GSJ: Volume 8, Issue 3, March 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

Achieving Sustainable Energy in Nigeria Through Photovoltaic (PV) Technology ;Problems and Prospects

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Abstract

The global quest for sustainable development has dramatically increased in our modern times and this raises the issues of a sustainable economic development and growth. Therefore, sustainable energy has become one of the most promising means of handling the challenges of energy demand problems of many consumers worldwide. However, solar energy is a clean energy source and thus power generation through this energy source imposes little or no environmental hazards. The research aim is to assess the problems and prospects of achieving sustainable energy in Nigeria through photo voltaic (PV) technology. Descriptive and correlative design was used in this research work. The sample population of the study was delimited to and comprises of selected practitioners in top five (5) solar firms in Nigeria, 136 respondents was randomly drawn from the various population of the study using a purposive sampling procedure. Data was obtained through the instrument of questionnaire. Oral interview was also used to get more information from the respondents. The data analysis techniques used for the test of hypothesis are multiple regression and correlation method using (SPSS) version 21. The study concludes that technical challenges, economic and financial challenges are the most striking barriers. The study recommends that Nigerian Government should invest in the development of Nigerian made PV panels which will contribute to the Nations GDP and GNI. This will be the natural consequence since these panels will be exported and foreign exchange will flow into Nigeria's economy.

Keywords: Photo Voltaic, Solar Energy, Renewable Energy, Sustainable Energy

1.0 INTRODUCTION

Energy plays the most vital role in the economic growth, progress, and development, as well as poverty eradication and security of any nation. Uninterrupted energy supply is a vital issue for all countries today. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible, and environmentally friendly. Security, climate change, and public health are closely interrelated with energy (Ramchandra and Boucar, 2011). Energy is an important factor in all the sectors of any country's economy. The standard of living of a given country can be directly related to the per capita energy consumption.

The global quest for sustainable development has dramatically increased in our modern times and this raises the issues of a sustainable economic development and growth. Therefore, sustainable energy has become one of the most promising means of handling the challenges of energy demand problems of many consumers worldwide (Hvelplund, 2006). Strategies in sustainable energy development includes the major technological changes which are improvement in efficiency of energy production, demand side energy savings and replacement of fossil fuels by various forms of renewable energy (RE).

The level of productivity in the commercial, agricultural and industrial sector is related to their energy use which on the other hand determines the developmental level of a nation. Energy sources which include coal, petroleum, natural gas, nuclear fuels and biomass are used in everyday activities. However, fossil fuel constitute more than 80% of the global primary energy consumption and these can be observed in the production of electricity which is an important form of energy required in all sectors of the economy (Awwad and Mohammed, 2007).

The International Energy Agency (IEA) in its 2006 World Energy Outlook stated clearly that the energy market will be dominated by oil continuously into the foreseeable future and RE will contribute about 15% to the total primary energy requirements by 2030 (IEA, 2006). The growing demand for energy consumption has raised concerns by experts who argued that with the global energy consumption at its current pace, economically exploitable fossil fuel reserves will not exceed 40 years for oil, about 60 years for natural gas and 230 years for coal (Jean and Marc, 2007).

In Africa, access to clean sustainable energy which is essential for its social, political and economic development has been an immense challenge and this has thrown the continent into a state of developmental crisis. Nigeria which is known as “the giant of Africa” in terms of energy resources with a population of 174,507,539 which makes it the most populous country in the world (CIA, 2013) and gross domestic product (GDP) of $522 billion (Worldbank, 2014a) still suffers from energy poverty which is due to the lack of development in sustainable energy.

About 49% of Nigerians live in the rural (Worldbank, 2014b) areas where access to electricity and fossil fuel is difficult to obtain. The extension of the national electricity grid does not cover the whole country; therefore most villages don’t have access to the electricity. This lack of electricity has caused the people to resort to the use of any available fossil fuel like petrol and diesel for electricity, kerosene and woods (fuel woods) for cooking. Moreover, the roads in which they ply in order to obtain the fossil fuel are bad and they meet a lot of cue at the petrol station where they will spend long hours trying to buy fuel.

Popular perception of renewable energy in Nigeria tends to focus on solar and occasionally wind power. Renewables have a relatively short history in Nigeria, especially in the public view. However, renewable energy from hydropower has actually been at the core of Nigeria’s grid electricity production since the 1960s. Until very recently, the Kanji and Jebba Dams (1300MW) accounted for around 50 per cent of Nigeria’s stable power sources, only recently being overtaken by gas power stations whose role continues to be constrained by the poor state of the national grid and unstable gas supplies.

Power supplies are very limited in Nigeria: electricity from the grid is available to only around 50 per cent of the population, and even then is erratic. This has been at the core of early renewable-energy development in Nigeria. It has provided a strong incentive to find something more stable and that does not result in the constant drain of cash associated with the high costs of power from the‘stand-by‘ generators which have become the main source of power for many basic rural services. Wind and solar power in Nigeria are poorly understood by the public and even policymakers. The successes are much less well known than the shortcomings, which have been all too visible with failed solar street-light schemes dotted across Nigeria‘s major cities. In the public mind, solar power installations have largely joined the many failed projects initiated by government—testimonies to poorly installed technology associated with patronage and corruption. Yet the successes for renewable energy in Nigeria should give pause to its critics. The small but growing number of solar energy projects that have been faithfully implemented have delivered far greater stability in service than comparable interventions.

