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FEASIBILITY OF MAKING SOLAR ENERGY AVAILABLE IN THE NORTHERN REGION OF NIGERIA

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Dedication

This dissertation is dedicated to Almighty God and to the most important people in my life: my dad (late) Prince Adeyemo R. Anjorin, my mother Mary Anjorin and all the members of the Anjorin Family.

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Finally, thank you to God, through whom all things are possible. I am living proof of that.

Tough times never last; tough people do.

ABSTRACT

This study was done to explore the feasibility of providing solar energy, at a household level using photovoltaic (PV) solar panels, to three states in northern Nigeria. Nigeria is a country that is limited by political and economic uncertainties as well as lack of a constant supply of energy (electricity), as 75 percent of the populace has no access to it. Solar energy would be an alternative that could help in enhancing government rural development initiatives and creation of job opportunities.

Quantitative research was used to determine various forms of feasibility. This research method showed the degree of achievability of supplying solar energy to the region. In addition, it assisted in determining how accessible solar energy could be as an alternative to hydro and fossil fuel energy.

The aim of the study was to determine the economic, technical, operational and legal viability of using solar energy in the northern region of Nigeria. To actually determine the practicality of this project in practice, there was the need to have a comparison of some expected metric against the observed metric. Findings from the study support the generation of informed decisions for stakeholders to improve the use of sustainable energy in Nigeria through enactments of favorable laws and policies to attract investors in renewable energy.

Keywords : Feasibility, Operational Feasibility, Economic Feasibility,Technical Feasibility, Legal Feasibility, Solar Panels, Costing, Northern Nigeria, Renewable Energy, Solar Energy

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CHAPTER ONE

Background

Energy sufficiency plays an important role in determining the levels of economic development and the maintainability of gains made by a nation. Access to sustainable sources of energy allows citizens of a nation to start and conduct their own businesses, using technology to access information (Khan, Merfeld, Pearsall, Geyer, & Dauskardt, 2008). In fact, the availability of energy is vital for sustaining large businesses and promoting the growth of small and medium enterprises (SMEs).

The depletion of the ozone layer due to human activities and their effect on the environment has resulted in increased concern from world leaders, engineers, industrialists, academics and scientists. The greenhouse effect arising from human activities is the main contributor to the depletion of the ozone layer (Mitavachan, Gokhale, Nagaraju, Reddy, Krishnamurthy, & Srinivasan, 2012). The attainment of the United Nations millennium development goals is partly dependent on significantly increasing the availability of electricity.

Further research into renewable energy products and systems has been motivated by the realization that the use of sustainable energy is vital to attaining energy sufficiency and minimizing environmental degradation. Research into power generation, irrigation and other areas where renewable energy can be applied has led to better systems for use with sustainable energy (Gude, & Nirmalakhandan, 2008). As developing nations seek to improve their economic performance, they are likely to enlarge their industries and increase their use of machines. These endeavors could result in significant increases in the amount of energy being consumed. Thus, Nigeria and other African nations have the responsibility of taking measures aimed at improving the use of clean, renewable energy.

Nigeria faces various challenges in the area of providing adequate power generation and distribution. The generation and transmission of electricity in Nigeria is below desirable levels. Production of electricity in Nigeria is mainly by gas and hydropower. Despite significant strides towards improving electrification especially in the rural areas, access to electricity in Nigeria is still a major challenge (Gutti, Ibrahim, & Musa, 2012). The infrastructural concession regulatory commission data reveals that approximately 60 percent of all Nigerian homes do not have access to electricity (Gutti et al., 2012). This is a large number of people, considering that Nigeria is the seventh most populous nation in the world with a population of approximately 170 million (CIA World FactBook, 2013).

Some nations have been successful in dealing with the setbacks they faced in providing sustainable energy. Nations that have been successful in ensuring energy sufficiency have used multiple sources of energy (Aldali, Henderson, & Muneer, 2011). These nations use not only hydropower and gas, but also alternative sources of energy such as solar, wind energy and biogas (Dean, 2010). Combining different sources of energy helped these nations improve their Total Electricity Installed Capacity (TEIC).

In Nigeria, the TEIC stands at 6,000 MW (Udah, 2010). Efforts targeting improvements in the TEIC have focused on developing new hydropower plants and wind farms. TheTEIC in Nigeria compares badly with developed and developing nations in relation to population size. It has 6,000 MW for a population of 170 million. In contrast, Libya has 6,000 MW for a population of 6 million, Egypt has 27,000 MW for a population of 83 million, and Morocco has 6,000 MW for a population of 32 million (Okanlawon, 2013). The U.S. has 1 million MW for a population of 315 million, whereas the UK has 93,000 MW for a population of 64 million (Okanlawon, 2013). In Africa, Nigeria is lagging behind South Africa, Libya and Morocco, among other nations that have taken the development of sustainable energy sources seriously. Nations that have managed to attain desirable TEIC levels have done so by harnessing renewable energy sources.

Nigeria is currently ranked among the top four investment destinations in the world. It is expected that investors will maximize on the opportunities presented by the favorable financial environment to invest in the energy sector (Udah, 2010). However, the lack of a constant supply of electricity, as well as political and economic uncertainties, limits the investment potential. The government could step up its efforts to increase the use of sustainable energy through the enactment of favorable policies to attract investors in renewable energy.

Solar energy is renewable from the sun (Rowland, Chambers, & Holzer, 2009). It is, therefore, inexhaustible and safe for the environment. Solar energy can be used for various purposes including water treatment, agriculture, electricity generation, lightning and solar chemicals. Of these areas of application, solar electric power generation is the fastest-growing area of application (Okafor, & Joe-Uzuegbu, 2010). The main sources of electric power in the modern world are nuclear reactions and fossil fuels. Most African nations, including Nigeria, rely on hydropower and fossil fuels. Hydropower does not generate adequate and consistent power for consumption at a national level. This is due to the influence of the weather (specifically the flow of water into the dams) on hydropower generation.

Nigeria is blessed with an abundance of energy resources. For instance, non-renewable resources include uranium, natural gas, coal and petroleum, while renewable sources include solar radiation, hydropower, wind and biomass. Yet despite the abundance of renewable and non-renewable energy resources, Nigeria has perennially been hit by electric power supply shortages (Okafor, & Joe-Uzuegbu, 2010). The supply of electricity, which is the most utilized energy source in the nation, is erratic. Since the first thermal power station was installed in 1920, there has been minimal expansion of the nation's electricity generation capacity to accommodate the increase in demand. In fact, only 40 percent of the Nigerian population is supplied with electricity from the main grid (Okafor et al., 2010). The remaining percentage with no access to electricity has private arrangements that mainly entail the use of diesel or gasoline-driven power generators.

The sun emits energy at high constant rates every day of the year (Childress, 2011). However, the availability of solar energy differs across regions. Most nations in Africa and the Middle East have abundant sources of solar energy due to availability of sunlight. Solar energy availability (measured in terms of sunlight hours in a day) in Nigeria differs across regions (Tsado, & Ganiyu, 2012). Its northern area has high levels of solar radiation compared to the southern area. Past studies targeting the availability of solar energy resources in Nigeria have revealed that its solar energy potential can be used for both domestic and industrial purposes (Opara, Efemena, & Egbujo, 2011).

Nigeria's annual solar radiation lies between 3.7 kWm^{-2} day^{-1} in the coastal region and 7.0 $kWm^{-2}day^{-1}$ in the semi-arid northern area of Nigeria (Gutti et al., 2012). On average, Nigeria's annual solar energy potential is 5.4 $kWm^{-2}day^{-1}$ (Gutti et al., 2012). In a day, Nigeria receives an average of 5.08 x 1012 kWh of energy. This implies that if solar appliances with 5 percent efficiency are used, 1 percent of the nation's surface area can produce 2.541 x 106 MWh of electricity (Gutti et al., 2012). This amount of energy is equivalent to slightly over 4.5 million barrels of oil in a day. Annually, Nigeria averages 6.25 hours of sunshine daily. The hours of sunshine range from 3.5 in the coastal areas to 9 hours at the far northern boundary. As a result, off-grid photovoltaic systems are recommended for individual households (Gutti et al., 2012).

The supply and demand gap in Nigeria's power is a result of inadequate development and expansion of the sources of energy and inefficient management of the energy sector (Osuagwu, Agbakwuru, & Chinedu, 2011). The inadequate supply of electricity has led to load shedding (power rationing). Rationing of power has adverse effects on commercial, industrial and domestic activities that depend on availability of power. The electric power reform act of 2005 sought to reform the electricity sector in Nigeria by allowing the private sector greater involvement in the generation of electricity (Latham & Watkins, 2011). Long-term private investment in the energy sector can allow for improved electricity generation and transmission.

The act set the precedence for the use of renewable energy for electricity generation to play a predominant role in Nigeria's energy sector. This move was informed by strategies used by developing nations such as China, Kenya, Indonesia and Thailand that have been successful in harnessing the potential of renewable energy. An important first step in exploring the potential of renewable energy is the enactment of deliberate policies by the government of Nigeria aimed at encouraging the private sector and second and third tiers of government, as well as local communities, to install and manage renewable energy for electricity purposes.

Nigeria has had successes and failures in the use of renewable energy, and some of the factors which caused these can be extended to solar energy. The reasons for failure include poor implementation of the renewable energy products and poor maintenance of renewable energy systems. In the case of solar energy, it is imperative that the users calculate or assess their energy consumption before determining the number and type of solar panels required (Sadjere, & Ariavie, 2012). Other considerations that determine the feasibility of solar energy have been discussed in other contexts. Most studies on solar energy in northern Nigeria and Nigeria in general focused on the amount of power that can be generated (Sadjere, & Ariavie, 2012). The focus of these studies was availability of solar energy as opposed to the feasibility of solar energy.

Efficiency is a major issue when using solar energy. Even the best performing solar panels have less than 20 percent efficiency (Zehner, 2013). When used for commercial purposes, the efficiency of the solar panels falls to 13 percent (Buttery, DeAngelis, Carwardine, Sheridan, & Siren, 2004). Efforts to combat this inefficiency are ongoing. The current corrective strategies target the use of different production techniques and materials (Roman, 2012). For instance, the use of carbon nanotubes and titanium oxide panels is considered the future of solar panels. However, these technologies are still in the preliminary testing phase.

The cost of photovoltaic (PV) panels is prohibitive for residential users (Karns, 2012). Greater involvement by the government through offering subsidies may be required to ensure customer buy-in. Advocacy groups in the area of the use of residential PV panels are in their formative stages, leaving customers exposed to predatory business behaviors. Combining solar energy with other renewable and non-renewable energy can help lower the price of electricity and solar panels (Isola, & Oderinde, 2010). In Nigeria, such a strategy could help combat perennial electricity rationing.

The poor efficiency of solar panels is not the only concern when analyzing the feasibility of solar energy in northern Nigeria. Lack of studies targeting the feasibility of solar energy in northern Nigeria may have resulted in reduced interest in solar energy use by scholars, residents and the government.

The TELOS framework is often used when analyzing feasibility. This framework covers the technical, economic, legal, operational and scheduling aspects of feasibility. Technical feasibility is concerned with the availability of technology and expertise in northern Nigeria, which is generally more remote than southern Nigeria. This remoteness is largely a result of the semi-arid climate. The availability of vendors that can sell the modules or parts required to install a functioning solar energy system is more problematic in this region. In addition, there is likely to be a lack of the expertise required to install and maintain the solar energy systems. The level of education in the northern region is low, which raises questions on the ability of users to correctly assess their needs for electricity and the availability of people skilled in the installation of solar energy.

Technical feasibility also includes the determination of the availability of the technical resources required for solar energy (Love, & Garwood, 2011). Sunlight hours per day is an important factor. Areas that have few hours of sunlight per day perform badly with respect to the technical feasibility of solar energy (Yaqub, Shahram-Sarkni, & Mazzuchi, 2012), while those that have many hours of sunlight in a day perform well. The seasonal changes are equally influential on the technical feasibility of solar energy. In regions that have many cloudy days in a year, it may be technically impossible to implement solar energy.

Operational validity pertains to the degree to which a solution addresses the problems it was designed to correct. This dimension has been used in analyzing the feasibility of solar energy, which is often used as a substitute for main grid electricity. As a result, the use of solar energy is prevalent in rural areas. As a source of electricity it should meet all the needs that would have otherwise been met by grid electricity (Mee, & Miller, 2011). This implies that solar energy should support the users' needs. It has been inadequate in some cases, due to weather and overloading by the users (Newell, & Newell, 2011). These operational issues could hamper the feasibility of solar energy in northern Nigeria.

Economic feasibility is defined as the cost effectiveness of solar energy, and is concerned with the assessment of the cost and benefits associated with its use (Schwarz, 2010). This is the most commonly used measure of feasibility by the existing studies on the use of solar energy. Costing methods used include net present value and discount-based costing approaches. Installation costs and maintenance costs are typically measured. The benefits associated with the use of solar energy include the foregone cost of electricity that would have been incurred when using grid electricity and the intangible benefits gained by using clean energy (Hadi, Abdel-Razek, & Chakroun, 2013). Economic feasibility should also entail analysis of the affordability of solar panels, inverters, installation and maintenance costs (Lucking, Christmann, & Spruce, 2010). Analysis of the cost of living and average household earnings in the region and comparing these values with the cost of solar energy can give insight into the economic feasibility of solar energy.

Lastly, legal feasibility is defined as the degree to which solar energy can be implemented within the existing legal framework, addressing conformance with the established legal frameworks. Vendors, installers and users of solar systems must conform to the existing legal frameworks regarding the use of solar systems (Swift, 2010). Existing legal structures aimed at promoting the use of solar energy could improve their validity. State and federal-level policies that encourage the use of solar energy could help improve the relevancy of solar systems. When analyzing the feasibility of solar systems in northern Nigeria, the focus of legal analysis was on the northern states, as opposed to Nigeria as a nation.

Statement of the Research Problem

The problem that this study sought to address was the inadequate and unsustainable energy production in Nigeria. Even though the country is endowed with natural energy resources such as crude oil, natural gas and coal, the production and distribution of electricity has always been problematic. This is blamed on an overreliance on non-renewable sources of energy such as oil and hydropower, and poor management of the energy sector. The study was concerned with addressing the poor development of renewable energy.

Analysis of nations that have managed to attain admirable levels of power generation revealed that such nations combined non-renewable and renewable sources of energy (Abu-Rub, et.al 2010). For Nigeria to generate power that meets the needs of its large population, renewable sources of energy have to be considered. The level of the use of renewable energy resources in Nigeria is negligible. Over 99% of the nation's power is generated by hydropower and gas (CIA World FactBook, 2013).

Despite the immense potential of renewable energy and specifically solar energy in the northern region, little has been done to harness it. An examination of the existing literature revealed that even though the availability of solar energy in northern Nigeria has been explored, most issues relating to the feasibility of solar energy there have yet to be researched. Most studies on the feasibility of solar energy target either the technical (in terms of the number of sun hours in a day) or the economic feasibility (cost and benefits analysis). However, other dimensions such as the technical feasibility, operational feasibility and legal feasibility of solar energy have only rarely been analyzed. In the case of northern Nigeria, little has been done to establish the feasibility of solar energy. Without doing so, stakeholders would be reluctant to invest, support and even use solar energy. Thus, establishing the feasibility of solar energy in the northern region of Nigeria is critical to improving the use of this clean and renewable source of energy.

Purpose of the Study

The purpose of the study was to establish the feasibility of solar energy in the northern region of Nigeria to aid in the determination of the viability of solar energy as an alternative source of energy. Nigeria's energy problems may be partly addressed by the adoption of renewable energy. Solar energy is a viable option in northern Nigeria, considering that the region enjoys many sunlight hours per day. The study addressed the gap in research relating to the feasibility of solar energy in northern Nigeria which may instigate the interest of investors, government, businesses, non-governmental organizations and citizens.

Research Aim

The aim of the study was to determine the economic, technical, operational and legal feasibility of using solar energy in the northern region of Nigeria. The term "solar energy," as used in the study, refers to household-level harvesting of solar energy using PV solar panels. The study was limited to the northern region of Nigeria.

Research Objectives

The following were the research objectives:

a. To determine the economic feasibility of using solar energy at a household level in the northern region of Nigeria.

b. To determine the technical feasibility of using solar energy at a household level in the northern region of Nigeria.

c. To investigate the operational feasibility of solar energy at a household level in the northern region of Nigeria

d. To investigate the legal feasibility of using solar energy at a household level in the northern region of Nigeria.

