RENEWABLE ENERGY TECHNOLOGY MEANS OF PROVIDING SUSTAINABLE ELECTRICITY IN NIGERIAN RURAL AREAS - A REVIEW

Abdulhakeem Garba[1] and Mohammed Kishk [2]

[1] *The Scott Sutherland School, The Robert Gordon University, Aberdeen, AB10 7QB,UK.*
[2] *Aberdeen Business School, The Robert Gordon University, Aberdeen, AB10 7QE, UK.*

Following the failure of the Power Holding Company of Nigeria (PHCN) and fossil fuel source applications for the provision of electricity in Nigeria, the country has been experiencing power energy shortages for over three decades now. More than 65% of the population lack commercial electricity, particularly in the rural areas. This has caused socio-economic problems involving relocation of manufacturing companies to neighbouring countries, unemployment, and endemic rural-urban migration. The research that underpins this paper aims to investigate the potential of Renewable Energy Technologies (RETs) in the provision of sustainable electricity in Nigeria's rural areas. This has been motivated by the strategic value of RETs in identifying when and where electricity is actually required thereby eliminating/reducing the high cost of gridline network and offering a more sustainable alternative to fossil fuels. A systematic review method has been used to examine various RETs regarding their viability and applicability in Nigeria. The sustainability of various RETs is then evaluated using SWOT analysis to screen the technologies to be used in an energy supply mix in Nigeria's rural areas. Biomass, hydro and solar sources are appropriate for use in Nigeria rural areas. The utilisation level of RETs in Nigeria is extremely low except for hydropower source. The major problems of RETs implementation are lack of implementable energy policy, government apathy towards development of RETs and the low purchasing power of majority of citizens. Further work includes the application of whole life costing (WLC) to assess and optimise the economic performance of the identified RETs.

Keywords: Nigeria, renewable energy technology, sustainable electricity, sustainability indicators, SWOT

INTRODUCTION

Due to the failure of the utility company Power Holding Company of Nigeria (PHCN) and fossil fuel system application for the provision of electricity in Nigeria, the country has been experiencing power energy shortage for over three decades, thus creating an unfavourable environment for both multi-national and local investors.

Nigeria is blessed with abundant conventional and renewable energy resources (see (ECN 2005) for details), but despite this, it is still unable to meet electricity needs of its citizens. Nigeria's power generation installed capacity was approximately 6500 MW in 2005 but 3959 MW was the only capacity available (Ibitoye and Adenikinju 2007) and this situation is yet to change. Furthermore, in the same period only 34% of Nigeria’s total population had access to electricity; this includes around 10% of rural

[1] a.garba@rgu.ac.uk

Garba, A and Kishk, M (2014) Renewable energy technology means of providing sustainable electricity in Nigerian rural areas - A review *In:* Raiden, A B and Aboagye-Nimo, E (Eds) *Procs 30th Annual ARCOM Conference,* 1-3 September 2014, Portsmouth, UK, Association of Researchers in Construction Management, 143-151.

communities; which constitute over 60% of total population (Ikeme and Ebohon 2005; Bugaje 2006).

The most disturbing situation is in the rural areas, where the power problems have subdued the local economy and prevented the development of cottage industries and businesses (Ikeme and Ebohon 2005). Although electricity access is not directly related to socio-economic growth but it is an impetus for development. The declining electricity access in the rural areas needs attention, namely through provision of sustainable electricity, otherwise the negative effects will continue to affect the inhabitants: increasing poverty level, endemic rural-urban migration, unemployment, health deterioration and depletion of forest biomass in the country.

According to Sambo (2009), fuel wood and charcoal (FWC) usage constitutes between 32%-40% of Nigeria's total primary energy consumption, with approximate annual consumption of 50 million metric tons of fuel wood alone. In addition, self-electricity generation is generally common in the country, and is projected to be between 4,000-8,000 MW, though this capacity may exceed the gridline source (Eberhard and Gratwick 2012). The reasons for this inconceivable condition of Nigeria power industry can be classified into technical factors (e.g. power generation stagnation, dilapidated power plants) or human factors (e.g. insufficient funding, leadership changes, electricity theft from ghost customers, non-payment of electricity bills by customers, corruption) (Adenikinju 2003; Sambo 2009).

Several government energy policies in Nigeria have targeted rural inhabitants in order to improve their energy access by subsidizing refined petroleum products at a cost of more than US$20 billion over the last three years. Unfortunately these policies didn’t attain their goals due to topography of some rural areas, diversion of the products by selfish marketers and poor road network. Furthermore, considering the cost of maintaining the grid network as a result of vandalism, alternative sources of power have to be sought with little or no transmission and distribution network as investors may not be willing to invest where there is low consumption and low income earners (Sambo 2009; Ikeme and Ebohon 2005; Kaundiya, et.al. 2009).

Nigeria electricity's sector problems, particularly in the rural areas may be mitigated through the adoption of alternative sources of electricity, such as renewable energy system (decentralized). This is because Nigeria rural communities' electricity demands are usually low. In addition, most RETs do not require gridline networks or transmission lines as electricity are generated close to the demand site. Hence, the aim of this research work is to investigate the potential of various RETs in the provision of sustainable electricity to Nigeria rural areas.