They also offer the most elusive of gains in rural Nigeria—plausible long-term sustainability. In the areas of vaccine storage, rural water supply and lighting for those on the lowest incomes, there are global innovations and improvements in affordability at a remarkable pace that can be adapted for Nigeria.

Renewable energy should never be considered in isolation. Progress in the field goes hand in hand with improved energy efficiency, which has been vital in driving down costs and making new applications feasible. Compared with the existing costs of power in Nigeria (mainly generators), there is a very strong case for quite radical interventions. This is also in contrast with other developing countries which have a more stable grid electricity supply. This research work seeks mainly to assess the problems and prospect of achieving of sustainable energy in Nigeria through Photovoltaic (PV) technology

Statement of Problem

The issue of global warming has drawn national and international attention. Targets have been set by different countries and regional blocks on reduction of greenhouse gas (GHG) effects. Martinot (2006) reported that the two largest global sources of GHG of which carbon dioxide (CO2) is the most common is electricity heat and transportation of which both contributes 32percent and 17percent respectively. He also revealed that the use of electricity, heaters, air conditioners and motor vehicles contribute to these sources. Furthermore, the land uses, forestation, manufacturing and construction activities contribute 24percent and 13percent respectively.

In a recent research, Solangi et al. (2011) discussed CO2 emission by Africa region as shown in the world CO2 emission in Table 7 and projected that by 2025, Africa will emit 1524 million tonnes of CO2. Bilen et al. (2008) opined that CO2 screens sunlight and allows the penetration of sun rays but prevents heat radiation re-emergence. Nigeria generates her electricity mainly from fossil fuels. In order to achieve the global challenges of CO2 emission reduction, there is urgent need to integrate renewable energy technologies into the nation's energy portfolio.

For this to be achieved, proper comparison and adequate choice of a renewable energy technology with considerable cost and little or no negative environmental impacts have to be made.

Also many African countries have chronic power shortage leading to outages and the need for expensive high cost back-ups power generation. Within her population, over 600 million people in Africa lack any form of access to electricity. In Nigeria, over 70% of Nigerian household do not have access to power supply (Nwofe, 2014).

Population increase therefore means that energy supply challenges will continue into the next decades. Amidst the envisage challenge, clean and sustainable energy supply is considered the only way Africa could attain its full potentials (World Bank, 2015). However, inherent barriers to this pathway remain. IRENA (2016) observed that targeted transformation in the energy sector by poor institutional capabilities, non-institutionalization of financing mechanisms and poor generic business sector improvement. Again, the cost structure for communicating the benefits photovoltaic to the stakeholders, policy makers and end-users are vastly unstructured. IRENA (2016) observed that there is total lack of up-to-date data on the true cost of PV in Nigeria and other parts of Africa. Absent of comprehensive data on the cost of PV inhibits efficient policy making towards expanding adoption rate (IRENA, 2015a), all these stirred interest for a research addressing these problems.

Aim and Objectives of the Study

The aim of the study is to assess the problems and prospect of achieving of sustainable energy in Nigeria through Photovoltaic (PV) technology. To the aim of the study, three objectives are set-out namely to:

1. Identify the prospects of sustainable energy in Nigeria through Photovoltaic technology
2. Determine the Key Barriers of Photovoltaic technology in Nigeria
3. Appraise strategies to mitigate and control the challenges of photovoltaic system for sustainable energy in Nigeria

Research Questions

1. What are the prospects of sustainable energy in Nigeria through Photovoltaic technology?

2. What are the Key barriers of Photovoltaic technology in Nigeria?
3. What are the strategies to mitigate and control the challenges of photovoltaic system for sustainable energy in Nigeria?

Hypothesis

HO1: There is no significant effect of the collective barriers on achieving sustainable energy in Nigeria .

HO2: There is no significant effect of each barriers on achieving sustainable energy in Nigeria.

Scope of the Study

The scope of the study is limited to the prospects and challenges of achieving sustainable energy in Nigeria using Photovoltaic Technology. The study area is in Nigeria, precisely top five (5) solar energy firms in Nigeria (three located in Lagos, one in Abuja and one in Enugu State). The study evaluated mainly the prospects of sustainable energy in Nigeria through Photovoltaic technology and key barriers of Photovoltaic technology in Nigeria; and moreover, previous studies in these areas focused mainly on literature reviews with no empirical basis. The study is further delimited to strategies to mitigate and control the challenges of photovoltaic system for sustainable energy in Nigeria

2.0 LITERATURE REVIEW

Solar Energy Potential of Nigeria

Nigeria's annual averaged daily sunshine potential is 6.25 hours; with 3.5hours at the coastal areas and 9.0 hours at the far northern hemisphere (Nwofe, 2014). The annual solar radiation in Nigeria is 5.25KW/m2/day; 3.5 kWm2/day at the coastal Area and 7.0kW/m2/day at the northern boundary (Ikuponisi, 2006). The total energy from the sun per day is 4.851 x 10^{12} KWh. When compared with energy from oil amount to 1.082 million tons of oil (mtoe). This dimension of energy is available only during 26% of the day. With an annual land area of 924 x 10^{3} km^{2}; and averaged of 5.535 kWh/m^{2}, the incident solar energy is 1.804 x 10^{15} kWh annually. Offiong (2003) situates Nigeria on latitude 4-14^{0}North of the equator with lots of solar potential. Other studies claimed Nigeria receives about $20MJ/M^{2}$ per day of solar insulation, although this amount varies with across zones.