Research Questions

The main research questions for this research thesis were:

a. What is the feasibility of replacing fossil or crude oil with solar energy in the northern region of Nigeria?
b. What kind of management/leadership structure is in place and would lend itself to the emergence of solar energy technologies as an alternative source of energy in Nigeria?
c. Based on best practices from other related shifts to renewable energy sources from other countries, what would have to change, if anything, in the northern region of Nigeria?
d. How would Nigerian governmental power and politics impact the shift to renewable energy usage?

Nature of the Study

As the study was concerned with determining various forms of feasibility, a quantitative research design which makes use of measurable quantities was used, as this is the most effective approach in showing the feasibility or lack of feasibility of utilizing solar energy. A quantitative research design, compared to a qualitative one, was better placed to meet the needs of the study. The risk of bias when using quantitative research design is reduced, so this ensured that the study was credible and could, therefore, be used by stakeholders in assessing the feasibility of solar energy in the northern region of Nigeria.

Theoretical Support for the Study

The feasibility of solar energy in Nigeria is tied to the sustainability of energy resources. This is because feasibility targets determination of the accessibility to solar energy and the sustainability over time. Furthermore, solar energy is an ecological resource. As such, frameworks that target sustainable use and development of ecological resources are applicable to solar energy feasibility.

There is a lack of comprehensive theoretical frameworks for understanding and studying sustainable development and its complexities. This lack stems from the value definition of sustainable development. In general, there are disagreements and contradictions over what should be considered sustained (Jabareen, 2008). Jabareen (2008) developed a theoretical framework for sustainable development that combined the various concepts targeted in the use of environmental resources. This framework was employed in this study because it combines most concepts of sustainable development and tries to address the contradictions and disagreements. The holistic approach to sustainable development by the study mirrors considerations on the feasibility of solar energy. In both cases, concepts ranging from the society involved to natural capital stock were considered.

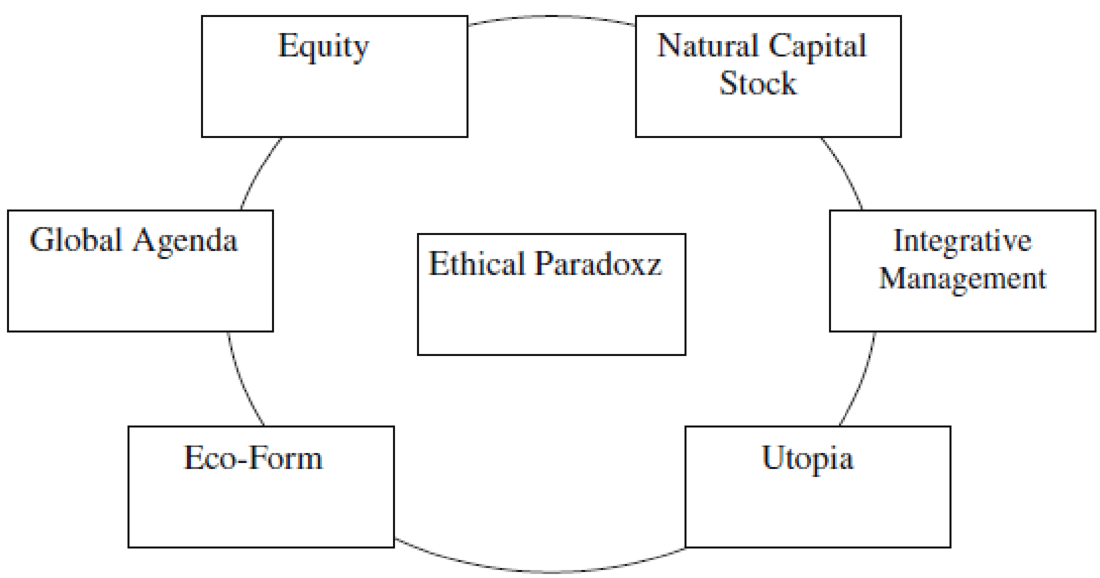

Figure 1: Conceptual Framework for Sustainable Development, Source (Jabareen, 2008)

The conceptual framework is made up of seven interrelated concepts. Within sustainable development discourse, there is an ethical paradox influenced by six concepts. The term sustainability defines the character of a process or processes that can be maintained indefinitely. On the other hand, development often involves environmental modification that requires deep intervention and results in the exhaustion of natural resources (Dempsey, 2009). The inclusion of the term development into the ecology-derived sustainability led to the increased analysis of sustainable development from social and capital dimensions (Jabareen, 2008). The Brundtland report, as an example, deemphasized the environment while underscoring human needs realization via development (Jabareen, 2008). This conceptual framework mitigates and moderates the paradox between sustainability and development. Although there is no universal definition of sustainable development, nearly all definitions approach it from the perspective of a tension between economic growth and environmental protection goals with a general preference for the former (Dempsey, 2009). Ethics is concerned with good and evil. In the context of this study, the ethical paradox was replaced by feasibility. Thus, using this conceptual framework, feasibility of solar energy is determined by six different concepts: namely utopia, eco-form, integrative management, natural stock capital, equity and global agenda (Jabareen, 2008).

The concept of natural capital stock, which refers to all natural and environmental resources, is applicable to this study. Natural capital refers to all natural assets whose reproduction can be modified or enhanced, but cannot be created by humans (Ionut, 2008). Natural capital stock is divided into three categories: non-renewable resources, the finite capacity of the natural systems to produce renewable resources and the capacity of the natural systems to absorb the effects of human action such as pollution without side effects that would result in heavy costs for future generations (Ehrlich, Kareiva, & Daily, 2012).

Feasible use of natural assets implies use in a manner that does not decrease the stock of capital or endanger opportunities for future generations. In the current study, natural capital stock refers to the availability of naturally occurring energy resources within Nigeria. Of the available natural energy resources, solar energy can easily be used in a sustainable manner. This is because solar energy harvesting techniques do not affect the strength of the solar rays. It is noteworthy that the availability of energy resources influences the feasibility and the willingness to explore alternative sources of energy (Jabareen, 2008). Importantly, analysis of feasibility must involve analysis of the renewability of the resources, its ability to produce renewable resources (solar energy) and the capacity to absorb the effects of human action (for instance, reducing the levels of pollution).

The concept of equity is essential in this conceptual framework. Equity is concerned with the social dimension of sustainable development. Researchers argue that an unjust society is unlikely to sustain its environment or economy (Mercier, 2009). From this perspective, sustainable development is a criterion for environmental justice. The concept of equity involves consideration of economic justice, quality of life, empowerment, public participation, freedom, democracy and equal rights for development. The use of natural resources is largely linked to social justice, quality of life, rights and equity. This is due to the belief that equity and general social considerations are related to environmental limits imposed on a supporting ecosystem (Jabareen, 2008). Many scholars are of the view that the sustainable use of natural resources requires balancing the social, economic and environmental goals (Kang, & Hur, 2012).

Another perspective to social equity involves consideration of the generational impact. The current generation could use natural resources in a manner that does not incur high costs and losses to future generations. This generation-based analysis of equity led to two different types of equity: intergenerational and intragenerational. Intergenerational equity refers to the use of resources by the current generation without compromising future generations' ability to meet their needs (Jabareen, 2008). Intragenerational equity is concerned with equity within a generation. In this study, equity in terms of the ability to afford solar panels and access to technical knowhow could significantly influence the feasibility of solar energy in northern Nigeria.

The concept of eco-form is used in representing the ecologically desired forms and designs of human dwellings or habitats. Research into sustainability strategies have focused on the ecological design and defining the urban forms that allow for sustainable functioning (Kitchen, & Marsden, 2009). Since the rise of the debate on sustainable development in the 1980s, various theoretical works on ecological design have emerged. The studies have adopted ideas and technologies relating to sustainability and ecology such as renewable energy, recycling, conservation, alternative building materials and organic foods (Jabareen, 2008). A common view among eco-form scholars and policy makers is that energy efficiency is critical to the attainment of ecological form through design. This is partly based on the assertion that better designs result in increased energy efficiency and reduced air pollution. Energy efficiency is a key matter when discussing the feasibility of solar energy. Even though solar energy is renewable, the efficiency in transforming this energy into usable power is vital to its feasibility.

Another dimension to the eco-form concept is the aspect of planning. Current literature suggests that sustainability is likely to be achieved when planning is carried out at local and regional levels (Jabareen, 2008). Efforts targeting sustainable use of energy resources at a local level are more likely to incorporate the use of alternative sources of energy. This brings out the importance of planning and increased awareness of sustainable energy use on the feasibility of solar energy.

Integrative management is concerned with an integrative approach to aspects of environmental protection, social development and economic growth. The integration of environmental economic and social concerns in the planning and management of sustainable development is an area that has received considerable attention in recent years. The achievement of sustainability and ecological integrity lies in the use of holistic and integrative approaches.

By the late 1980s, some researchers were challenging the view that economic objectives should take greater precedence over environmental concerns by stating that environmental health is critical to economic and social success (Kitchen, & Marsden, 2009). Currently, more researchers are of the view that environment and development are interlocking global crises; thus, the challenge lies in finding ways to integrate environmental and developmental concerns in order to attain sustainable development (Ulrich, 2010). Current practices in many countries where social, environmental and economic factors are separated in the policy, planning and management of aspects relating to sustainable development are faulty. Four areas that need improvement with respect to integrative management are integration of environmental concern and development, provision of effective regulatory and legal frameworks, the establishment of systems for integrated environment and economic accounting, and effective use of economic instruments, markets and other incentives (Kitchen, & Marsden, 2009). Improvements in these four areas could result in increased consideration of the environment and development in political and economic decision-making. In analyzing the feasibility of solar energy, various social, legal and economic factors were considered. This was to ensure conformance with the integrative management concept and a holistic approach to analyzing feasibility.

The concept of utopianism envisages human habitats based on the concept of sustainable development. Utopian thinking allows for the questioning of the presuppositions in present-day sustainability practices (Crampsie, 2012), and allows visionaries to envisage the desired future with respect to sustainable energy use. This imagination is critical to the improvement of the existing sustainability practices. Importantly, most utopian thinkers outline the importance of values and balancing between developmental and environmental goals. The utopian approach has, however, been criticized as lacking in practicality, considering the importance of resources in driving modern economies.

The concept of a political global agenda is equally important to the adopted conceptual framework. Sustainable development discourse has led to ideas currently being reconstructed. For instance, in the 1990s environmentalists were mainly concerned with their local and national space (Jabareen, 2008). Over time, the issues of sustainable development and use of natural resources took a global dimension. As examples, discussions on factors affecting the environment and sustainability of energy resources have transcended national boundaries. Environmentalists are currently viewing Earth as a unified globe. In addition, there are increased efforts to address the root causes of sustainability threats and to provide the developing world with the tools and resources required to be at the same level as the developed world (Deutz, 2009). Despite these efforts, the growing divide between rich and poor and the developed and developing nations poses a major threat to security, stability and prosperity. From this, it is apparent that the global political agenda relating to sustainability can influence the strategies used at a national level. Currently, there is a surge in calls for increased development of renewable energy potential in both developed and developing nations.

Assumptions

Several assumptions were made when carrying out the study. The first assumption was that households would be willing to participate in the study despite the volatile nature of northern Nigeria. In the recent past, northern Nigeria has been in the headlines for religious violence. Carrying out a study in such a setting could be demanding irrespective of the magnitude of the violence. However, it was assumed that households would be willing to participate in the study. This assumption was based on the friendly nature of Nigerians in general and the involvement of locals in the data collection exercise. The latter measure reduced suspicion and the handling of practical issues relating to data collection.

The second assumption was that the households would have access to the data required to determine the feasibility of solar energy. The data required in this study included energy consumption, access to solar panel vendors, amount of money spent on energy per month and the household income. Accessing this data could be problematic since households do not necessarily keep it. Thus, the study assumed that the households would be able to provide the data collection team with the necessary data because the participants were given a two-week time period within which they could seek the collected data.

Scope and Delimitation

The study targeted feasibility of solar energy in northern Nigeria at a household level. Households were defined as houses; that is, occupants of a single residential house (home) were considered a single household. The study only targeted adult participants that were capable of providing the information required to assess feasibility. Minors under the age of eighteen years, irrespective of their ability to provide relevant information, were not included in the study.

Adults who could not provide the information required due to language barriers or lack of access to the required information and persons with visible mental disabilities and problems were not included in the study. These measures were aimed at minimizing the risk of including participants that could have provided inaccurate data, as well as from an intention to act with conformance to ethical regulations regarding the conduct of research. Geographically, the study was limited to three states in the northern area of Nigeria.

Lastly, the study only focused on the feasibility of solar energy, though other forms of energy were included in this analysis in order to compare alternatives. In the current study, solar energy was compared to the sources of energy used in the participating homes. Despite the inclusion of other energies in assessing feasibility, the focus of the feasibility analysis was on solar energy for households. Though there are multiple considerations when analyzing projects and sources of energy, such as acceptance, this study was limited to feasibility. Specifically, the study was limited to four forms of feasibility, namely operational feasibility, legal feasibility, technical feasibility and economic feasibility. Others forms of feasibility and other non-feasibility considerations were not included in the study.

Limitations

The main limitation of this study was that it was difficult to estimate the number of participants required to ensure that the sample was representative of the population. Data on the number of households within the three Nigerian states included in the study was not easily accessible. Determination of the sample sizes required for the results to be representative of the population would require an estimate of the population (the number of households in each state).

Next, there was a high likelihood that some items in the questionnaires may have been left out or estimated. Some of the questions required the participants to make estimates, which may not necessarily be accurate. This limitation was a result of lack of documentation on energy use. In Nigeria, most households buy fuel from local vendors who do not necessarily give receipts. As such, there was no documentation to be used in estimating household energy consumption. Therefore, the participants estimated the household energy consumption in certain cases. The errors resulting from these estimations cannot be determined. This left room for validity and reliability concerns in the results.

Significance of the Study

The study contributed to the existing knowledge on the feasibility of solar energy and energy use practices in Nigeria, and focused on the feasibility of solar energy in northern Nigeria. The types of feasibility being addressed by the study had yet to be covered by existing studies on solar feasibility. In addition, the study addressed a gap in solar energy feasibility in the northern region of Nigeria and helped establish the feasibility of solar energy, thereby highlighting areas relating to this topic that need to be researched further. In addition, the study offered insight into factors responsible for the feasibility, or lack of it, of solar energy in Nigeria. These aspects could be researched further to improve the feasibility of solar energy in the northern region of Nigeria.

The study's findings are important to the energy sector. The findings help inform different stakeholders in the energy sector on the feasibility of solar energy in the northern region of Nigeria. The government, as an example, may use the findings to identify areas that need to be improved to ensure solar energy is feasible. Nigerians living in this region, businesses, NGOs and state governments may use the findings to establish areas that need improvement and to inform their actions with respect to improving the feasibility, viability and use of solar energy.

Definition of Terms

a. **Feasibility:** This is the analysis of the current and future potential of a project or venture based on extensive investigation with the aim of aiding decision making. Feasibility helps in determining if a project or venture is doable.

b. **Operational Feasibility:** The degree to which a solution (solar energy) solves an identified problem. In the study, the problems include erratic power supply and lack of coverage by the national grid.

c. **Economic Feasibility:** This is a measure of the positive economic benefits associated with a proposed system. Economic feasibility often involves consideration of both the cost and benefits of a proposed solution.

d. **Technical feasibility:** This is concerned with the determination of the adequacy of the available technical resources (both people and equipment) required to implement a given solution.

e. **Legal Feasibility:** The degree to which a proposed solution is in line with the existing legal requirements. This involves considerations of the existing laws relating to the installation of solar equipment and the acquisition of such equipment.

f. **Solar panels:** This is the hardware or equipment required to harvest solar energy. Solar panels transform solar rays into electrical energy.

g. **Costing:** The method used in determining the cost of a proposed solution. Costing typically involves the use of different methods. Costing is vital in determining the solution with the least cost.

h. **Northern Nigeria:** This refers to states that border other nations to the north of Nigeria or simply the northernmost states in Nigeria.

i. **Renewable Energy:** Sources of energy that can be renewed with or without the intervention of man.

j. **Solar Energy:** This is energy from the sun in the form of radiation.

Summary

This chapter presents the background of the study, the problems statement and the purpose of the study. Other aspects covered in this chapter include the theoretical framework as well as the scope, the limitations and the definition of the key terms of the study. The main aim of this chapter was in setting the tone and establishing the basis for the study, detailing the reasons for carrying it out.

