and in making an essential part of energy transition through policy recommendations. We would be very grateful if you would agree to take part in this study.

What will I be asked to do if I take part?
If you decided to take part, this would involve the following:
You will be asking question regarding solar technologies inform of an interview which will be recorded and may last between 30-40 minutes. These questions range from awareness of solar energy potentials, solar technologies for lighting and cooking, solar projects and partners, solar diffusion and markets, solar technologies barriers to recommendation(s) on how to remove such barriers at different scale (e.g. state, LGA/community and individual household).

What are the possible benefits from taking part?
If you take part in this study, your insights will contribute to our understanding of solar technologies and their prospect in addressing problem of energy for lighting and cooking especially for poor people.

Do I have to take part?
No. It's completely up to you to decide whether or not you take part. Your participation is voluntary and you are free to withdraw at any time, without giving any reason. If you decide to withdraw at any point, your decision will carry no any negative consequences on you in any form.

What if I change my mind?
As explained above, you are free to withdraw at any time and if you want to withdraw, I will extract any data you contributed to the study and destroy it. Data means the information, views, ideas, etc. that you and other participants will have shared with me.

What are the possible disadvantages and risks of taking part?
Taking part in this study is harmless and risk free. As mentioned above you have unconditional freedom. If there is any disadvantage to occur, is may be by taking your valuable time (30-40 minutes).

Will my data be identifiable?
After the interview, only I, the researcher conducting this study will have access to the data you share with me as well as team of my supervisors. The only other person who will have access to the data is a professional transcriber who will listen to the recordings and produce a written record of what you and others have said. The transcriber will sign a confidentiality agreement.

I will keep all personal information about you (e.g. your name and other information about you that can identify you) confidential, that is I will not share it with others. I will anonymise any audio recordings and hard copies of any data. This means that I remove any personal information.

How will my data be stored?
Your data will be stored in encrypted files (that is no-one other than me, the researcher will be able to access them) and on password-protected computers.

I will store hard copies of any data securely in locked cabinets in my office.

I will keep data that can identify you separately from non-personal information (e.g. your views on a specific topic).

In accordance with University guidelines, I will keep the data securely for ten years, after which data will be destroyed.

How will we use the information you have shared with us and what will happen to the results of the research study?

I will use the data you have shared with only in the following ways:

I will use it for academic purposes only. This will include my PhD thesis and other academic publications such as journal articles, conferences and or to forward summary of its outcomes in form of policy recommendation(s). Also a few copies of my thesis could be circulated to library archives including the funding body of the research.

To reiterate, when writing up the findings from this study, I would like to reproduce some of the views and ideas you shared with me. When doing so, I will only use anonymised quotes (e.g. from our interview with you), so that although I will use your exact words, you cannot be identified in our publications.

Who has reviewed the project?

This study has been reviewed and approved by the Faculty of Science and Technology Research Ethics Committee, Lancaster University.

What if I have a question or concern?

If you have any queries or if you are unhappy with anything that happens concerning your participation in the study, please contact the researcher or team of supervisors on the following addresses:

Researcher:

Sule Zubairu
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B26, B – Floor, LEC 3
Lancaster University
LA1 4YQ
Tel:+44 1524 510017
Email: n.markusson@lancaster.ac.uk

If you have any concerns or complaints that you wish to discuss with a person who is not directly involved in the research, you can also contact:

Head of Department:

Professor Philip Barker
B061, B-Floor, LEC 1
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LA1 4YQ
Tel:+44 1524 510262
Email: p.barker@lancaster.ac.uk

Thank you for considering your participation in this project.