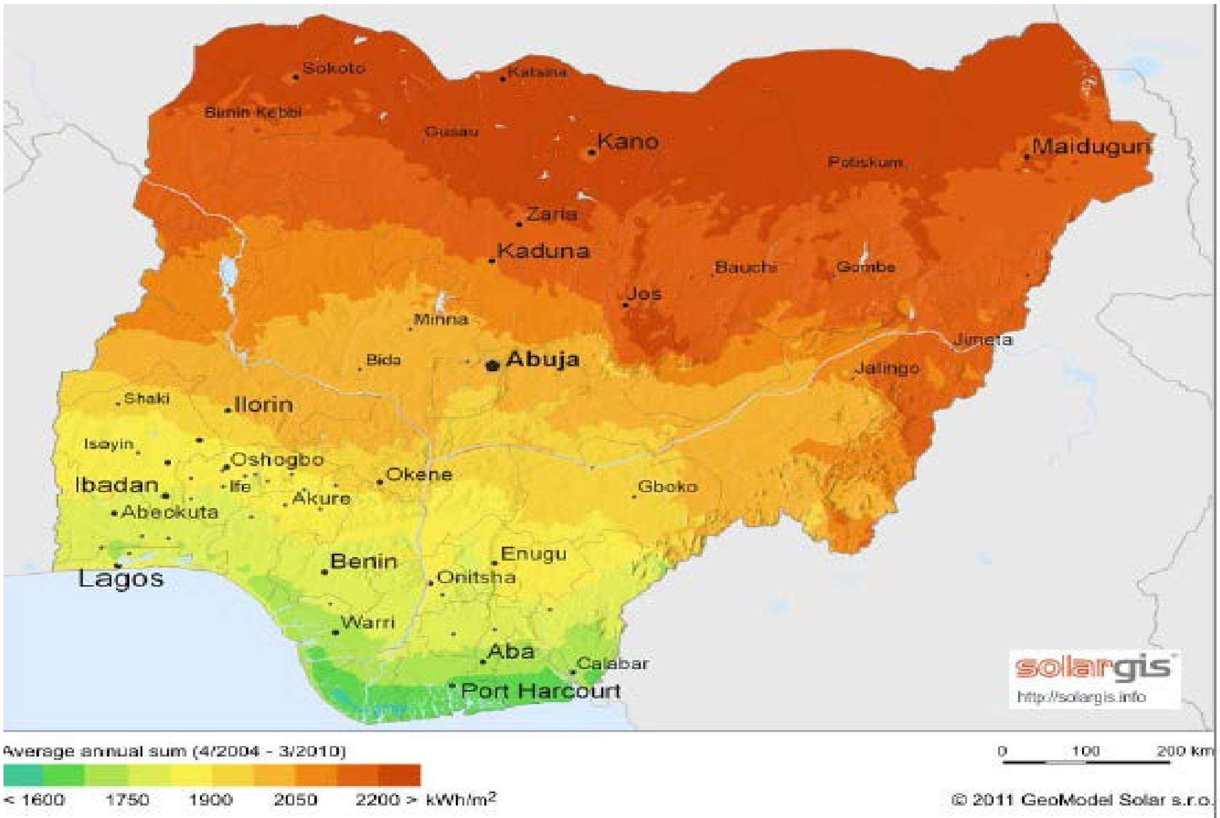


Figure 1: Map of Nigeria showing the Solar Potential of Nigeria (Ikponusi, 2006)

Solar Energy Uses in Nigeria

The National Energy Policy Document [NEPD] (2006) declared that Nigerian states are well situated within the sunshine belt. The annual averaged total sunshine varies from 12.6 MJ/m2/day (3.5kWh/m2/day) in the coastal latitude to 25.2 MJ/m2/day (7.0 kWh/m2/day) in the far north. Solar energy application in Nigeria is therefore not new. Application areas of solar energy in Nigeria include solar electricity, water heating, cooling and heating, water purification, pool heating, and solar cooking (Manzuma and Mbamali, 2014). According to Ilenikhena and Ezemonye (2010), the premier solar energy application in Nigeria happened in 1985 that is, street lighting in Kwakwalawa Village in Sokoto State. The widespread application is intrinsically develops from the numerous benefits including cost reduction over life cycle, no greenhouse gas, infinite green energy, decentralization of power, point of use generation, off-grid generation, solar jobs opportunities, not subject or price volatility, aesthetics and saving eco-system. However, these benefits are not without drawbacks.