The next chapter reviews the existing literature on different concepts relating to the feasibility of solar energy in Nigeria. The third chapter addresses research methodology, discussing the method used in carrying out the research. The fourth chapter is on the results and discussion, with the presentation and discussion of the results of the study. The last chapter of the conclusion and recommendations summarizes the study by stating the key findings and presenting recommendations based on the results.

CHAPTER TWO

LITERATURE REVIEW

Energy Crisis in Nigeria

This literature review consists of perspectives from different authors related to the energy crisis in Nigeria. This range of views extends from empirical to anecdotal and the suggested methodologies range from accounting-based to qualitative, as in observations and interviews. A few of the key authors reviewed here include Adurodija et al, Chendo, Mukhopadhyay, Odukwe, et al. Their work in this area has been extensive and they offered much in terms of insights and research that has already been conducted which led this researcher to insights that could further the field through this dissertation project.

In this review the term "energy crisis" has been defined in such a way as to help further the understanding for the reader based on the potential outcome of this research. The review further aids the reader in understanding why this is important and why there might be a need for the valuation of intangible assets. A number of potential tools and methodologies for measuring this value were reviewed and analyzed. Some approaches that have been used to implement these types of methods are also shared with the reader.

After an exhaustive search of the following databases, nothing additional was found that would be of value to this body of knowledge. Databases searched include University Microfilms, Inc. (UMI); Econolit; Academic Search Premier; Business Source Premier; ERIC; Sociological Abstracts; ABI Inform; and Wilson Business Abstracts. Keywords used in this literature search were combinations of the following: knowledge management, organization(al), learning, measurement, valuation, deficit, value, tools, barriers, intellectual, capital, and implementation.

The term "energy crisis" and its associated economic, social and political consequences are not new on the international scene. Tremendous interest has emerged on oil politics and the consequences of crises related to the same. Looking at the international scene, the oil war in 1973 provoked many Western countries to adopt alternative sources of energy. The essential substitutes for fossil fuel that have been methodically researched and developed in these countries include coal, tar sands, biogas, nuclear energy, wind energy and, most importantly, solar energy. However, according to Adenikinju (2003), technological, economic and leadership limitations and inadequacies have hampered the less-developed countries from maximally utilizing these resources.

As observed by Chaurey (2010), domestic energy in many third world countries is derived from biomass (charcoal, fuel wood and animal residues). Among many African countries, fuel wood and paraffin constitute the most fundamental sources of fuel. Northern Nigerian households rely fundamentally on fossil fuel for lighting. However, the aforementioned sources of energy have been indicated in considerable health as well as socio-economic detriments in the Third World. Additionally, these sources are not renewable and are therefore not sustainable. Both urban and rural dwellers continue to live in strife because of the increasing fuel prices. As industrial development and urbanization increases in Northern Nigeria, the need for a sustainable source of energy also rises.

Overdependence on fossil fuel has stunted the growth of industries in northern Nigeria because the prices of fuel have gradually risen over the years. The increases have been driven by the crisis in world economics and uprisings in many other oil-producing countries. Additionally, the overreliance on fossil fuel affects the lives of many rural households who do not need it directly. As Adurodija et al. (2008) opines, many poor families from the rural areas may not pay directly for fuel, but they give valuable labor time in return for the available fuel. This can push them into exploitive wage-labor relationships.

The oft-mooted notion of the ladder of energy suggests that as income increases in households, they tend to switch to advanced energy forms such as electricity (Adjebeng-Asem (1990). However, in reality most households use a combination of energy forms regardless of their income. Fundamentally, fuel choices among households are driven by several factors including availability of resources, education and distance from the supplier.

As observed by Agbo (2006), meeting the challenge of providing adequate, reliable and widely accessible energy services to rural households involves more than summing up numbers and correcting other technical aspects from the domestic perspective. It may involve tackling critical challenges to access to energy in the Nigerian rural economy, sustainability and reduction of poverty through production activities in this sector. These factors contribute to the need of a sustainable source of energy. Solar energy comes as one of the most sustainable forms of energy that can be adopted in northern Nigeria.

Many studies have been conducted regarding solar energy in Nigeria. Several other studies have also investigated how suitable solar energy is in replacing fossil fuels as the primary source of energy. Based on studies conducted by Adikibi (2000), the northern part of Nigeria can harness the benefits of solar energy maximally. Nigeria as a whole lies within the sunshine belt with an average daily radiation of about 7kWhm-2day-1. Additionally, the country receives approximately 6 hours of sunshine per day. Northern Nigeria can harness this benefit with appropriate technological and management structures (Cowan & Kline, 1996). As noted by Ingwe et al. (2007), with the prevailing efficiencies of solar generators, if solar collectors covered only 1 percent of Nigerian landmass, over 1,850,000 GWh of solar electricity would be harnessed yearly. This would constitute over a hundred times of what the current grid provides and what is consumed in the whole country (Ngoka, 2001; Akinbulire et al., 2008).

Frameworks for Inception of Solar Energy in Northern Nigeria

The feasibility of introducing solar energy in northern Nigeria would require a framework that would facilitate the achievement of high-quality results. According to Kamp et al. (2009), the framework needed for the introduction of solar energy in northern Nigeria should not only focus on technology, but also on the socio-economical aspects of the country and the stakeholders involved. Dealing with the introduction of solar energy in a country that has a complex local context is not a trivial matter. Kamp (2012) notes, Nigeria needs a combination of frameworks in order to provide a broad understanding of the local scenario, and to draw optimal results.

Several frameworks have been suggested through various studies to help understand what would be required to introduce solar energy in northern Nigeria. Some of those widely researched include multi-level perspective (MLP), Strategic Niche Management and Function of Innovation Systems. Suurs et al (2007) discusses the multilevel perspective deeply, giving the levels at which innovation would be necessary for the adoption of solar energy to occur.

The levels discussed are macro-level or landscape, socio-technical regime and the technological niche. The framework would make the adoption of solar energy easier in northern Nigeria, because it does not focus on technology only but also on the regime and landscape. On the other hand, the strategic niche management (SNM) approach employs the MLP to focus on a new locus comprised of learning, expectations and networks.

As noted by Markard & Truer (2008), niches are spaces where new technologies develop and become viable via gradual experimentation and learning through a network of actors. The niches can be used to get through the regime (leadership) and change the landscape. Hekkert & Negro (2009) add that, for a niche to reach the expected standard there must be constant interaction with different dimensions of the regime. For the introduction of solar energy in northern Nigeria, niches should be protected through subsidies (Kamp, 2008). The protection is necessary for the performance of technology that is still not sufficiently mature to compete with the solutions that are already in existence.

However, Negro et al (2006) observes that the creation of niches in research and development in northern Nigeria would not be adequate. For successful introduction of solar energy in northern Nigeria, new technologies would need to be tested, experimented and pilot projects created before they are introduced (Suurs et al., 2009). Furthermore, in cases of renewable energy, the market for technologies is limited. This market is only created through technological evolution in the protected niches. Northern Nigeria would have to consider networks such as the users, the government, researchers and organizations involved (Van Eijck & Romijn, 2007).

For the case of northern Nigeria, political and cultural features play a crucial role in the adoption of solar energy. Therefore, perfect understanding of the regime and landscape is essential. Suurs et al., (2009) observes that the SNM would be insufficient in driving the adoption of solar energy, since it does not take socio-technical aspects into consideration. However, he adds that the SNM would be well-suited because of the learning processes and study of expectations that the framework puts into consideration. A combination of SNM and MLP would act as an appropriate framework. However, the framework does not cover all the essential aspects needed to understand the complexity of the situation in northern Nigeria.

The complexity, however, can be faced through the Function of Innovation Systems (FIS) as postulated by Munroe. The framework is convenient in analyzing and understanding the aspects of solar energy inception in northern Nigeria. According to Truffer (2008), recent research in technological innovative systems theory developed innovative systems that can gain market acceptance. Kemp (2008) developed the division of research into functions. Different functions can be modified or renamed to suit the context of the adoption of solar energy in northern Nigeria.

For the context of northern Nigeria, several functions can be used to drive an easy adoption of solar energy. As explained by Negro et al (2006), the functions include knowledge development, knowledge diffusion and guidance of research, support from advocacy groups and mobilization of resources. Suurs et al (2009) included several other functions; market formation and entrepreneurial activities are among them.

A combination of the aforementioned functions can help drive smooth adoption of solar energy in northern Nigeria. Negro et al (2006) stated that knowledge for adoption of solar energy in northern Nigeria can be done through interaction, actions and use of the established technologies. Several mechanisms can be used in knowledge diffusion to instigate the adoption of solar energy in northern Nigeria. Among the components of this function discussed by Negro et al (2006) are workshops and conferences. As noted by Ingwe et al., (2007) & Ebohon (2002), there is little knowledge in place among people in northern Nigeria regarding solar energy. The spread of knowledge among different players in the region can increase the feasibility of the adoption of solar energy in northern Nigeria.

Innovation systems require a combination of actors from different backgrounds in the region to drive the switch from fossil fuel to solar energy. This combination is identified by Ibitoye & Adenikinju (2006) as one of the factors than can help understand the problems in the region, thus driving the further innovation necessary for the switch. Additionally, without the diffusion of knowledge, there would be minimal or no research and development necessary for the use of solar energy in the region (Fadare, 2009).

Essential Requirements for Inception of Solar Energy

According to Negro et al. (2006) and Linderman & Rono (2009), the government should play a crucial role in guidance of research if the overreliance on fossil fuel is to be mitigated. Significant innovations are required for maximum harnessing of solar energy (Cloutier & Rowley (2010). However, Chaurey & Kandpal (2010) note that there is still little guidance of research to drive smooth adoption of solar energy in northern Nigeria. As postulated by Mills, stimulation of markets through incentives to companies can help in this issue. Guidance of research is essential in shaping needs and meeting the expectations of the actors involved.

The replacement of fossil fuel with solar energy requires deep exploration of resources and alternatives in the innovations offered (Kennedy-Darling et al, 2008). However, Kamp (2008) notes that too much focus on variety may lead to a dilution effect that could cause stakeholders to miss the opportunities that other solutions offer. Therefore, it is essential to create a perfect balance between the long-term vision of the installations and the alternative chosen (Gujba et al, 2010a). Negro et al. (2006) note that support from advocacy coalitions can also drive the switch. This support involves counteraction of resistance to change and creation of legitimacy of the projects that can be used in harnessing solar power in the region.

However, Chendo (1996) observes that the northern region of Nigeria falls short in that there is little support from any advocacy groups. This has slowed the development of structures that could help in replacement. Advocacy coalitions can help build legitimacy of the technologies that people in the region come up with to help in harnessing solar energy (Ilenikhena, 2010). Also, northern Nigeria could face problems in the quest of replacing fossil fuel with solar energy because of resistance to change (Ekweme, 2012). This reluctance to utilize new technologies comes fundamentally because of competition with the existing products (Jacobsson & Johnson, 2000). This counteracts the stimulation and enthusiasm to develop new technologies in the area. Lobbying activities may play an essential role in cases of renewable sources of energy. However, marred by little education and knowledge in these areas, northern Nigeria may find it difficult to replace fossil fuel (Maconachiea et al, 2009). Additionally, a recent study conducted by Okuro (2012) indicates that political instability in the region has resulted in resistance to change in many areas of development in northern Nigeria.

For the prospect of replacing fossil fuel with solar energy to be feasible, Negro et al. (2006) observes that there needs to be massive mobilization of resources in northern Nigeria. This refers to the allocation of finances, materials and human capital for the harnessing of solar energy. As noted by Suurs et al (2009), subsidies and investments can help mobilize resources in northern Nigeria. For example, investments in new factories could help in the creation of policies that would attract foreign investments in the region. However, the North has few of these and thus may lag behind on the project.

Market formation and entrepreneurial activities are other factors essential for the switch. Market formation for technologies pertinent to solar energy can take the form of tax exemptions, subsidies and environmental standards (Suurs et al., 2009). The aforementioned factors are capable of orienting the market towards certain technologies in the area (Ekuro, 2012; Nnorom et al, 2009). However, Moyo (2009) adds that such market formations are largely absent in the Nigerian context, and this has acted as a setback in the quest for replacing fossil fuel with solar energy. Policies and incentives are essential in management and leadership structures, since they drive emerging technologies, which are costly, to the next level of development.

Support is essential in the creation of cost-effective solutions in the adoption of solar energy technology in northern Nigeria. However, with lack of support from the established government structures, the overreliance on fossil fuel in the North may continue indefinitely (Okoro et al., 2008). Suurs et al. (2009) asserts that entrepreneurial activities are an essential component for the development of new technologies and innovations. They are an avenue for the creation of markets for the established, self-sustained businesses in solar power production.

However, Okoro et al. (2008) observes that entrepreneurial activities pertinent to solar energies are limited or insignificant regarding the adoption of solar energy in the north as a whole. The established businesses for harnessing solar power are small-scale and cannot meet the demand for energy for the whole region (Johnson, 2000). Because of these issues, the replacement of fossil fuel with solar energy may take some time until entrepreneurial activities are encouraged in the region.

Parameters to Be Considered for FSI MLP Combination

For the prospect to be feasible, Markard & Truer (2008) suggest three key parameters that should be taken into consideration. Actors (stakeholders), rules (institutions) and the technologies should be deeply considered before the prospect can be achieved. Recent studies show that a combination of the FIS approach and analysis of the cumulative causation concept can benefit the inception of new technologies in the area. The cumulative causation concept involves the build-up of a technology which accelerates system's functions of interaction and reinforcement upon each other (Suurs et al., 2009).

Cumulative causation can stimulate innovation, although there are many barriers and consequences involved. It refers to a self-reinforcing procedure during which an innovational drive into a system triggers further changes in the same direction as the original impulse. This could be either an advantage or a disadvantage to some people/geographical locations; it is a mechanism that accounts for the uneven geographical distribution of economic activity (Suurs et al., 2009). In the case of Nigeria, the combination of FSI and MLP frameworks can make the prospect of replacing fossil fuel with solar energy feasible. The combination has been used in other studies pertinent to solar energy (Suur et al., 2009; Negro et al., 2006).

As noted by Markard and Truffer (2008), a combination of the frameworks ties together two or more unrelated aspects of innovation, thus facilitating a flawless translation of results acquired from one framework into the other. However, Okoro et al. (2008) opines that some extra features should be added to match the case of Nigeria. Cultural analysis is the first aspect suggested that is pertinent to the adoption of solar energy in northern Nigeria. Nigerian culture differs from most other cultures in developed countries that have been studied in line with renewable sources of energy. Understanding the culture of people in the northern region has been mentioned by Okoro et al. (2008) as one of the most crucial elements that could foster easy adoption of solar energy. Secondly, for the prospect to be achieved there must be extensive studies on how corruption in the region might affect the market for solar energy there (Linderman & Rono, 2009).

The combination of these frameworks creates unique aspects that can be used in many developing countries, including Nigeria. The aspects discussed under MLP and FIS models are combined to create a strong link between the components needed for the switch. The projects that can be started which are pertinent to solar energy need to take into consideration the key problems within the region. Additionally, the projects need to understand how the local culture of the region is defined and how easily the culture would be willing to instigate the adoption of solar energy.

Problems with the Prospect of Solar Energy that Northern Nigeria Faces

Several analytical studies have been developed to guide the situation at hand in Nigeria. These studies focus on the problems that Nigeria faces, which may make the prospect of replacing fossil fuel with solar energy unattainable. According to OFID statistics (2010), Nigeria is one of the poorest countries globally in spite of the large oil deposits in the Niger delta.

Two trends pertinent to poverty alleviation are common. Donations from the developed countries are one of the aspects that can be used in the context of adopting solar energy. However, Chineke & Ezike (2009) observe that donations for such projects have significant negative effects that may destroy the economic systems within the region. Chineke & Ezike (2009) add that donations have been the principal cause of the stagnation of African economies.

However, other researchers argue that, without donations, African and developed economies would plummet. In the case of the adoption of solar energy, requirements for funding would benefit the locals to a significant extent. The fact is that Nigeria, especially the northern region, is poor and needs intervention from donors. Projects for the generation of solar energy could be a massive failure considering the levels of poverty and government negligence in northern Nigeria (Okoro et al., 2008).

Violence is another aspect that may hinder the adoption of solar energy in the northern region. In 2008, Nigeria was ranked eighteenth among the most unstable countries globally. Nigeria has had a series of ethnic crises since it returned to democracy in 1999. As observed by Campbell (2011), there is a significant divide between the north and south. The north is for the most part Muslim and poor, but has more political power than the south, while the south has a Christian majority and oil wells, and is richer than the north. This divide may act as one of the factors that could slow down the adoption of solar power in the northern region.