Photovoltaic System

Yeung (2007) traced the origin of the term ‘photovoltaic’ to Greek where ‘photo’ indicates light and ‘Volta’ to an Italian scientist who invested chemical battery in 1800. The photovoltaic effect is therefore a direct conversion of solar energy to electricity. Panels are fabricated using material that allows electrons to energize when subjected to light, freed from their atom (Yeung, 2007). The current is said to flow in one direction like is obtained in battery; hence, the electricity is referred to as direct current (DC). Photovoltaic system is a system that utilizes renewable solar energy to create electricity. PV cells are combined together in module, and modules are also combined to form array. Arrays are therefore mounted to roof (mainly) in BAPV adoption to capture light. It is a member within the family of renewable energy technologies. Renewable energy technologies are the energy flow from sources which are replenished at similar manner as used rate (Manohar, Ramkissoon&Adeyanju, 2015). Other renewable sources include solar thermal, wind and hydro-electric technologies.

There are three types PV cell technologies in the market namely: mono-crystalline silicon/polycrystalline silicon; amorphous silicon and thin film technology of copper indium diselenide (CIS) (Yeung, 2007). The mono-crystalline silicon is single-crystal silicon, and has the highest efficiency rating of over 15% (Yeung, 2007, Offiong, 2003). The polycrystalline silicon is more expansive than mono-crystalline developed from block of cast silicon. Polycrystalline has a conversion efficiency of 10-15% (Yeung, 2007). The amorphous silicon has the least conversion efficiency amongst all technologies of about 4-7%. PV cells (panels) are the most significant component of the PV system and the cost trend of the entire system is increasingly linked with its costs (Jelle&Breivik, 2012). Hence, development towards cost management consider crystalline silicon technology more expensive and other technologies are direct response to mitigate costs including thin film with lower efficiency (Tyagi, Rahim, Rahim, &Selvaraj, 2013).

Classification of Solar Photovoltaic System

Bouhou (2015) identified two types of solar technologies that is, photovoltaic (PV) and concentrating solar power (CSP). CSP systems apply mirrors to focus sunlight onto a receiver that heat a fluid at high temperature hitherto converted into electricity. The most popular in residential sector is photovoltaic panels. The panels can be rooftop mounted or building integrated. The power generated can be used directly or stored in battery for future uses. The PV generated power is classified as grid-connected and off-grid connected. Grid-connected system are channeled directly into the national distribution network. This understanding implies that, the excess electricity produced is injected into grid and home-based PV system serves as a mini-power generation plant. Off-grid PV systems generate mainly energy needed by household at given time and the excess are stored in battery for future uses. It is therefore not in doubt that estimated part of fossil-based fuel can be displaced by solar resources (Shaban, 2016).

Another classification system within cost management literatures identified building attached and building integrated photovoltaic systems. According to Jelle and Breivik (2012), BIPVs are integrated into the building fabric to replace traditional building material or components. The difference between both systems therefore is that, BIPV forms part of the building component performing structural or other function besides providing solar power to the building while BAPV are attached to the completed building. BAPVs are considered add-ons to the building structure, and are not directly related to the functional perspective of any building elements (Peng, Huang & Wu, 2011). Building integrated photovoltaic system (BIPVs) technologies include roof cladding; wall integrated and curtain walling photovoltaic panels. BAPVs are considered more attractive option mainly due to its flexibility in land space and longer service life (Bouhou**, 2015**). BAPV is therefore more prevalent technology than BIPV notably in developing countries including the United States of America (Bouhou, 2015, NEH, 2016). Penchant to BAPV technologies also include difficulty of integration associated with the use of BIPV (Gyimah, 2014). BAPV products are further flexible and suitable for sustainable regenerated and retrofit projects (Jelle&Breivik, 2012).

Types of Solar Photovoltaic System

There are three types PV cell technologies in the market namely: mono-crystalline silicon/polycrystalline silicon; amorphous silicon and thin film technology of copper indium diselenide (CIS) (Yeung, 2007). The mono-crystalline silicon is a single-crystal silicon, and has the highest efficiency rating of over 15% (Yeung, 2007, Offiong, 2003). The polycrystalline silicon is more expensive than mono-crystalline developed from block of cast silicon. Polycrystalline has a conversion efficiency of 10-15% (Yeung, 2007). Hence, development towards cost management consider crystalline silicon technology more expensive and other technologies are direct response to mitigate costs including thin film with lower efficiency (Tyagi, Rahim, Rahim, &Selvaraj, 2013).

Drawbacks in Solar Energy Uses in Nigeria

Prominent drawbacks include cost, bulky nature of solar panels, solar inefficiency, and storage. A study by Okafor and Uzegbu (2011) classified the problems of solar energy adoption in Nigeria into technical challenges, economic and financial, national policies and awareness, social cultural and environment constraints, and political, institutional and legislative barriers. Elusakin, Olufemi and Chuks (2014) linked poor planning, technological gap and operational challenges with off-grid power projects in Nigeria. Uyigue (2009) adds that lack of awareness and trained professionals and skills dearth, lack of research and over dependency on importation are other significant drawbacks to the use of renewable energy in Nigeria. Akinboro, Adejumobi and Makinde (nd) summarized constraints inhibiting cost-effectiveness of photovoltaic system in Nigeria as lack of affordability; low level of research and development, low awareness, lack of technology know-how, government policy, building regulation, and component failure. Others include cost of generation, theft and vandalism, technical problems among others. Several studies including (Kahneman, 2011) decried absence of provable financial benefits in the application of solar PV system in global domain. However, absence of financial incentive did not deter solar PV system market spread in many places including (Boubou, 2015). Scholars such as Kahneman (2011) therefore believe other factors drive its adoption than the rational choice model.

Economic Characteristics of Photovoltaic Technologies

Nigeria depends heavily on fossil for electricity generation due to the vast deposits of crude oil and natural gas in the country. Notwithstanding the vast deposit of crude oil, Nigeria generates less than 4000MW of electricity with per capita consumption of 0.03kw.This is the present situation despite the fact that the installed total capacity as far back as 1999 was put at 11,756MW (Oparaku, 2007). Photovoltaic technologies which are renewable and free for all unlike most conventional energy sources have the potentials to increase the total energy mix, improve the per capita consumption and extend electricity to rural and remote areas, considering the unharnessed potentials confirmed by (http: //www.reegle.info/policy-and-regulatoryoverview/NG, 2012;Stephen et al., 2012; Iloeje, 1997, cited in Ilenikhena, 2007, p.104; Okoro and Madueme, 2004).

Okoro and Madueme (2004) suggested introducing solar energy in Nigeria to improve the energy mix and to avoid energy crisis as a result of heavy dependence on fossil fuels,but warned that the cost of power generation through solar energy is enormous due to cost of photovoltaic (PV) modules. However, it is worthy of note that photovoltaic equipment has low maintenance cost and continuing research in photovoltaics will force the prices of modules down. This assertion on the enormous initial cost of PV modules is shown in Table 3 and confirmed by (Khan, 2010; Bilen et al., 2008; Sambo, 2007).

It is also worthy of note that solar electric power does not require construction of kilometre roads and buildings for its initial take off unlike hydropower and the rest and on completion does not require the building of flood control measures.

Furthermore solar technologies like the building integrated photovoltaic (BIPV) has the capability of offsetting partially the cost of the modules by replacing part of the building material as well as generating the required electricity (Pearsall, 2013). This is not realisable in hydropower technologies. This view is confirmed by Jones et al (2000) who opined that integration of PV arrays with the building fabric offers opportunity to replace other building components and as such offsetting cost of PV installation.

BIPV, a photovoltaic technology does not waste land, as no additional land area is required for the installation (Pearsall, 2013). The ground mounted PV systems have the potentials of reclaiming land area. The desert regions of Nigeria can be highly advantageous for this project hence reclamation of the desert areas as confirmed in Solangi et al (2011) and prevent further desert encroachment. This potential of land reclamation is not found in hydropower technologies.

Photovoltaic technologies create recycling opportunities of solar modules at the end of their life cycle and hence employment opportunities for millions of unemployed Nigerian youths and savings of land fill space among other benefits unlike hydropower and other conventional methods of electricity generation.

In agricultural sector, Nigeria has the opportunity of enjoying the efforts made by researchers worldwide in areas of solar water heating for dairy processing and irrigation projects, also there will be local solar support refrigeration for storage of agricultural produce and vaccines for livestock and solar dryers for drying crops thereby increasing its agricultural productivity, ameliorating food shortage and creating employment opportunities. This is not applicable to hydropower technologies and even where hydropower is used for irrigation, there is the challenge of flooding. Okoro and Madueme (2004) also confirmed that considerable efforts have been made in the agricultural sector in areas of solar water heater, micro irrigation and solar crops dryers. Furthermore they assert that PV cells now replace power sources in our domestic appliances, like battery re-chargers, portable radios, emergency roadside telephones, buoys and even homes.

One interesting feature of Photovoltaic technology is that it can be privately owned by individuals or communities as the systems are smaller in capacity unlike hydro technologies. It can also be owned by the government and big private investors in the case of very large systems as it is applied to hydro technologies (Pearsall, 2013).

Environmental Characteristics of Photovoltaic Electrical Power Generation

Solar energy is a clean energy source. Electric power generation through this energy source imposes little or no environmental hazards. Unlike most conventional source of power generation and even some renewables like wind energy technologies, PV technologies generate no noise though the inverter systems could produce a system humming noise which is normally absorbed by the domestic noise background.In a research by Various (1996, cited in Tsoutsos et al., 2005, p.292) it was emphasised that though PV systems are devoid of liquid, radioactive or CO2 emission, CIS and CdTe modules are prone to emit toxic substances to the environment especially when fire accident occurs in any of the array.Fthenakis and Zweibel (2003) however showed that the Cd emission in relation to CdTe used is 0.001percent (equivalent to 0.1g/GWh). This is insignificant and as such has no health implication.

The aesthetics of building integrated photovoltaics (BIPV) cannot be over emphasised as BIPV if properly installed always add to the beauty of the environment. This assertion is in agreement with Tsoutsos et al. (2005) who see the PV technologies worthy of usage in urban areas to replace existing building cladding materials and recommended for use in scenic areas and National Parks.