The recent attacks from the Boko Haram sect is a clear indication of how such projects could be likely to fail in the region. It is opposed to Western civilization, education and development. The introduction of new technologies is likely to cause a ripple of crisis in the region, since the sect is strong in the north (Ani, 2010). Secondly, such violence may turn off foreign investors who may be interested in introducing new solar technologies within the area. The north is a highly volatile region, and this is likely to slow the inception and adoption of solar energy in the area.

Corruption comes as another essential factor that may impede the feasibility of solar power projects in Nigeria. It has one of the highest rates of corruption in Africa and in the world. Studies conducted by Onwujekwe et al. (2010) indicate that the high rate of corruption presents a loss to the Nigerian society because prices are rendered high through such corrupt mechanisms. Pertinent to the replacement of fossil oil with solar energy, corruption is likely to lead to long chains of illegality that may lead to the failure of the projects. As established by Campbell (2013), the Nigerian government theoretically puts zero duty on renewable sources of energy. In addition, corruption within the custom offices does not allow this; custom officers still charge duty for solar appliances with such a trend, and only a change in policies and governance would render the vision of replacing fossil fuel with solar energy feasible.

Poor understanding of the local preferences and needs and their acceptance of new technologies in the north is another factor that may hinder solar energy projects. As noted by Bugaje (2008), understanding of the social, economic and cultural requirements of a community is crucial for the success of any renewable energy alternative. In northern Nigeria, women understand the needs for energy the best. However, Aganga (2010) observes that women are rarely consulted in making decisions pertinent to solar energy projects. To make the projects feasible, there needs to be understanding of the needs for energy per households for appropriate sizing of solar systems (Adeoti et al., 2000).

Maintenance is a requirement that must be considered in introducing solar energy in the region. As observed by Adeoti et al. (2000), the northern population lacks skills that would be essential in the operation and maintenance of large-scale solar power projects. This would require the outsourcing of expertise, which may also be affected by political tensions between the north, the south and corruption. The replacement of fossil fuel with solar energy as the key source of energy in northern Nigeria, therefore, is an issue that requires many considerations because of some of the limitations listed above.

An analysis of the Nigerian culture can assist in understanding the situation in Nigeria, as already indicated. A comparison of the Nigerian culture with the Dutch has been used to shed light on this situation. The culture has high power distance. People have respect for leaders in the community. This means that groups should be involved in decision-making processes pertaining to solar energy development and installation in northern Nigeria.

From this dimension, it can be concluded that for acceptance of solar energy technologies, the leaders must be pleased and involved. Strong bonds must be created with community leaders to ensure that the projects are accepted. A perfect way to make the technology acceptable is by involving the locals in the installation and maintenance processes. This would require the creation of awareness among the local people to ensure that they are well versed with the technology (Ibitoye & Adenikinju, 2006).

The problems that confront the acquisition, development and installation of solar systems in northern Nigeria need to be addressed for appreciable progress to be achieved. Firstly, affordability must be considered. This gives the capability to access solar devices that remain expensive and are not easily acquired. Additionally, little research has been carried out regarding solar thermal or photovoltaic energy devices. The devices are yet to become commonplace within households in northern Nigeria. The use of such devices is scant in northern Nigeria, and is only present in research centers and universities. Therefore, the availability and installation of the devices is still a vision for the future. This illustrates that northern Nigeria as a long journey before there can be wide production and deployment of solar devices.

Awareness of the existence of solar energy devices remains low in Nigeria. Those aware of solar energy and those who use it have only a few watts of lighting. They do not know that solar photovoltaic can be connected in parallel or series since it is in modular form. Solar power can heat through the combination of temperature and mass running in megawatt or kilowatt to run turbines that generate an equal amount of power to the conventional power supply. Solar energy seems like science fiction to many people living in northern Nigeria (Ingwe et al, 2007).

Presently, there is little knowhow on the technological fabrication of the equipment involved in solar energy generation. Northern Nigeria would have to rely on expatriates in case of solar power generation of commercial value. Additionally, the inadequacy of technology means that repairs and maintenance are hard to carry out within this region. Households usually use inverters for small-scale generation of solar energy. In case the inverters breakdown, they are referred to the main laboratory, from where they are repaired. Most of the devices available are imported at high prices by unqualified personnel or vendors. This means that the devices that would be technically suitable for northern Nigeria may not be easily distinguishable from the unsuitable ones.

Policies and Political Issues Pertinent to Renewable Energy in Northern Nigeria

Nigeria lacks clear policies, investments and tasks pertinent to renewable energy. The government has failed to make policies that would be suitable for the common person to increase awareness of the existence of solar energy and the benefit it can bring to the people in northern Nigeria. However, it is evident that problems marring the inception of solar energy in northern Nigeria could be filtered in a short period if the government were to pay proper attention to the research, development, commercialization and inception of solar energy devices in northern Nigeria.

As noted by Hekkert (2009), Nigeria has high individual power-generating capacity, but this remains limited because many buildings in northern Nigeria lack solar energy compliance -- usually by accident, not design. Additionally, component failure occurs when fully installed and operational devices fail shortly after installation, and this would also retard the rate at which solar energy is fully installed in northern Nigeria. Since solar energy is new in many parts of the world, including northern Nigeria, the users would then turn back to other energy sources. Equipment and component failure occur fundamentally because the devices used lack guarantees and warranties that would make repairs easy. Therefore, for full development and installation of solar energy, mechanisms must be sought to ensure that end-users get perfect devices and after-sale services (Ibitoye & Adenikinju, 2006).

Presently, comparing the cost of equipment and installation of solar energy with other energy sources, solar energy is expensive in the short-term, but effective and cheap in the long-term. The result shows that it is expensive for up to four years of installation. Solar energy devices are costly and they are usually imported apart from the cables and other accessories. However, this result shows that, after five years, solar energy is cheap and attractive since the running costs are low. A high percentage of northern Nigerians are low-income earners and thus cannot afford devices. Unless the prices of the devices are lowered, the inception of solar energy in northern Nigeria could remain unattainable (Kamp, 2012; Iledare & Subeu, 2010).

Solar energy inception has also become a political problem recently in northern Nigeria. The policy behind the acquisition and installation of the equipment at a technical and governmental level is not encouraging. Little or no legislation backs the utilization of renewable sources of energy such as solar energy, unlike other sources such as thermal, hydro and nuclear energy. The government has never embarked on any large-scale projects of installation or acquisition of solar power plants.

This indicates that the government must change its current policies and attitude towards solar energy if solar energy must replace fossil fuel in northern Nigeria. From a technical perspective, electric engineers saddled with the design and development of electricity in industry and homes have not developed designs for the provision of solar energy installation in homes and industries. Additionally, in the areas of research and development, solar thermal is more developed than PV although many of the achievements are yet to be commercialized. On the contrary, only a few indigenous R&D have been recorded in northern Nigeria on solar PV (Kamp, 2012).

The Nigerian governmental power and politics play a crucial role in the development and installation of solar energy systems. The government is responsible for the creation of policies that would encourage their massive use, as well as other renewable sources of energy. The government is also responsible for the introduction of large-scale projects that can help increase the availability of electricity in the area. Additionally, the government is responsible for the subsidies and reduction of taxes for the PV, solar thermal generators and other equipment. The government should encourage other private projects through provision of subsidies that would further encourage research and development on solar energy (Aganga, 2010).

However, politics may play a reverse role in the introduction of solar energy in northern Nigeria. As observed earlier, Nigeria is divided into the politically strong north and the economically stable south. The politics of the land may influence the nature of the policies that are established pertinent to solar energy (Akinbulire et al., 2008). For example, the economically stable south may be left out in terms of energy development. The south and the north are divided and political tensions have persisted and increased in the recent past. The government, therefore, must unite the two sides and ensure security before long-term projects are started.

Essential Management Changes

For solar energy installation to become feasible, energy wastage must also be stopped. Presently, an unhealthy attitude of energy wastage has developed among Nigerians. For instance, many households tend to install halogen security lights that consume excessive energy. Additionally, energy-inefficient equipment is installed in their households. With proper stand-alone solar energy, 500W of solar power would be enough per household with energy-efficient equipment. Many homes and industries use halogen and incandescent lamps that generate a lot of heat and light inefficiently (Garba, 2009).

Other industries in northern Nigeria use electric motors, boilers and compressors that consume a lot of energy and constitute a high percentage of the energy consumed per industry. Consequently, there is a lot of potential to save energy in industries with energy-efficient equipment. Energy wastage would render solar energy projects inefficient (Nnorom & Osibanjo, 2007). Unless the problem is countered, solar energy in northern Nigeria could not take place. Vandalism and theft is another problem that needs countering, in order for solar energy projects to be feasible in northern Nigeria. Although the cases reported are not many, theft of solar panels and other solar energy equipment poses a risk to such projects (Chendo, 1999).

Mismanagement of Energy in Nigeria

It is essential to reflect on the Nigerian situation; the country is endowed with high oil resources but still has an energy crisis. There is low connectivity to the national grid. Many Nigerians believe that problems are instigated by mismanagement of local resources. Power cuts are high, because few financial resources are allocated to the development of alternative, renewable sources of energy.

As per the conceptual framework guiding this study, integrative management is critical to the sustainable use of resources. Nigeria is endowed with various forms of energy. Importantly, the northern region of Nigeria has an immense solar energy potential. There has been minimal effort by both the federal and state governments to harness this energy. From a management perspective, this could be due to poor appreciation of solar energy and its potential and failure to use an integrative approach to economic and environmental policy making. Since economics is central to the federal and state government agenda, the use of the integrative management approach to economics would have resulted in increased consideration of the energy issues. Thus, the problems in energy supply and management in Nigeria are partly a result of the poor management of energy resources in the nation.

Factors Favoring the Prospect of Solar Energy in Northern Nigeria

Regardless of the problems, if they are countered several other aspects within northern Nigeria make the vision possible. First, the geographical location of northern Nigeria is described as favorable in many research studies. As noted earlier northern Nigeria lies in the equatorial region, and this highly favors the development of solar energy. Application of solar energy in telecommunications in remote and rural areas needs no fuel for transportation (Oduwe & Enibe, 2007). This reduces the problems encountered in the remote areas, which include shortage of fuel supply (OFID, 2008).

The Nigerian population also serves as a favorable aspect of the potential development and installation of solar energy in northern Nigeria. As noted earlier, the highest population in northern Nigeria lives in the rural areas. Nigeria has a total population of over 140 million, of which less than 20 percent is connected to the national grid, and less than 5 percent of the population in the rural areas. The installation and utilization of solar energy in Nigeria is low. As a result, implications of the prospect of solar energy in northern Nigeria are high, because of the demand and utilization capability.

The inability of the Power Holding of Nigeria (PHCN) to supply people in northern Nigeria with required electricity serves as another driving force for the projects. The organization is marred by a mirage of problems arising from low generation capacity and outdated equipment. These problems may act as driving forces for the research required for the inception of solar energy as an alternative to fossil fuel. The installation capacity for the generation of electricity, of which 98 percent is owned by the federal government, was on the rise until the early 1990s. However, no further increase has taken place to date. The introduction of solar energy would serve as a perfect replacement for fossil fuel in northern Nigeria (Ingwe et al, 2007).

In spite of the problems that confront the inception of solar energy in northern Nigeria, it would still be feasible to make the project a success. Past research has indicated alternatives and solutions that could be applied to make solar energy projects viable. The first aspect that must be considered is the purchasing power and affordability of electricity. Considering Nigeria's population and income distribution among northern Nigerians, the affordability of electricity could trigger the massive development of solar power.

This problem could be handled in two ways. First, the government could opt to give incentives to Photovoltaic manufacturers or reduce taxes on imported solar power generators. Second, the government could opt to give subsidies on solar thermal and PV generators, as well as other related accessories. These two mechanisms have been tested in other countries and have been found highly efficient in introducing solar energy. For example, Germany started giving subsidies to encourage the massive deployment of solar panels of commercial significance (Campbell, 2011).

Available resources have shown that in the regime and landscape of northern Nigeria, solar energy can offer appreciable benefits. First, the growing cities within the north act as a driving force towards the development of solar energy. Solar energy for rural electrification can offer a perfect solution to the persistent problem of power cuts. Poverty in the region may also help in increasing the use of solar energy in the area. Decentralized solar power systems with financially sustainable business models could help the poor in the area.

Holistic views on the solar energy situation in northern Nigeria have also been suggested by Adenikinju (2003) as a way of speeding up its inception. It is right to claim that the level of government policies on energy depends on the level of use of that particular form of energy. The issues of cost and awareness of the existence of solar power potential in northern Nigeria can be taken as a government responsibility.

Government projects in the rural and remote areas could utilize solar energy to create awareness of its existence. Several state-owned and private projects have already been started to increase this awareness. For example, the River Basin Development Authorities have installed and awarded several borehole systems that utilize solar energy. The University of Agriculture in conjunction with Betamag Engineering and Management Services Nig. Ltd is also involved in campaigns with the aim of creating awareness of solar energy. Such moves can be used to increase the awareness of solar energy as an alternative to fossil fuel (Adegbulugbe, 2004).

The technology of installation must also be considered as a factor that could help drive the massive use of solar energy in northern Nigeria. Many houses there that are connected to the national grid could benefit from such a move. The use of hybrid power sources would encourage effective use of solar power systems. Additionally, the increase of the average size of PV systems may lead to new strategies such as the elimination of the AC-DC converter placed between PV arrays and the inverter (Adjebeng-Asem, 1990).

The technology of fabrication of solar power components must also be considered to make the projects feasible. Repairs and maintenance are difficult since most of the components and equipment used in solar energy systems are imported. The solution is to import service stations, especially when large components are being imported (Adun, 2008). This may also act as a solution to component failure, as well as assisting in the careful choice of equipment. Alternatively, northern Nigeria can opt for local design and production of solar energy components to increase affordability and lower the costs of acquisition.

Government policies would have to be changed to ensure that the projects are feasible. The key elements of the national policy on energy development and application of renewable energy include several aspects which, if followed, could help adopt solar energy in northern Nigeria. Though these policies include several guidelines that dictate the milestones to indicate progress in renewable energy application, little is being done to ensure the policies are followed.

According to Aduronija & Asia (1998), the government should promote efficient methods of energy use and create decentralized energy supply systems in rural northern Nigeria.

The energy market could be opened through government efforts. The Minister of Finance argues that the key problem for the introduction of solar power in northern Nigeria is lack of investments. One of the strategies that has been suggested through various studies is the opening of the energy sector to private investors. Through such moves, the federal government of Nigeria could increase the efficiency of the power sector, as well as reduce the cost of borrowing and donations. Additionally, such moves would instigate massive research and development of solar energy accessories. However, according to Banerjee & Duo (2011), the deregulatory processes are extremely complex. The risks involved are high, and the consequences can be negative if such moves are not carefully made.

Additionally, transmission losses could be faced through appropriate measures. Transmission and distribution loss account for almost a quarter of the energy generated by PHCN. Investments in solar energy projects, especially decentralized generation systems in the rural areas, could be one of the most efficient ways of dealing with problems. This strategy would help reduce transmission losses. If the projects are to succeed, large-scale projects would ensure that the grid is free of transmission and distribution losses.

The stakeholders in solar energies could also consider pushing the supply rather than pulling the demand. In many cases of solar energy projects, the opinion of the masses is neglected. This creates a lack of participation in the processes involved in designing solar energy systems (Chaurey & Kandpal, 2010). It would be beneficial to start pilot projects that take little time to accomplish and take people's opinions into consideration to ensure that they are in accordance with their needs.

The government could offer support to local projects as well as corporations' projects started by the people. The projects could consider long-term orientation. Many of the energy-related projects in northern Nigeria portray short-term vision, a common characteristic of many developing countries, including Nigeria. The government and other stakeholders should develop projects that are oriented to the long-term to ensure that a significant population benefits from solar energy projects (Suur et al., 2007).

On the issue of the private sector, there are few solar appliance suppliers in Nigeria with significant credibility. The main market for the private suppliers is the government and, in some cases, affluent families. Nigerian NGOs also do not focus on solar energy, but solely on the reduction of poverty. However, with government support and lobbying from other stakeholders, solar energy may become widely available in northern Nigeria (Okoro et al., 2008).