In solar technology the issue of land use has been controversial. Tsoutsos et al., (2005) opined that impact is dependent on topography of the landscape, PV system installed areas, the type of land and proximity to areas of natural beauty or sensitive ecosystems, and the biodiversity. This is expected to occur during modification of landscape, construction and transportation of materials. However in a recent research Solangi et al. (2011) outlined the merits of solar energy technology as follows:

- No emissions of CO2,NOX , SO2or particulates;
- Degraded land reclamation;
- Transmission lines from the grid are reduced;
- The quality of water resources are improved;
- Increase in the national energy portfolio

3.0 METHODOLOGY

Descriptive and correlative design was used in this research work, Descriptive survey is one in which a group of people or items are studied, by collecting and analyzing data from only a few people or items considered to be a representative of the entire group. Therefore, the descriptive survey is relevant to this study, because sample from the population was used and inference was made on the entire population.

The population of this study refers to the totality of persons or organizations that has the capacity to undertake and implement photovoltaic technology projects in Nigeria. Due to the nature, size and cumbersome burden of getting at the entire population, the sample population of this study was delimited to and comprises of selected practitioners in top five (5) solar firms in Nigeria, such as Ecozar Technologies, Leks Environmental Ltd Lagos, Wavetra Energy Ltd Lagos, Solar Force Nigeria PLC Abuja, Astrum Energy Solutions Enugu.The main aim of choosing this type of population was to be able to get current and past information from people who have participated in the implementation of photovoltaic technology projects and thus experienced the implementation challenges that the projects face. The researcher adopted the purposive sampling method in this research work, due to the nature, size and cumbersome burden of getting at the entire population.. A sample of 136 respondents was randomly drawn from the various population of the study using a purposive sampling procedure. Purposive sampling procedure is when the researcher uses a convenient means of getting a sample from a given population.

The sample size was statistically determined using the formula of Taro Yamane (1964)

The formula is stated below

$$n\frac{N}{1+N(e)^2}$$

Where
N = Population size
e = Level of significance
n = sample size.

Thus:

$$n=\frac{136}{1+136x\ (0.05)^2}$$

$$n=\frac{136}{1+136x\ 0.0025}$$

$$n=\frac{136}{1+1.34}$$

$$\frac{136}{1.34}$$

$$n=101$$

n=101

The data was obtained through the instrument of questionnaire. Oral interview was also used to get more information from the respondents. Questionnaires were distributed to the relevant staff in accordance with the sample size.

The questionnaire was designed based on likert five point scale. The structure of the scale from the respondent indicates their opinion which is any of the following:

Strongly disagree = I point

Disagree = 2 points

Neutral = 3 points

Agree = 4 points

Strongly agree = 5 points

These were designed and distributed to the professionals. The major aim for this questionnaire was to ensure that exact information is gotten as more people are reached, more opinions gotten. About 101 questionnaires were distributed. The instrument was subjected to face validity, content validity test and construct validity test through testing it using the research done in the past.

Inter-item reliability test was applied to test the reliability of the research instrument. Multiple items were used to measure a single concept in the questionnaire. This involved a set of related questions which were designed to measure a certain concept being associated with each other.

Cronbach'scoefficient α test was applied to test the reliability. This was applied for each of the five research questions. A cronbach α value ranging from 0.5 to 0.7 was considered acceptable as indicating internal reliability of the instrument. A score of >.7 was regarded as an adequate proof of internal consistency.

Cronbach's formula

$\alpha = \frac{K}{K-1}\left(\frac{1-\sum Pi\,(1-Pi)}{\sigma_x^2}\right)$ Where α is the cronbach's coefficient, k is the number of items piis the proportion of respondents answering a research question in a certain way.

The data analysis techniques used for the test of hypothesis are multiple regression and correlation method.

In multiple regression, as in simple regression, the model describing the relationship between dependent variables y and a set k independent variable X1, X2,...... XK can be expressed as:

Y= bo + b1 X1 + b2 X2 + b3 X3 + b4 X4+ b5 X5 +b6 X6 +b7 X7 + b8 X8……………

The test was conducted at 0.05 level of significance. A computer software based multiple regression analysis called statistical program for social science (SPSS) version 21 was used in the data analysis. The decision rule is thus if power of text (p - value) or significance is less than a, the null hypothesis is accepted, and the alternative hypothesis rejected, but if the other way round, therefore, the test is therefore said to be significant.

Dependent Variable:

Y = Achieving Sustainable Energy through Photovoltaic Technology

Independent Variables(Key Barriers)

X1= Economic and Financial Challenges

X2 = Social, Cultural and environment challenges.