As observed, Nigeria is highly endowed for the development of solar energy, which could be instigated by factors such as a high demand for electricity, industrial development and the geographical location of Nigeria, among others. However, several other issues make such projects unrealizable. A reflection of the factors mentioned herein indicates that Nigeria might have a long way to go before solar energy is widely acceptable in the northern region. Through policy-making, the government could play the central role in ensuring the success of the projects.

Determining the feasibility of implementing solar energy on a large scale in northern Nigeria is an important first step in addressing some of the issues impeding the development of solar energy. Since few studies have been carried out to determine the feasibility of solar energy in Nigeria, the research design adopted for such a study would have to deal with the major concerns relating to the practical harnessing of solar energy. A quantitative research design is better suited to address issues where there may be competing views or indecision (Creswell, 2003).

Quantitative research designs typically employ objective scientific techniques (Creswell, 2003), which results in objective rather than subjective findings, as is the case in qualitative studies (Creswell, 2003). As such, a quantitative research design is best suited to deal with the gaps in research on the potential of solar energy in Nigeria. Furthermore, a quantitative research design is ideal for handling certain aspects of feasibility, for example economic feasibility involving the use of costing methods and cost and benefits analysis.

These quantitative techniques result in numeric findings that can be used to make a direct comparison of solar energy to other forms of energy being used. Thus, the use of quantitative research design is in line with the nature of the problem being addressed when handling feasibility. A feasibility study is an investigation of the viability of an idea, which in this study is the viability of the use solar energy in the northern region of Nigeria. The study answers the question of whether there is any feasibility of using solar energy in place of the hydro/fossil energy in the region. This helps in knowing whether the research in the field can proceed.

Currently, there are no concerted efforts from the government to locals and corporations working on solar energy projects. To ensure that the locals and other companies are supported, the government and other stakeholders should lobby for stable pricing policies to support the local projects. Such moves have not been implemented (Chineke & Ezike, 2009). However, the implementation of the practice would help increase solar energy system incorporation in northern Nigeria. It is imperative that people in the area be involved in the decision-making processes to ensure that the projects are acceptable among the local communities. From all the resources available, it was discovered that the viability in terms of economics dominate the study. The research was conducted on the feasibility of making solar energy available or replacing other sources of energy with it by looking at the legislation in place, technology available, resources and economic factors to guide appropriate managerial decisions.

Summary

This chapter reviews the existing studies. Some of the aspects addressed include the energy crisis in Nigeria, frameworks for the inception of solar energy, the problems facing the prospect of solar energy in northern Nigeria and the factors favoring the prospect of solar energy. This chapter also covers issues relating to the management of solar and energy resources in Nigeria. The next chapter details the research methods that were used in this study.

CHAPTER THREE

METHODOLOGY

This chapter details the research methods that were used in the study, as they influence the validity and reliability of the findings. It is imperative that the research methods utilized be in line with the nature of the research problem. This chapter covers the research design, target population, sampling procedure, sample, treatment, instrumentation, data collection procedures, and data analysis.

Description of the Research Design

A comparative quantitative survey design was used in the study. The choice of the research design was influenced by the nature of the research problem. First, a quantitative research design is preferred over a qualitative research design. The study was concerned with the determination of the operational, economic, legal and technical feasibility of using solar energy in the northern region of Nigeria. Determination of feasibility in practice typically involves the comparison of some expected metric against the observed metric. For instance, the cost of an item can be compared to personal earnings to determine whether an item is economically feasible. Comparison is made easy through the use of quantitative research design.

It is noteworthy that qualitative research design can also allow for the comparison of different cases. However, qualitative research designs are prone to biases, since researchers' views or perceptions can cloud their analysis of the data. The use of a quantitative research design limits this risk by allowing the use of scientific (empirical) methods in the analysis of data. The use of empirical methods reduces the risk of subjective analysis of data which is imminent when using qualitative research design. Objectivity in the analysis of the data is of critical importance in the study so the findings can be used by different stakeholders in the energy sector.

The second reason for using a quantitative research design was the nature of the variables considered in the study. Some of the variables included the cost, foregone costs and benefits. Most of these variables are quantitative (numerical) while the qualitative variables could be quantified easily. The nature of the relevant variables strongly influenced the study.

Since most of the variables are quantitative, it was reasonable to use a quantitative research design as opposed to a qualitative research design. This practical consideration involved deliberation over the difficulty in converting qualitative data to quantitative data and vice versa. Simply, there are established methods such as the use of the interval scale (Likert scale) that can be used to convert qualitative data to quantitative data. Thus, it was practical to use a quantitative research design relative to a qualitative research design to address the research problems.

The philosophical stance adopted by the researcher is influential on the research design, as well. A positivist phenomenology was adopted by the researcher. This philosophical stance holds that truth can be measured objectively and established through research, and is based on objectivity or realism, as opposed to subjectivism. Positivism is the view that truth can only be relative and is not relativistic (constructed through observation). Under this philosophical viewpoint, the use of solar energy in the northern region of Nigeria is (operationally, economically, legally and technically) feasible, or not. Positivism encourages the use of structured scientific approaches in the determination of universal truth. This philosophical stance was influential on the choice of the research design.

The study targeted the northern region of Nigeria. This is a large area and therefore the entire population could not be included in the study, considering the time and practical limitations. The use of sampling was therefore expected. Quantitative research design is recommended when the results of a study are to be projected to a larger population as was the case in this study, since the results of the sample were projected to the northern region of Nigeria. The use of quantitative research design allowed the researcher to design the study in a manner that considered the population size and to use a sample that is representative of the population. Thus, generalization was made possible through the use of a quantitative research design. Since the region covered was large and sampling was used, it was logical to use quantitative research design to allow for the generalization of the findings.

The study findings and recommendations offered insight into the feasibility of solar energy in the northern region of Nigeria. These recommendations were critical in determining whether the use of solar energy in northern Nigeria is a viable option. From this perspective, the study informed the final course of action with respect to the use of solar energy in the northern region of Nigeria. Use of quantitative research design is recommended when the findings inform a course of action. Thus, the significance of the results to the Nigerian energy sector has also informed the decisions on the research design.

A survey design was used in the study, which is suitable when attempting to collect data from a large population. In addition, a survey design is well-suited for studies that involve a widely distributed population. Different attributes of the population have to be captured when sampling, so the study involved a large, widely distributed sample from the northern region of Nigeria. Additionally, information relating to the different forms of feasibility to be investigated in the study were already acquired in order to inform the design of a questionnaire and therefore ease the use of a survey design. When compared to experimental and quasi-experimental research, a survey design is more in line with the nature of the study, which was to compare, rather than seek cause and effect or causal relationships. Thus, a survey research design was in line with the nature of the research problem and complemented the vastness of the population under consideration.

A comparative research design was used in the study. The observed values of the target variables were compared with the expected values (required values). This comparison informed decisions on whether the use of solar energy is feasible. The definition of feasibility by default implies comparison of values. As such, a comparative research design was in line with the nature of the research. A descriptive research design would have been inadequate in determining the feasibility of solar energy, since this type of design typically involves the single measurement of a variable. The use of a comparative research design allowed for the measurement of observed variable values and the expected variables to determine the different types of feasibility. A comparative research design thus complemented the purpose and aim of the research.

Target Population

The target population in the study was the households and legal experts in the northern region of Nigeria. The northern region of Nigeria includes the states of Kwara, Benue and Kogi. The vast majority of Nigerians living in this region are Muslim. The study was carried out at a household level, targeting households that were not connected to the electricity grid and were either using solar energy or other sources of energy such as paraffin and generators.

The tropical dry climate is predominant in northern Nigeria. Compared to the southern and central regions of Nigeria, the northern region receives little rainfall. Rainy seasons in the northern part of Nigeria last for only three months. The remaining months are characterized by hot and dry weather. The temperatures in the northern region of Nigeria often rise to as high as forty degrees Celsius. The northern region of Nigeria includes both plains and high regions. The plains are very hot and have lengthy dry periods. The Jos plateau is much cooler and wetter than the rest of northern Nigeria.

The Fulani and the Hausa are the two predominant ethnic groups in northern Nigeria. The Fulani are pastoralists during the dry seasons, and during the wet season they settle down. The Fulani are generally a more rural ethnic group than the Hausa, while more of the Hausa live in urban centers. The traditional Hausa house has a flat roof that can be used for sleeping when temperatures are extremely high. Hausa are farmers who kill their animals for meat and sell their crops, whereas the Fulani are herders who rely on their animals for milk and rarely kill their cows.

The target population was rural dwellers who live in semi-permanent and permanent dwellings. The legal experts who play a role in determining the legal feasibility of solar energy were also part of the target population.

Sampling Procedure

Probability sampling was used in the study (William, 2006). Generalization of the findings to the northern region of Nigeria was of critical importance. Specifically, stratified random sampling as used in the study involved three strata: the states of Kwara, Benue and Kogi. Members of a stratum are homogeneous (have a shared attribute). In the study, the shared attribute was the state of origin. Strata are heterogeneous in that members of a stratum have at least one attribute that is universally different from members of a different stratum. Random sampling was used to populate the strata. The members of a stratum were selected in a manner such that every member of a stratum had an equal chance of being included. Randomization using random number generators was used to ensure that inclusion in a stratum was probabilistic. The other reason for using probabilistic sampling was to ensure that the use of scientific methods data analysis was grounded on relevant practical considerations. Most empirical methods are based on the assumption that the variables are identical, independent and random. The use of non-probabilistic sampling would have resulted in questions raised on the validity of the findings and the basis for using empirical methods. Thus, the use of stratified random sampling was important to ensure that the methods used in data analysis and the results of the study were valid and reliable. The use of stratified random sampling also helped in the determination of state-level factors that may be influencing the feasibility of solar energy in the northern region of Nigeria.

Sample

The study targeted households that have permanent and semi-permanent dwellings in the rural areas of the selected states. Both households that use solar energy and those that do not were included in the study. The focus on the rural households was based on the observation that most households in urban areas are connected to grid electricity. The inclusion of households that have semi-permanent and permanent dwellings was informed by the fact that households that consist of temporary dwellings are unlikely to invest in sources of energy with mostly long-term benefits such as solar energy. Next, the sample frame was made up of at least one-tenth of all households. The sampling approach ensured that the sample was representative of the northern region of Nigeria by ensuring that the major ethnic groups as well as other ethnic groups were represented in the sample. Additionally, the study targeted legal experts that had a mastery of the state and federal level legislation that may influence the use of solar energy. Every state was represented by three legal experts. The legal experts helped in determining the legal feasibility of solar energy. Data was collected in relation to the economic situation of the region; this helped to inform managers and stakeholders in making decisions concerning the feasibility of using solar as an alternative option for energy supply.

Instrumentation

The study involved measuring four different types of feasibility that are relevant to the use of solar energy in the northern region of Nigeria. In determining the instrumentation that would be used, definitions of the different forms of feasibility were developed. Operational feasibility was defined as the degree to which solar energy meets the needs of the users. Technical feasibility was the degree of availability of technical resources and expertise. (This definition does not include the sunlight hours since the northern region of Nigeria has at least six sunlight hours each day.) The definition of economic feasibility was the cost effectiveness of solar energy. Lastly, legal feasibility was defined as the degree to which solar energy could be implemented within the existing legal framework.

There are established methods of estimating some forms of feasibility, such as economic feasibility. However, the researcher could not find existing instruments dedicated to measuring the other forms of feasibility. As a result, he was required to develop a tool that would be used in measuring them. The major challenge when using a self-developed tool is establishing the validity and reliability of the tool, which requires a pre-study or pilot study dedicated to testing the instruments used. During the pilot study, statistical analysis was used to establish the items that would best predict the target variable. As a result, the final questionnaire that was used in the study had desirable validity and reliability scores (greater than 0.6).

Operational feasibility involved the determination of the degree to which solar energy solved the energy needs of the participants. This involved the determination of the energy problems and challenges faced by Nigerians in the northern region. Next, the study involved determination of the degree to which solar energy could or has solved the identified problems (depending on whether the participants used solar or other forms of energy). This assessment was based on participants' responses to five-point Likert type questions. The responses ranged from 1-strongly disagree to 5-strongly agree. This approach to instrumentation helped in ensuring that the participants responded to questions that were relevant to their energy needs.

Economic feasibility was concerned with the cost effectiveness of solar energy. Several approaches have been used in establishing economic feasibility, and all the methods currently used implement the concept of time value of money. Theoretically, a dollar's worth today is more than a dollar's worth in the future. Payback analysis, return on investment and net present value are the three commonly used methods in assessing economic feasibility. Payback analysis is used to determine the period within which an investment yields a return, and can also be used to determine if an investment can pay for itself. This method involves determining the period within which the accrued benefits overtake the accrued and continuing cost or simply the payback period. The net present value involves determination of the current value of a dollar at a time in the future.

$PV_n = 1/(1 + \boldsymbol{i})^{\boldsymbol{n}}$, where n is the number of years and i is the discount rate.

The discount rate is similar to the interest rate and is often taken to be the opportunity cost of investing money in other projects or investments. Lastly, return on investment (ROI) compares the lifetime profitability of an alternative solution. ROI is the ratio of the returns from an investment to the amount invested in a project. Comparing the ROI of solar energy and grid electricity can be used in the case of the study. Payback analysis was used in the study because this method has been used by other studies on the feasibility of solar energy and is more realistic considering that participants do not have access to grid electricity.

Technical feasibility was defined as the availability of technical resources and expertise. A major concern when handling technical operations in rural areas is access to technical resources and expertise. Availability of expertise was measured through participants' responses to statements.

The responses were weighted on a five-point Likert scale with 1-strongly disagree and 5-strongly agree. The closed questions (statements) covered issues of access to and availability of technical resources (solar panels, bulbs, inverters) and technical expertise (installation and maintenance experts) within a reasonable distance from the participants. Importantly, these items were analyzed in a pre-study to improve the validity and reliability of the measures.

Legal feasibility was the degree to which solar energy can be implemented within the existing legal framework. Analysis of the existing state and federal-level legislation regarding the installation and use of energy helped in determining the legal feasibility of solar energy. The focus on instrumentation was the degree to which the existing laws and legal structures encourage investment in solar energy, ease installation and maintenance of solar energy and allow for additional financial assistance or payment methods or plans. The participants in the study are poorly placed to analyze and respond to legal issues. As such, legal experts from each of the three states were involved in determining the legal feasibility of solar energy in the three states.

Table 1: Five-point Likert type questions.

Variable	**Measurement**	**Participants**	**Reliability and Validity**
Economic Feasibility	Payback analysis	Homeowners	Used by existing studies on feasibility
Legal Feasibility	Five-point Likert scale questions	Legal Experts	Pre-study/Pilot study
Operational Feasibility	Five-point Likert scale questions	Homeowners	Pre-study/Pilot study
Technical Feasibility	Five-point Likert scale questions	Homeowners	Pre-study/Pilot study

Data Collection

Data collection was done using questionnaires, which are the most commonly used tool in studies utilizing a survey design. The choice of questionnaires over interviews was influenced by a number of factors. Questionnaires are easier to administer than interviews because the participants can do them independently. Unlike interviews, the researcher or representatives do not need to be present for the questionnaire to be completed.

Other approaches to data collection, such as interviews and focus groups, require the presence of the researcher or his representatives. Interviews and focus groups consume more time and require greater involvement in their coordination. The time for the interview, the meeting place and the duration of the interview are all practical considerations that must be considered.

When using self-administered questionnaires, on the other hand, the researcher does not need to worry about the administration of the questionnaire. Thus, it is more practical to use questionnaires when the study targets a large, widespread population. The study involved household-level analysis of the feasibility of solar energy across three states in the northern region of Nigeria. As such, the participants were expected to be geographically dispersed. The sample size was also large. Thus, the nature of the target population necessitated the use of questionnaires.

Self-designed questionnaires were used in the study. The design of the questionnaires was informed by the instrumentation requirements. Analysis of existing literature on the assessment of the different forms of feasibility informed the decisions on the items that were included in the questionnaire. As such, the cost (including opportunity costs) and benefits associated with the use of solar energy were required from the participants.

Other questionnaire design considerations were also important in ensuring that the questionnaire was usable. The researcher endeavored to use simple and clear language that was easily understood by the participants. In addition, the researcher avoided the use of non-standard questions. The general structure of a typical questionnaire was also followed. This implies that the questionnaire was designed such that the simple demographic details were presented at the beginning, whereas the difficult and more specific questions are presented at the end. In addition, the questions increased in specificity (from general to more specific). Lastly, to minimize the length of the questionnaire, the questions were limited to those that were necessary in assessing the four forms of feasibility targeted by the study.

The next step involved validating the instruments. Validation mainly targeted variables to be measured using five-point Likert scale items. A pre-study was carried out. Analysis of the data from the pre-study helped in determining the items that were strong predictors of the variables. Some of the items that were originally included in the questionnaire had to be eliminated. The pre-study also helped in the determination of practical challenges that could be faced in the actual data collection.

The researcher recruited the help of an individual well-versed with the state, employed on a part-time basis, to disseminate the questionnaires in each of the three states. Each state had a representative that was tasked with the dissemination of the blank questionnaires and the collection of the filled questionnaires. The use of the internet and/or mail was impractical for the purposes of this study, as many Nigerians who live in rural areas do not have reliable postal addresses. Furthermore, since the study mainly targeted households that lack (grid) electricity and were located in rural areas, it was unlikely that the use of email would be feasible. Using single access and drop-off points was a viable option; however, it would have resulted in significant reductions in the response rate since it would have been difficult to coordinate the collection of the filled questionnaires.

The participants were given two weeks within which to completely fill out all of the required details. The relatively lengthy two-week duration was aimed at easing the process of completing the considerably detailed questionnaire. Some of the questions required the participants to consider their energy usage carefully. The two-week period allowed the participants adequate time to consider these intricacies. It was also expected that some of the participants might have language difficulties.

When recruiting state representatives, the researcher ensured that the selected participants were fluent in English, Nigerian pidgin and Fulani or Hausa. Persons fluent in both Fulani and Hausa were preferred for the position. In situations where the respondents had difficulties in understanding the English language, the representatives stepped in and offered translation services. In such cases, the researcher representative asked questions and recorded the responses on the questionnaire. The data collection in the three states was carried out concurrently for a period of one month. The one-month period was enough for the researcher to traverse large parts of the state.

The study did not involve the manipulation of human subjects. The participants in the study were people over the age of eighteen years who reported personal data. The questionnaire detailed the measures used to guarantee the privacy and confidentiality of data collected from the participants. Some of the measures used included not requesting the personal identification information on the participants or their households and keeping the data collected from the participants in a password-protected computer. Since treatment was not required in the study and it had no known adverse effects on the participants, a consent form was not required.

Data Analysis

The approaches that were used in data analysis depended on the type of feasibility considered. The research design was also influential on the approach to data analysis. Typically, the nature of the research questions influences the research design which affects the approach to data collection and the strategies that can be used in data analysis.

A quantitative research design was used in the study. As such, the measurement of the variables resulted in quantities that could be analyzed using scientific techniques. The representation of the results of the data analysis was important in ensuring that the study findings were easily understood. The study targeted four different types of feasibility. The discussions of the data analysis focused on specific research questions.

Research questions

The main research questions for this study were:

- What is the feasibility of replacing fossil or crude oil with solar energy in the northern region of Nigeria?
- What kind of management/leadership structure is in place and would it lend itself to the emergence of solar energy technologies as alternative source of energy in Nigeria?
- Based on best practices from other related shifts to renewable energy sources from other countries, what would have to change, if anything, in the northern region of Nigeria?
- How would Nigerian governmental power and politics impact the shift to renewable energy usage in Nigeria?

Theoretical question:

- Which theoretical framework is available to appraise the use of solar energy as a source of energy in the northern region of Nigeria?

Empirical question:

- Who are the interested parties involved in substituting solar energy for fossil fuel sector in Nigeria?

Other Questions:

- What kind of management policy is in place for the emergence of solar energy technologies as an alternative source of energy in Nigeria?
- Are there any politics involved in the energy sector in Nigeria?
- What are the stances of western fossil fuel companies in the adoption of renewable energy in Nigeria?
- Are there any technological skills and resources among the locals that could enhance the use of solar energy?
- What would be the impact of the introduction of solar energy as an alternative source of energy on the country's economy?

Operational feasibility was one of the aspects covered in the study, the measurement of which involved the use of five-point Likert-type questions to establish the degree to which solar energy could solve or has solved the identified problems. The Likert scale is an interval scale. The use of an interval scale has some implications on the permitted statistical operations. The representation of the findings involved the use of graphs and frequency tables. These visual aids clearly highlight the frequency of different responses.

The first step in computing operational feasibility entailed inputting the data into statistical analysis software. The data was coded such that 1-strongly disagree, 2-disagree, 3-neutral, 4-disagree and 5-strongly agree. This coding allowed for statistical analysis of the responses. First, summary statistics for the items were calculated. Next, graphic representations and tables of the summary data were generated.

Lastly, the data analysis involved the use of empirical methods aimed at establishing whether the degree of conformance with the needs of the participants was above a given threshold level. If the observed degree of conformance was significantly above the desired level, solar energy was assumed operationally feasible. The use of one-sample t-test was used to determine if the feasibility scores were above the desired levels.

The study also involved the measurement and analysis of the technical feasibility of solar energy through the use of five-point Likert-type questions to establish the degree of availability of technical resources and expertise. The overall technical feasibility was the average of the scores on the availability of technical resources and technical expertise. The representations of the findings were presented via line graphs.

These visual aids clearly highlight the frequency of different responses. The first step in computing technical feasibility entailed inputting the data into statistical analysis software. The data was coded such that 1-strongly disagree, 2-disagree, 3-neutral, 4-disagree and 5-strongly agree. This coding allowed for statistical analysis of the responses. First, summary statistics for the items were calculated.

Next, graphic representations and tables of the summary data were generated. Lastly, the data analysis involved the use of empirical methods aimed at establishing whether the technical feasibility was above a given threshold level. If the technical feasibility was above a desired level, solar energy was assumed operationally feasible. The use of one-sample t-test aided in determining if the technical feasibility was above the desired levels.

In analyzing the research question on the economic feasibility of solar energy, tables and line graphs were used. The data presented on economic feasibility was mainly in ratio level measurement. The data included costs and benefits associated with the use of solar energy. The data was summarized for each household.

When carrying out the payback analysis to determine the cost effectiveness of solar energy, the average cost and benefits for entire states were considered. A table was used to show the payback analysis calculations for each state. Next, a line graph was generated to show the payback period for all three states. The payback period was compared to other payback periods computed by studies on economic feasibility of solar energy in other parts of the world.

The study also involved the analysis of the legal feasibility of solar energy. Instrumentation of legal feasibility was measured using a five-point Likert type scale. The data was coded such that 1-strongly disagree, 2-disagree, 3-neutral, 4-disagree and 5-strongly agree. The summary statistics of the participants' responses was presented using bar graphs.

The graphs highlight the participants' perceptions regarding the degree to which the existing legal structures support or inhibit the use of solar energy in the northern region of Nigeria. Data analysis involved the use of empirical methods aimed at establishing whether legal feasibility was above a given threshold level. The use of one sample t-test aided in determining if the legal feasibility was above the desired levels.

From the description of the data analysis, it is apparent that similar empirical approaches were utilized in analyzing the operational, technical and legal feasibility. The analysis of the economic feasibility of solar energy, however, adopted a slightly different approach. Overall, the data analysis involved the use of descriptive statistics such as frequency tables and graphs, central measures of tendency such as averages, and inferential analysis in the form of a one sample-test at 5 percent significance level. Due to the complexity of some of the calculations and the need for high levels of accuracy, SPSS version 19 was used to ease the calculations.

Summary

The study utilized a comparative quantitative survey design. The use of this design was largely influenced by the nature of the research problem. Data collection involved the use of researcher-designed questionnaires. The target population of the study was made up of legal experts and households that do not have grid electricity in the rural parts of the northern region of Nigeria. Three states were targeted for data collection.

The questionnaires were self-administered except in cases where the respondents did not understand the English language. The researcher employed assistants who were responsible for distributing the questionnaires and collecting them once completed. Data analysis involved the use of descriptive statistics, visual aids and inferential statistics.

The next chapter presents the findings of the study after the implementation of the procedures detailed in this one. The discussion of the findings in relation to the research objective and the purpose of the study are also addressed.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results of the research detailed in the previous section, including the participant demographics and responses. In addition, a discussion of the major findings with respect to the research questions is included. This chapter is essential in ensuring that the research questions were adequately addressed and ultimately helps in determining the degree of success of the study.

Pre-Study

A pre-study involving 100 participants was carried out to determine the validity and reliability of the questionnaire. Analysis of the Cronbach's Alpha scores revealed a score of 0.589, which was below the desired levels. This led to the deletion of some items. For instance, initially there were two questions regarding the degree to which each participant's energy source met their needs (one asking the participants their agreement or disagreement with the statements 'the energy source meets all of my needs' and the other 'the energy source meets most of my needs'). The former item was deleted from the questionnaire. In addition, some changes were made in the coding mechanism. The Cronbach's Alpha scores of the resulting questionnaire ranged between 0.601 and 0.713 (see appendix).

Sample Demographics

Table 2: Type of Participant

The type of participant

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	User	384	97.7	97.7	97.7
	Expert	9	2.3	2.3	100.0
	Total	393	100.0	100.0	

Of the 393 participants in the study, 97.7% (n=384) were power users. This implied that these participants were included in the study by virtue of their usage of different forms of power as homeowners in northern Nigeria. The remaining 2.3% (n=9) were included in the study as experts on the state and federal governments' involvement in facilitating the use of solar power in the selected three states. Both experts and users were equally distributed across the three selected states, with the implication that each state contributed 128 users and 3 experts.

Table 3: Gender

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	343	87.3	87.3	87.3
	Female	50	12.7	12.7	100.0
	Total	393	100.0	100.0	

A gender-based analysis of the sample revealed that there were more male than female participants. Male participants made up 87.3% (n=343) of the sample, whereas female participants only made up 12.7% (n=50) of the sample. The high proportion of male participants in the sample was expected, considering that in Nigeria most households are headed by males. Also, the predominantly Muslim northern Nigeria was expected to have a slightly higher proportion of male-headed households.

Table 4: Employment Status

Employment status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Employed	299	76.1	76.1	76.1
	Unemployed	36	9.2	9.2	85.2
	Retired	33	8.4	8.4	93.6
	Between Jobs	25	6.4	6.4	100.0
	Total	393	100.0	100.0	

The employed constituted 76.1% (n=299) of the sample. The unemployed and retired made up only 9.2% (n=36) and 8.4% (n=33) of the sample respectively. Employment status was found to be influential on the feasibility of solar energy since a significant initial financial outlay is required for the use of this form of energy.

The participants in the study included the users of different types of energy. Most participants were users of solar and paraffin. Electricity users made up a considerable proportion of the participants (Fig. 2). There were few petrol, diesel and biogas users in the sample. It is noteworthy that the sample was not representative of the use of different power sources in Nigeria overall, since the researcher endeavored to include as many solar users as possible.

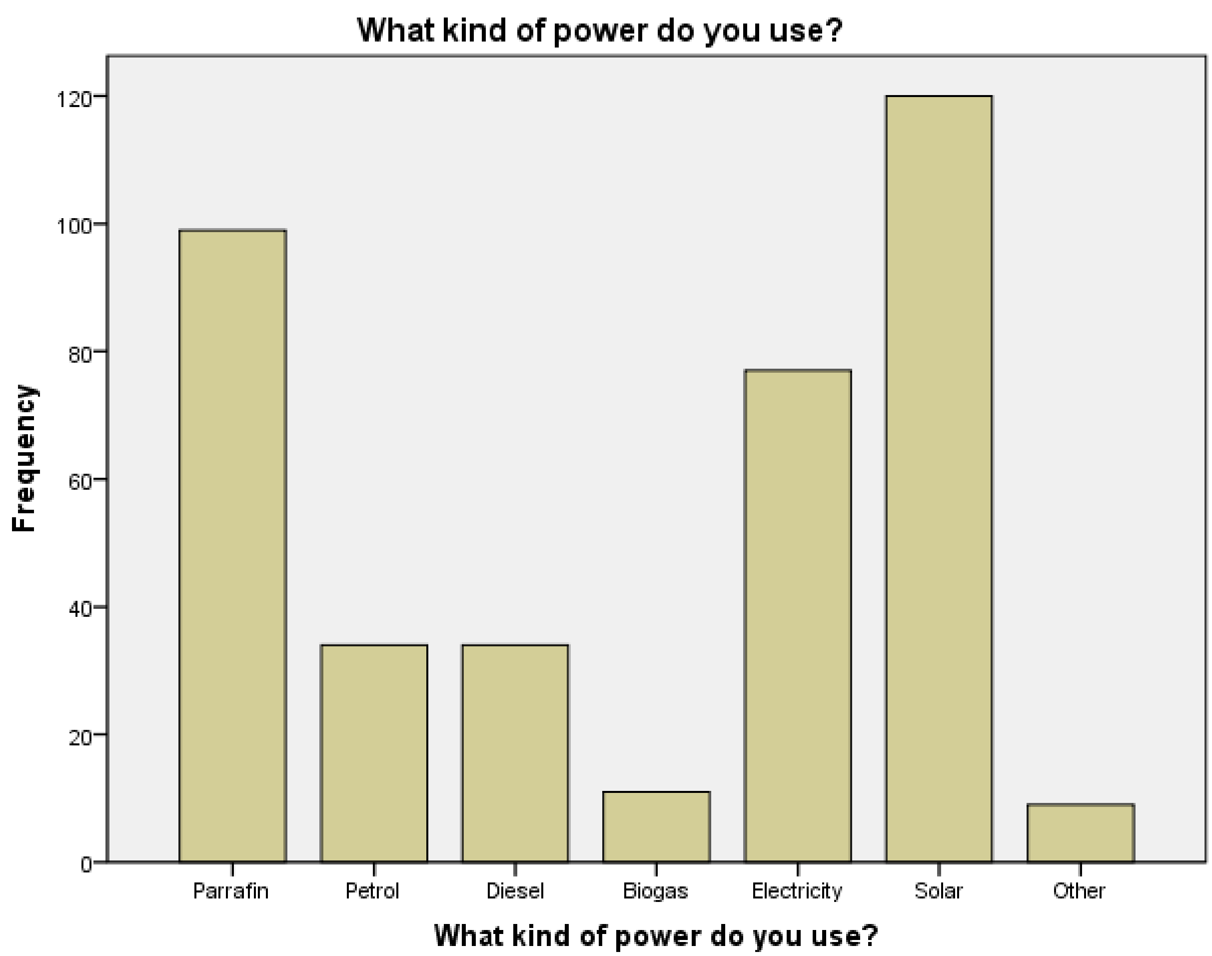

Figure 2: Power Used

Results

Table 5 presents the mean household earnings and expenditure on power across the different power sources used. From the table, it was evident that the two renewable sources of power (biogas and solar) were associated with the least monthly expenditure on power (₦468.4 and ₦399.9). Users of fossil fuels (paraffin, petrol and diesel) had the highest monthly expenditure on power (ranging between ₦1747 and ₦1843). Monthly expenditure on electricity averaged ₦1502 per month. From this, it was evident that the use of solar power in northern Nigeria was associated with the minimum monthly expenditure among the power sources considered in the study.

Table 5: Monthly Household Earnings and Power Expenditure

What kind of power do you use?		Mean (₦)	Std. Deviation
Paraffin	Expenditure on power	1843.3131	368.19243
	Household Earning PM	51454.0909	28323.11047
Petrol	Expenditure on power	1747.2059	386.73691
	Household Earning PM	50408.7941	26085.91469
Diesel	Expenditure on power	1810.4412	351.87491
	Household Earning PM	52856.2647	28303.25723
Biogas	Expenditure on power	468.3636	113.65322
	Household Earning PM	44734.0000	23735.10028
Electricity	Expenditure on power	1501.9610	276.53050
	Household Earning PM	57107.0130	26933.96597
Solar	Expenditure on power	399.8667	174.03955
	Household Earning PM	49132.4083	25057.74876
Other	Expenditure on power	998.8889	111.00163
	Household Earning PM	52008.2222	31707.69837

Table 6: ANOVA Monthly Expenditure

ANOVA

Expenditure on power

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.528E8	6	25472351.617	300.557	.000
Within Groups	31950897.418	377	84750.391		
Total	1.848E8	383			

Table 7: Post Hoc Monthly Expenditure

Multiple Comparisons

Expenditure on power

Tukey HSD

(I) What kind of power do you use?	(J) What kind of power do you use?	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Electricity	Paraffin	-341.35209*	44.23482	.000	-472.4792	-210.2250
	Petrol	-245.24484*	59.94425	.001	-422.9400	-67.5497
	Diesel	-308.48014*	59.94425	.000	-486.1753	-130.7850
	Biogas	1033.59740*	93.83622	.000	755.4349	1311.7599
	Solar	1102.09437*	42.50774	.000	976.0870	1228.1018
	Other	503.07215*	102.55420	.000	199.0666	807.0777
Solar	Paraffin	-1443.44646*	39.52617	.000	-1560.6155	-1326.2774
	Petrol	-1347.33922*	56.55892	.000	-1514.9991	-1179.6793
	Diesel	-1410.57451*	56.55892	.000	-1578.2344	-1242.9146
	Biogas	-68.49697	91.71060	.989	-340.3584	203.3645
	Electricity	-1102.09437*	42.50774	.000	-1228.1018	-976.0870
	Other	-599.02222*	100.61294	.000	-897.2732	-300.7712

*. The mean difference is significant at the 0.05 level.