X3 = Inadequate Resource Assessment

X4 = Standards and Quality Control Challenge

X5 = Legislative/Institutional and Political

X6 = Technical Challenges

X7= National Policies and Awareness Challenge

X8 = Market Distortions

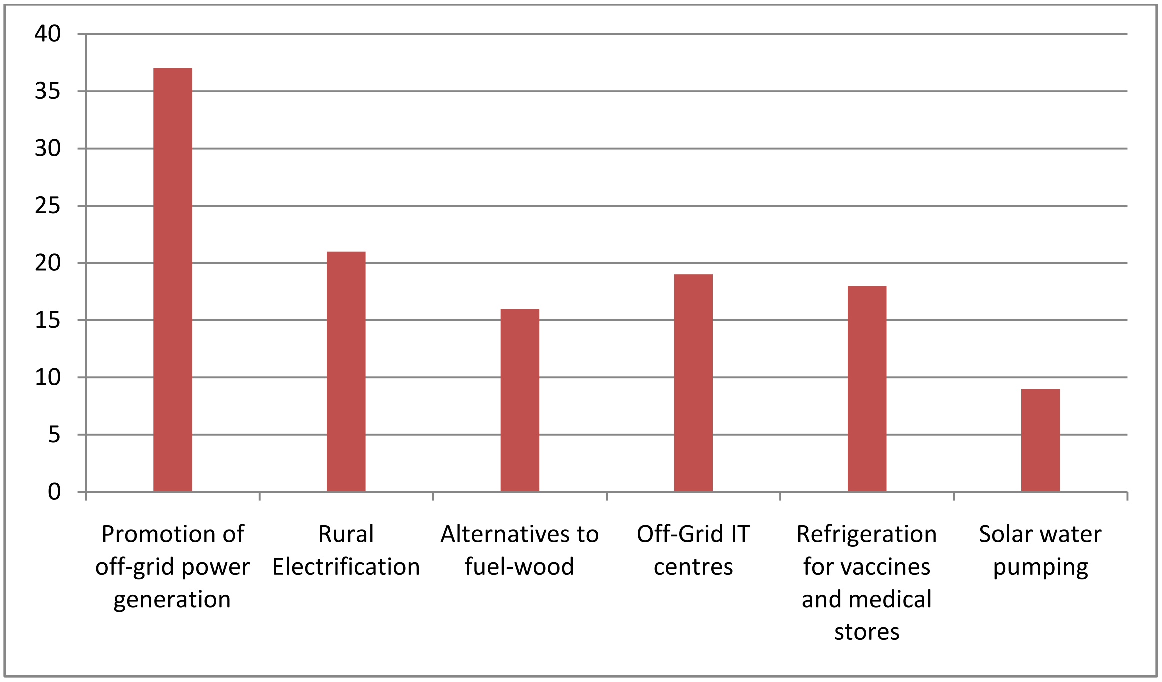
4.0 RESULTS AND DISCUSSIONS

Research Question One

What are the prospects of sustainable energy in Nigeria through Photovoltaic technology?

Table 1: Response to prospects of sustainable energy in Nigeria through Photovoltaic technology

PROSPECTS	FREQUENCY	PERCENTAGE (%)
Promotion of off-grid power generation	37	41.6
Rural Electrification	21	23.6
Alternatives to fuel-wood	16	17.9
Off-Grid IT centres	19	21.3
Refrigeration for vaccines and medical stores	18	20.2
Solar water pumping	9	10.1
TOTAL	89	100



The result above clearly depicts that among the identified prospects of sustainable energy in Nigeria through Photovoltaic technology, promotion off-grid power generation is the most likely area of success and the most needed area of importance for sustainable renewable energy in Nigeria through photovoltaic technology, if challenges are mitigated, followed by rural electrification etc

Research Question Two

What are the Key barriers of Photovoltaic technology in Nigeria

Table 2 Model summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.953[a]	.909	.900	.72614	.909	99.951	8	80[a]	.000

a. Predictors: (Constant), VAR00008, VAR00005, VAR00006, VAR00001, VAR00007, VAR00002, VAR00004, VAR00003

Table 3 ANOVA[b]

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	421.616	8	52.702	99.951	.000[b]
	Residual	42.182	80	.527		
	Total	463.798	88			

a. Dependent Variable: VAR00009

b. Predictors: (Constant), VAR00008, VAR00005, VAR00006, VAR00001, VAR00007, VAR00002, VAR00004, VAR00003

Table 4 Coefficients[a] for y

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.934	1.775		1.089	.279	-1.598	5.466
	Economic and Financial Challenges	.206	.049	.180	4.195	.000	.108	.303
	Social, Cultural and environment challenges	.280	.068	.262	4.143	.000	.146	.415
	Inadequate Resource Assesment	.253	.101	.196	2.516	.014	.053	.454
	Standards and Quality Control Challenge	.258	.084	.224	3.083	.003	.092	.425
	Legislative/Instituonal and Political	.212	.061	.187	3.495	.001		
	Technical Challenges	.352	.059	.333	5.972	.000	.091	.332
	National Policies and Awareness Challenge	.153	.070	.137	2.194	.031	.235	.469
	Market Distortions	.099	.078	.052	1.267	.209	.014	.291
							-.057	.255

a. Dependent Variable: VAR00009

From table 2, the model summary indicates that there is a very strong relationship between y and X_1, X_2,X_3, X_4, X_5, X6, X7, X8 with the coefficient correlation R = 0.953 (95.3%) and coefficient of determination R^2 0.909 (90.9%).

From table 4, all the barriers except Market distortions are significant. It has significance value of 0.209 which is above 0.05 level of significance.