Analysis of the differences in monthly expenditure across the different power sources used revealed a significant difference (F (6, 377) =300.6, p-value<0.05). This implied that there was a significant difference in the monthly expenditure on power across the different sources of power. Post hoc analysis revealed that the monthly power expenditure by participants that use solar power was significantly lower than the monthly power expenditure by participants who used paraffin, petrol, diesel and electricity (in all cases p-value<0.05) (Table 6).

Analysis of other factors that affect the feasibility of solar power in northern Nigeria is presented in Table 8. The analysis was aimed at determining if there was significant agreement with the corresponding statements. There was no significant agreement or disagreement with the statement that installation of a solar power system is affordable (t (119) =-1.63, p-value=0.106>0.05).

There was also no significant agreement or disagreement with the statement that solar power vendors are readily accessible (t (119) =-1.144, p-value=0.255>0.05). The participants significantly disagreed with the statements that the state government encourages the use of solar energy and the federal government encourages the use of solar energy (t (8) =-4.264, p-value=0.003<0.05; t (8) =-3.578, p-value=0.007<0.05). Thus, it was evident that the experts are of the view that both the federal and state government do not encourage the use of solar energy.

Table 8: Other Factors

One-Sample Test

	Test Value = 3					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Installation of solar power system is affordable	-1.630	119	.106	-.21667	-.4799	.0466
Solar power vendors are readily accessible	1.144	119	.255	.15000	-.1095	.4095
Solar power technicians are readily available	-.923	119	.358	-.11667	-.3671	.1337
The state government encourages the use of solar energy	-4.264	8	.003	-1.11111	-1.7120	-.5102
The federal government encourages the use of solar energy	-3.578	8	.007	-1.33333	-2.1927	-.4739
The government offers subsidies for solar energy equipment	-2.135	8	.065	-.77778	-1.6179	.0623

The data analysis also involved the comparison of responses based on the form of power used. The focus of the analysis was on affordability, meeting the power needs of the clients, running costs and maintenance costs. The results presented in table 9 reveal that there are significant differences in the responses across the different power categories in the participants' views of affordability of power ($F(6, 377) = 32.07$, $p\text{-value} < 0.05$), form of power meeting most of the participants' power needs ($F(6, 377) = 6.88$, $p\text{-value} < 0.05$), high running costs ($F(6, 377) = 84.66$, $p\text{-value} < 0.05$) and high maintenance cost ($F(6, 377) = 80.54$, $p\text{-value} < 0.05$).

Table 9: ANOVA Comparison of Different energy sources

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
This power source is affordable	Between Groups	255.377	6	42.563	32.069	.000
	Within Groups	500.371	377	1.327		
	Total	755.747	383			
The power source meets most of my power needs	Between Groups	65.791	6	10.965	6.879	.000
	Within Groups	600.949	377	1.594		
	Total	666.740	383			
The power source is associated with high running costs	Between Groups	352.565	6	58.761	84.658	.000
	Within Groups	261.675	377	.694		
	Total	614.240	383			
The power source is associated with high maintenance costs	Between Groups	328.345	6	54.724	80.541	.000
	Within Groups	256.155	377	.679		
	Total	584.500	383			

Table 10: Comparison of Different energy sources

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) What kind of power do you use?	(J) What kind of power do you use?	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
This power source is affordable	Solar	Paraffin	1.62828*	.15642	.000	1.1646	2.0920
		Petrol	2.14314*	.22382	.000	1.4796	2.8066
		Diesel	1.96667*	.22382	.000	1.3032	2.6302
		Biogas	.01212	.36293	1.000	-1.0637	1.0880
		Electricity	1.38874*	.16822	.000	.8901	1.8874
		Other	1.35556*	.39816	.013	.1753	2.5358
The power source meets most of my power needs	Solar	Paraffin	.66919*	.17142	.002	.1610	1.1773
		Petrol	1.04412*	.24529	.001	.3170	1.7712
		Diesel	.89706*	.24529	.005	.1699	1.6242
		Biogas	.47727	.39774	.894	-.7018	1.6563
		Electricity	.62013*	.18435	.015	.0737	1.1666
		Other	1.86111*	.43635	.001	.5676	3.1546
The power source is associated with high running costs	Solar	Paraffin	-2.33131*	.11312	.000	-2.6666	-1.9960
		Petrol	-2.39608*	.16186	.000	-2.8759	-1.9163
		Diesel	-1.54314*	.16186	.000	-2.0229	-1.0633
		Biogas	-1.50303*	.26246	.000	-2.2810	-.7250
		Electricity	-1.33420*	.12165	.000	-1.6948	-.9736
		Other	-1.64444*	.28793	.000	-2.4980	-.7909
The power source is associated with high maintenance costs	Solar	Paraffin	.15303	.11192	.819	-.1787	.4848
		Petrol	-2.34608*	.16014	.000	-2.8208	-1.8714
		Diesel	-2.34608*	.16014	.000	-2.8208	-1.8714
		Biogas	.27424	.25967	.940	-.4955	1.0440
		Electricity	.04048	.12036	1.000	-.3163	.3973
		Other	-.81667	.28488	.065	-1.6612	.0278

*. The mean difference is significant at the 0.05 level.

Post hoc analysis of the results revealed that there was a significantly higher agreement on the affordability of solar energy compared to paraffin, petrol, diesel and electricity (in all cases p-value<0.05) (Table 9). This was also observed in responses on meeting the participants' power needs (p-values=.002, .001, .005, .015 respectively).

There was a significantly higher disagreement with the statement that the power source is associated with high running costs among solar power users compared to paraffin, petrol, diesel and electricity users (p-values<0.05 in all cases) (Table 10). There was a significantly higher disagreement with the statement that the power is associated with high maintenance costs among solar power users compared to petrol and diesel users (p<0.05 in both cases) (Table 10).

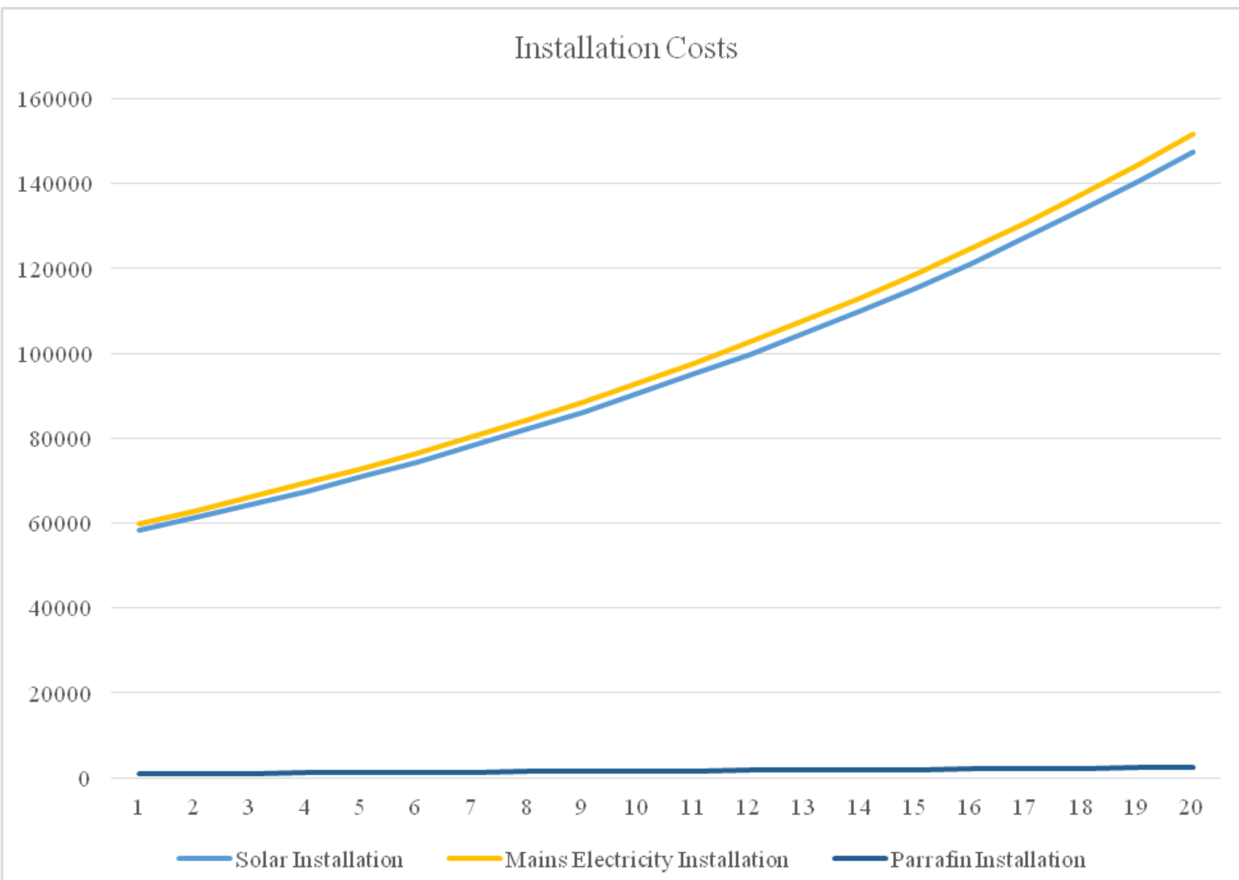

Figure 3: Installation Costs

Analysis of the costs of installing and running the three most commonly used power sources in the sample is presented in figures (3, 4, 5). The costs are compounded over a period of twenty years. From figure 3, it was evident that the cost of installing electricity is comparable, though slightly higher, than the cost of installing solar power. The cost of installing parrafin-based power systems is very low compared to electricty and solar power. Analysis of the running costs reveals that the parrafin expenses are the highest, followed by grid electricity.

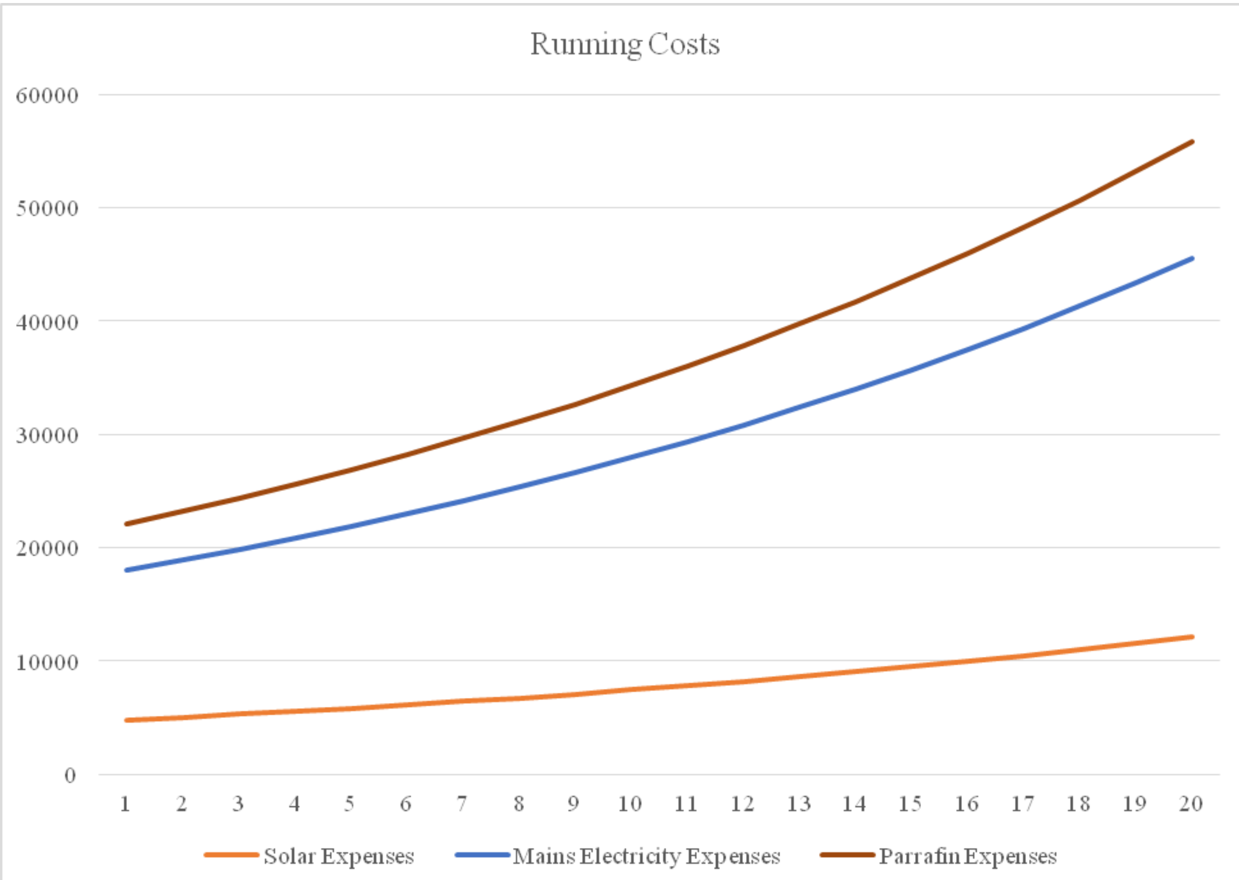

Figure 4: Running Costs

The gap between the running cost associated with solar power and the running costs associated with parrafin and mains electricity is large (Fig. 4). Analysis of the total cost of installing and running the different power sources revealed that mains electricity was associated with the highest cost, followed by solar energy (Fig. 5). The use of parrafin was associated with the least overall cost.

Figure 5: Total Costs

Discussion

The discussion focuses on the research questions. The first research question targeted the feasibility of replacing crude oil with solar energy: What is the feasibility of replacing fossil or crude oil with solar energy in the northern region of Nigeria?

A cost-based assessment of economic feasibility revealed that the use of paraffin (the most common fossil fuel used) was associated with more high maintenance costs than using solar energy. In fact, solar energy users' monthly expenses were significantly lower than the monthly expenses on power by paraffin, diesel, petrol and electricity. Thus, based on the recurrent monthly expenditure, solar power was by far the most cost-effective power source.

Apart from paraffin, all other power sources have significant installation costs. The use of petrol and diesel, as examples, require the use of generators. The installation costs for petrol and diesel power are lower than mains electricity and solar energy. From a cost dimension, the high installation costs associated with the installation of solar power offset the low recurrent maintenance costs associated with this power source.

Solar energy supports most of the participants' power needs relative to fossil fuels and electricity. This was attributed to the high costs of fossil fuels and the intermittent supply of electricity in northern Nigeria. Thus, the strengths of solar energy include low maintenance costs, affordability (attributed to the low maintenance cost) and meeting most household power needs.

The main limitations of using solar energy in northern Nigeria include unaffordable installation of solar power, inaccessibility of solar power vendors, unavailability of solar technicians and lack of support or subsidies from state and federal governments. Thus, economically, the recurrent expenses associated with solar energy are feasible; operationally, solar power meets most household's power needs; technically, there is inadequate support in terms of vendor presence and technical personnel; legally, the government has done little to encourage the adoption of solar energy.

What kind of management/leadership structure is in place and would it lend itself to the emergence of solar energy technologies as alternative source of energy in Nigeria?

The leadership structure that is currently in place lacks several dimensions that would be necessary to allow for improvement in the availability of solar energy expertise and vendors. Under the current management structure this is problematic, considering that the use of solar energy is associated with the use of specialized equipment that would have to be readily available to the users. Importantly, without encouraging the adoption of solar energy in rural areas, it would be unlikely for experts and vendors to be attracted to the region.

Thus, the disinterest by state and federal governments in encouraging the use of solar energy in northern Nigeria is an important reason for the low level of the adoption of solar energy technologies. The current approach where the citizens must take the initiative, as is the case in mains electricity connection, and the state and federal governments oversee the energy sector, discourages the growth of solar energy. If the government were to encourage the adoption of solar energy rather than play a passive regulatory role, then solar energy could become a feasible option.

Based on best practices from other related shifts to renewable energy sources from other countries, what would have to change, if anything, in the northern region of Nigeria?

Analysis of regions that have been successful in harnessing renewable energy revealed the need for changes in the Nigerian approach to solar energy in order for a shift to solar energy to take place. One area that would have to change is the involvement of both the state and federal governments. As it is, the state and federal governments do very little to encourage Nigerians in the northern region to take up solar energy, though the government could encourage businesses that deal in solar systems to set up shop in northern Nigeria. Incentives such as preferential licensing would help attract vendors and technicians.

Next, the governments and non-governmental organizations could encourage Nigerians to take up solar energy so residents in this region would be exposed to different solar technologies and made aware of the options and suitability of solar energy. Lastly, NGOs and financial institutions could step in to provide financial assistance for persons wishing to install solar energy systems. Provision of financial support would help offset the high costs associated with installing solar energy systems.

It is, however, noteworthy that not all solar power systems are associated with high installation costs, since most portable solar systems are low cost. Informing the masses of the potential of solar as a complementary and alternative energy source is vital to the development of this form of energy. If leaders in the energy sector, political arena and social interest groups were to take a leading role in informing residents of northern Nigeria of the potential of green energy, then this educational process could take place.

How would Nigerian governmental power and politics impact the shift to renewable energy usage in Nigeria?

The Nigerian government's power and politics could influence the shift to the use of renewable energy, and specifically the use of solar energy. First, political will would be required for the government and legislators to make changes that would make northern Nigeria attractive to solar appliance vendors. Secondly, the state and federal governments would have to work together in implementing changes that would improve access to solar products. Interaction between these levels of government is not always smooth. Lastly, the Nigerian government would have to encourage the involvement of various non-government and financial institutions in promoting and easing access to renewable energy. These are areas where the governments are currently lacking. Change is unlikely unless both the state and federal governments prioritize the use of green energy and take steps to encourage citizens to follow.

Summary

This chapter presents the findings of the study and a discussion of their implications on the research questions, which was critical to the overall success of the study. It was revealed that the use of solar energy requires a low recurrent expenditure and is more affordable than fossil fuels and grid electricity.

However, the feasibility of solar energy in northern Nigeria is affected by the lack of technical expertise and inaccessibility of vendors. The high installation cost for home systems and the minimal involvement of both the federal and state governments in encouraging the use of solar energy and subsiding solar products are other issues. The government must adopt a holistic approach to renewable energy that involves a change in political will, encouraging investors in solar energy (both local and international) to set up shop in northern Nigeria and provide financial assistance (directly or indirectly) to persons that wish to use solar power there.

The next chapter includes the conclusion and recommendations, highlighting the main findings, limitations, and assessment of the degree of success of the study, and offering recommendations that could help improve the use of solar energy in northern Nigeria. Directions for future research are also addressed.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

This is the last chapter, which reviews the study and crafts recommendations based on the findings. The specific aspects of this chapter include the findings and conclusions, limitations, the implications of the study on practice, recommendations for future study, reflections and a conclusion of the entire study.

Findings and Conclusions

The study mainly targeted the determination of the economic, technical, operational and legal feasibility of solar energy in northern Nigeria. Cost-based analysis revealed that the recurrent expenditure associated with the use of solar energy is significantly lower than the recurrent expenditure associated with the use of fossil fuels (paraffin, petrol and diesel).

However, the initial installation cost of a solar energy system is comparable to the installation cost of petrol and diesel, and significantly higher than the installation cost of paraffin. The implication is that the high installation cost associated with solar energy makes it economically infeasible. Solar power energy is not technically and legally feasible due to lack of access to vendors and technical expertise and lack of support from the government, respectively. Operationally, the utilization of solar energy is feasible as it supports most households' power needs and is readily accessible.

It is possible to replace fossil fuels with solar energy in northern Nigeria because the failures in economic, technical and legal feasibility could be corrected with the input of the state and federal government and changes in energy policies aimed at attracting solar energy investors and encouraging residents of northern Nigeria to adopt solar energy. The high initial installation cost could be addressed through subsidizing solar products and tailoring solar installation payment plans that meet the financial capabilities of the residents of northern Nigeria.

The lack of technical expertise and solar products vendors could be addressed through encouraging investment in solar energy businesses, which in turn would attract expertise in solar energy to northern Nigeria. The lack of encouragement by the government could be addressed through changes in state and federal government views of solar energy and the realization that the use of renewable energy is vital to meeting national and state power needs. If experts in the energy sectors (both professionals and scholars) were at the fore in lobbying the state and federal governments, it could change their view towards solar energy.

The leadership structure in place has not encouraged the utilization of solar energy in northern Nigeria and does not offer subsidies as incentives for solar energy enthusiasts. If the policy makers and key players in the solar energy sector and the energy sector in general at state and federal levels were to review their approach to solar energy, leadership could develop the structures required to encourage the adoption of solar energy. These would include improving access to financial services and supporting the implementation of energy policies aimed at improving access to solar products and the usage of solar energy and renewable energy in northern Nigeria.

Several changes would be required for Nigeria to be successful in harnessing the potential of solar energy. First, the involvement of the state and federal governments would be necessary to encourage the use of solar energy. Secondly, due to the high installation costs associated with the utilization of solar energy, financial assistance measures would have to be instigated, including providing financial assistance for solar installation and subsidizing solar products. Lastly, the masses would need to be educated on the benefits associated with the usage of solar energy and renewable energy. The change in attitude towards solar energy associated with education would be essential to ensuring the uptake of solar technology.

The study highlighted the potential influence of Nigerian power and politics on the shift to renewable energy. The shift would require political will, cooperation between state and federal governments and the willingness to involve various stakeholders in promoting and easing access to renewable energy. Currently, there are notable deficiencies in these requirements.

Limitations of the Study

A number of limitations were faced during the research. The first challenge was accessing the participants. Due to the frail political environment in northern Nigeria, persons tasked with data collection were often viewed with suspicion. The intended participants were suspicious of strangers. This factor resulted in fewer homesteads participating in the study.

The second issue in accessing the participants was that most homeowners or persons that could provide information on energy use in the homes were not always available during the daytime. Most of the people that fell into the category of the targeted sample were in their place of work when the researchers visited their homes. As a result, the data collection crew was not able to adequately inform such homeowners of the ilk of the study, which was critical in aiding and easing their involvement in it.

Implications for Practice

The findings have various implications on the management of renewable energy in northern Nigeria. From the study, it is evident that the recurrent costs associated with the utilization of solar energy are low compared to other forms of energy. However, the installation cost is still very high. Efforts targeting improvement in the feasibility and usage of solar energy within northern Nigeria would have to target the high installation cost, lack of expertise and poor access to solar vendors in northern Nigeria.

The major players and stakeholders in the energy sector including the state government, the national government, financial service providers and nongovernmental organizations would have to come together and devise avenues through which initial installation of solar energy could be made affordable to more Nigerians living in the northern region. Potential strategies could include attracting investments in the solar energy sector, encouraging vendors to set up shop in northern Nigeria and subsidizing the solar products required for solar installation (batteries, panels, cables, charge regulators, bulbs and inverters) and developing financial plans tailored for persons interested in installing solar energy.

Despite the perennial power, problems and challenges faced in grid electricity distribution in Nigeria, the state and federal governments have shown little interest in developing solar energy. The governments do not offer subsidies on solar energy products and do not encourage the utilization of solar energy. Owing to the fact that solar energy supports most power uses and is associated with minimal recurrent expenditures, if the federal and state governments were to review their stance on solar power in northern Nigeria, it could improve the overall energy situation there.

The governments (state and federal) could take steps aimed at encouraging the utilization of solar power and even go further to facilitate the usage of solar energy by subsidizing solar products and encouraging investments by solar products businesses in northern Nigeria. Such investments would improve access and attract expertise in solar energy to northern Nigeria. If the leadership structure in the energy sector, and specifically the renewable energy sector, were reviewed, Nigeria could realize its economic goals, and the current energy production and distribution could be improved.

Efforts targeting the use of renewable energy in northern Nigeria are lacking, as evinced by the inadequacy of solar energy expertise and vendors in northern Nigeria. It is imperative to note that the current leadership structure offers minimal encouragement and direction with respect to developing renewable energy, and specifically solar energy, in northern Nigeria. If the leadership structure were to reconsider its approach to energy development to allow for the implementation of measures that would encourage the availability and adoption of solar energy in northern Nigeria, this could change.

Power and politics are influential on social and economic development. The utilization of solar energy could affect both the social and economic welfare of the people of northern Nigeria. The current lack of interest in solar energy by the state and federal government is shown by the lack of support and unwillingness to subsidize solar products despite their immense potential in improving access to energy.

The governments, notably state and federal-level legislators, could support efforts aimed at encouraging the utilization of solar energy and renewable energy in general. This political will would be critical in driving change and ensuring that various stakeholders in the community were actively involved in looking for ways through which solar energy could be made affordable and accessible to people living in northern Nigeria.

Implications of Study and Recommendations for future Studies

Future studies could explore the feasibility of solar energy relative to other renewable forms of energy. Use of econometric models and quantitative methods of data analysis to quantify the benefits and costs associated with the utilization of solar energy would help in developing a more accurate feasibility analysis. In future, use of regression models to determine the factors that influence the feasibility of solar energy in northern Nigeria could be considered. Such studies would pave the way to ensuring that efforts aimed at improving the feasibility of solar energy focus on the important factors. Furthermore, future studies could target the determination of the best avenues to improving the feasibility of solar energy and gaining required political support. Lastly, studies of the same region could look for novel ways of attracting a larger sample by overcoming the access limitations.

Reflections

The study was very demanding, especially the process of coding the data. Proper organization and coordination with the data collection team was critical in ensuring that the set timelines were met. The study helped me appreciate the potential of solar energy in northern Nigeria. From the findings, it became apparent that solar energy has immense potential. I now appreciate that solar energy and renewable energy in general could be the way forward to improving distribution and access to energy in northern Nigeria.

However, this potential has yet to be harnessed because of the lack of support from the state and federal governments. Importantly, the study helped me to understand the intricacies associated with research. I realized that even though the academic knowledge is important, there are personal attributes such as communication skills, determination and organization that are critical to the successful completion of a research study.

Conclusion

The aim of this study was to determine the economic, technical, operational and legal feasibility of solar energy in northern Nigeria. The focus of the study was on household-level harvesting of solar energy using photovoltaic solar panels. In addition, the study sought to determine the nature of the leadership and management structure in place, the changes that would be required in the Nigerian approach to renewable energy in order to further utilize solar energy and the potential effects of Nigerian power and politics on the shift to renewable energy. It employed a comparative quantitative survey design, with the target population of households and experts in the energy sector from the northern region in Nigeria. Three northern states were included in the study, with each state contributing 128 household heads and 3 experts. The study revealed that the utilization of solar energy in northern Nigeria is operationally feasible. However, the use of solar energy is lacking in economic, legal and technical feasibility due to high installation costs, lack of support from the state and federal government and lack of access to vendors and technical expertise, respectively.

Furthermore, the current leadership and management structures have not encouraged the utilization of solar energy by not becoming actively involved in supporting the uptake of solar energy or making technical and financial access to solar energy easier. Changes such as increased involvement of state and federal governments in encouraging the utilization of solar energy, instigation of financial assistance programs and education of the masses on the benefits and potential of solar energy would be required for Nigeria to harness solar energy successfully. Lastly, the study highlighted the potential influence of Nigerian power and politics on the shift to renewable energy. The study made recommendations for further research using econometric models that could quantify the qualitative gains associated with the utilization of solar energy to develop a more accurate analysis of its feasibility.

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APPENDIX

Table 11: Reliability for Government support items

Reliability Statistics

Cronbach's Alpha	N of Items
0.63	3

Table 12: Reliability Solar Feasibility

Reliability Statistics

Cronbach's Alpha	N of Items
0.713	8

Table 13: Reliability (other forms of Energy)

Reliability Statistics

Cronbach's Alpha	N of Items
0.601	5

Table 14: Cost of Solar Installation

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
What was the cost of solar energy system installation?	120	35020.00	79775.00	58346.4667	13123.50432

Table 15: Compounded Cost Analysis

Year	Solar Installation	Solar Expenses	Total Solar	Mains Electricity Installation	Mains Electricity Expenses	Total Mains electricity	Parrafin Installation	Parrafin Expenses	Total Parrafin
1	58346.5	4798.4	63144.9	60000	18023.5	78023.5	1000	22119.8	23119.8
2	61263.8	5038.32	66302.1	63000	18924.7	81924.7	1050	23225.8	24275.8
3	64327	5290.24	69617.2	66150	19870.9	86020.9	1102.5	24387.0	25489.5
4	67543.3	5554.75	73098.1	69457.5	20864.5	90322	1157.63	25606.4	26764
5	70920.3	5832.49	76753	72930.4	21907.7	94838.1	1215.51	26886.7	28102.2
6	74466.5	6124.11	80590.6	76576.9	23003.1	99580	1276.28	28231.0	29507.3
7	78189.9	6430.32	84620.2	80405.7	24153.3	104559	1340.1	29642.6	30982.7
8	82099.3	6751.83	88851.2	84426	25360.9	109787	1407.1	31124.7	32531.8
9	86204.3	7089.42	93293.7	88647.3	26629	115276	1477.46	32681	34158
10	90514.5	7443.89	97958.4	93079.7	27960.4	121040	1551.33	34315	35866.3
11	95040.3	7816.09	102856	97733.7	29358.4	127092	1628.9	36030.8	37659.7
12	99792.3	8206.89	107999	102620	30826.4	133447	1710.34	37832.3	39542.6
13	104782	8617.24	113399	107751	32367.7	140119	1795.86	39723.9	41519.8
14	110021	9048.1	119069	113139	33986.1	147125	1885.63	41710.1	43595.8
15	115522	9500.51	125023	118794	35685.4	154481	1979.93	43795.6	45775.5
16	121298	9975.53	131274	124736	37469.6	162205	2078.93	45985.4	48064.3
17	127363	10474.3	137837	130973	39343.1	170316	2182.88	48284.7	50467.5
18	133731	10998.0	144729	137521	41310.3	178831	2292.02	50698.9	52990.9
19	140418	11547.9	151966	144397	43375.8	187773	2406.62	53233.8	55640.5
20	147439	12125.3	159564	151617	45544.6	197162	2526.95	55895.5	58422.5

Informed Consent

Title of Study: Feasibility of Making Solar Energy Available In the Northern Region of Nigeria
Investigator: Adedotun O Anjorin
Contact Number: 6198251916

Purpose of study:
The purpose of the study is to establish the feasibility of solar energy in the Northern region of Nigeria which will turn aid in the determination of the viability of solar energy as an alternative source of energy. Nigeria's energy problems may be partly addressed by the adoption of renewable energy. Solar energy is a viable option in Northern Nigeria considering that the regions enjoy many sunlight hours in a day. The study will address the gap in research relating to the feasibility of solar energy in Northern Nigeria which may instigate the interest of investor, government, businesses, non-governmental organizations and citizens.

Participants
You are invited to take part in research study Feasibility of Making Solar Energy Available in the Northern Region of Nigeria. The research will be conducted by Adedotun.O.Anjorin. Kindly, read this form thoroughly before agreeing to participate.

Procedures
If you agree to participate in this research, sign this consent form.

Risk and Benefits
You will be asked to answer another questions that directly ask about your age, marital status, Number of household and Location. Some of the questions maybe personal but the information will not be shared with third party. You may refuse to answer any of the questions on the form.

Confidentiality
The records of this will be kept private. All information's will remain confidential. In any sort of report of the study, information that will reveal the identity of the participant will be omitted. In addition, participant vital personal information will not be included in the questionnaire and survey. All data's will be kept in a locked file; only researcher for this study will have access to the records.

Voluntary nature of study
Your decision whether or not to participate in this research is voluntary. After signing the consent form, you are free to discontinue your participation in filling the questionnaires and surveys. You do not need to complete it, if you feel uncomfortable doing it.

Please initial box

1. I confirm that I have read and understand the information sheet dated November 18^{th}, 2013 for the above study. I have had the opportunity to consider the information, ask questions and have had these questions answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reasons. ☐

3. I understand that any information given by me could be used in future reports, articles or presentations by the research team ☐

4. I understand that my name will not appear in any reports, articles or presentations. ☐

5. I agree to participate in the above study. ☐

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Name of the Participant	Date	Signature
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Researcher	Date	Signature