Ranking of Results

Table 5 The Variables are Ranked Based on their Significance Value and Mean Value

Variables	**Sig Value**	**Mean Value**	**Ranked**
X1Economic and Financial Challenges	0.000	4.195	2nd
X2 Social, Cultural and environment challenges	0.000	4.143	3rd
X3Inadequate Resource Assesment	0.014	2.516	6th
X4Standards and Quality Control Challenge	0.003	3.083	5th
X5Legislative/Instituonal and Political	0.001	3.495	4th
X6Technical Challenges	0.000	5.972	1st
X7National Policies and Awareness Challenge	0.031	2.194	7th
X8 Market Distortions	0.209	1.267	8th

Research Question Three

What are the strategies to mitigate and control the challenges of photovoltaic system for sustainable energy in Nigeria.

Table 6 Responses on strategies to mitigate and control the challenges of photovoltaic system for sustainable energy in Nigeria

STRATEGIES	FREQUENCY	PERCENTAGE (%)
Private Sector Encouragement	27	30.3
Allocation of Resources to Photovoltaic technology	21	23.6
Capacity Building	10	1.2
Government Development of Policies on Renewable energy efficiency	19	21.3
Preparation of Standards and Codes of Practice	6	6.7
Research and Development	10	11.2
Awareness on photovoltaic technology resources exploitation and utilization	18	20.2
Resource survey and assessment	9	10.1
TOTAL	89	100

Test of Hypothesis

Hypothesis One

HO1: There is no significant effect of the collective barriers on achieving sustainable energy in Nigeria .

From table 2, the power of test, p — value (sig) F sig change value= 0.000 < α = 0.05. Therefore, the test is said to be significant. The study concludes that significant effect of the collective barriers on achieving sustainable energy in Nigeria.

Hypothesis Two

HO2: There is no significant effect of each barriers on achieving sustainable energy in Nigeria.

From table 4, the significance value of each of the factors are significant except for variable 8 (market distortions) which has a value of 0.203.

It is pertinent to conclude that there is significant effect of barriers on achieving sustainable energy in Nigeria.

DISCUSSION OF RESULTS

1. The discussion of the test shows that there is a significant effect of the collective barriers on achieving sustainable energy in Nigeria.
2. Also it clearly reveals that there is significant effect of each of the individual barriers on achieving sustainable energy in Nigeria.
3. The study further revealed that among the identified prospects of sustainable energy in Nigeria through Photovoltaic technology, promotion off-grid power generation is the most likely area of success and the most needed area of importance for sustainable renewable energy in Nigeria through photovoltaic technology.
4. The key barriers to Photovoltaic technology adoption, utilization, implementation in Nigeria according to their order of significance are Technical Challenges, Economic and Financial Challenges, Social, Cultural and environment challenges, Legislative/Institutional and Political, Standards and Quality Control Challenge, Inadequate Resource Assesment, National Policies and Awareness Challenge; however, Market Distortions is seen from the outcome of the results not to be a key barrier in Nigeria.

5.0 CONCLUSION AND RECOMMENDATIONS

Conclusion

In this study, the researcher has shown Nigeria's photovoltaic technology prospects and challenges in achieving sustainable energy. Pragmatic strategies to be followed to help mitigate the challenges steps were highlighted. No doubt, several plans have been developed by several governments in Nigeria but the problem has always been with the implementation. However the study concludes that:

1. Promotion of off-grid power generation, Rural Electrification, Alternatives to fuel-wood, Off-Grid IT centres, Refrigeration for vaccines and medical stores and Solar water pumping are the major prospects of sustainable energy in Nigeria through Photovoltaic technology.
2. Economic and Financial Challenges, Social, Cultural and environment challenges, Inadequate Resource Assessment, Standards and Quality Control Challenge, Legislative/Instituonal and Political, Technical Challenges, National Policies and Awareness Challenge are the key barriers to achieving sustainable energy in Nigeria through Photovoltaic technology. However, Market Distortions is not a key barrier in Nigerian context.
3. Technical challenges and Economic and Financial Challenges are the most striking barriers from the findings of the study. As such these concurs with the findings of Abdullahi, Suresh, Renukappa and Oloke (2017) on Key Barriers to the Implementation of Solar Energy in Nigeria: A Critical Analysis; where the posited that Nigeria should look into development of its own solar energy potential by investing in trainings for professionals and increasing funding solar technology in the country.
4. Private Sector Encouragement, Allocation of Resources to Photovoltaic technology, Capacity Building, Government Development of Policies on Renewable, Preparation of Standards and Codes of Practice, Research and Development, Awareness on photovoltaic technology resources exploitation and utilization, Resource survey and assessment are strategies to mitigate and control the challenges of photovoltaic system for sustainable energy in Nigeria

Recommendations

From the findings of the study, the following recommendations were made

1. Nigerian Government should invest in the development of Nigerian made PV panels which will contribute to the Nations GDP and GNI. This will be the natural consequence since these panels will be exported and foreign exchange will flow into Nigeria's economy.

2. There is need for human capacity building of professionals in the photovoltaic technology. Human capacity building will stimulate an avalanche of technological know how which will be required to both develop newer technologies and maintain the existing ones.
3. Government and Private Sectors in Nigeria should establish PV technology clusters and hubs in Nigeria which will stimulate Industrial growth through establishment of new firms (SMEs) that produce and market Solar PV panels and other accessories.
4. Relevant Government Agencies should develop and implement a working renewable energy policy which will help Nigeria plan to begin in the right direction.
5. The government should create the right investment climate for investors in renewable energy In Nigeria.

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