In the next section, RETs and rural electricity in Nigeria are discussed. This is followed by a critical review of various RETs in Nigeria with emphasis on their potential, utilization levels and constraints. Then, a SWOT analysis of major RETs is performed and presented. Finally, conclusions are drawn and further research work is introduced.

RET AND RURAL ELECTRIFICATION IN NIGERIA

The Majority of rural dwellers in Nigeria are low energy consumers and living below the poverty line of US$ 1.25/day (UNICEF 2011) with electricity requirements below 1MW and around 10% electricity accessibility; those who fit this description constitute over 60% of total population of the country. In line with economy and strategy reasons, both government and Independent Power Providers are finding it difficult to provide sustainable electricity to these communities. Although the government, through several energy policies, has expressed interest in providing electricity to these communities, reality suggests that it is unrealistic to do so considering the country's centralised energy system (dependent on fossil fuel sources) which will require gridline extensions to provide this electricity. Therefore, authorities have sought alternative and sustainable energy sources for rural areas in order to minimise rural-urban migration, which has put pressure on the cities' infrastructures, and encourage the development of cottage industries, thereby minimising current security and unemployment problems in the country.

RETs may be the one and only energy source that can provide sustainable electricity to Nigeria's rural areas considering the number of the villages, the distance between generation and demand centres, the economy of the gridline network and the energy insecurities as a result of unrest in the Niger Delta region. RETs present the strategic value of identifying when and where electricity is actually required, thereby eliminating/reducing gridline networks because of the closeness of generation to demand centres; they also can operate on smaller power scales and are more sustainable than fossil fuels. Capital costs may be high, but in the long term they are cheaper than fossil fuel sources. Furthermore, some RETs have laudable characteristics, such as zero fuel costs (e.g., wind and solar sources), benign environmental impact with little waste or pollutants, and no urban smog. However, there are several barriers to their utilisation, such as a lack of investments and expertise, inadequate policy framework (particularly in developing countries), high capital costs, intermittency of resources (mostly solar and wind sources), and the fact that they may lead to food crises, particularly if biomass sources are unregulated (Shunmugam 2009; Kaundiya *et al*. 2009).

RET RESOURCES UTILIZATION IN NIGERIA

Nigeria has abundant RET sources; however, only two sources are currently being used: hydropower and traditional biomass (Akinbami 2001). The following section will examine major RETs in Nigeria with a view to filter them for distributed application in rural areas.

Wind Energy in Nigeria

Wind energy technology has experienced significant global growth in the last decade, with its installed capacity doubling every three years (WWEA 2012). Unfortunately, this is not the case in Nigeria. The country is categorised under a poor-moderate wind regime, so, consequently, wind energy cannot be applied on a bigger scale except for irrigation and village electrification.

According to Ajayi (2007), wind energy resources are very poor in the southwest and south-south onshore regions of the country, but offshore areas of the same zones bound by the Atlantic Ocean have excellent wind energy resources. However, a lot of authors recommend its application for specific locations (Ojosu and Salawu 1990; Ohunakin *et al*. 2011; Ngala *et al*. 2007; Fagbenle *et al*. 2011).

Currently there is not an official record of significant wind energy application in Nigeria. According to Sopian et. al. (2011) 2.2MW of electricity has been generated by wind energy in Nigeria, but reality suggests that it has been abandoned due to the lack of maintenance and technical knowhow.

Other obstacles facing sustainable wind energy utilisation in Nigeria include the lack of a corresponding market, general apathy towards the development of wind technology, and poor budgetary allocation (Ajayi and Ajayi 2013 and Oyedepo 2012)

Solar Energy in Nigeria

Nigeria solar energy has capacity of producing 4.2 X 105 GWh of electricity/annum (Akinbami 2001). The solar potential is 27 times greater than that of the nation's fossil fuel sources (Augustine and Nnabuchi 2009).

Nigeria has commenced solar panel manufacturing with an annual capacity of around 7.5 MW. This will resolve the lack of technical knowhow and the high cost of imported solar panels previously witnessed in the country. According to Adeoti *et al*. (2001), it is possible to use solar energy to generate enough electricity to meet the needs of people throughout the year in all locations throughout the country.

Currently, solar energy systems are used in Nigeria for small- and medium-sized power applications including street lighting, domestic/office powering, water pumping, rural electrification, rural health centres (e.g., refrigeration of vaccines), powering of telecommunication boaster stations and ATM machines. For the appropriate development of solar energy technology, the following problems must be addressed: creating a reliable policy framework, reducing the costs of components, stopping the use of sub-standard components, strengthening the poor maintenance culture, and improving the lack of statistical data and capacity utilisation (Shaaban and Petinrin 2014; Mohammed *et al*. 2013; Oyedepo 2012).

Hydropower Energy in Nigeria

Nigeria has hydropower potential of approximately 14,735 MW, with waterways in excess of 3,000 KM. However, only 1,960 MW have so far been exploited, representing 14% of the total capacity (i.e., 1930 MW (Large hydro) and 30 MW (Small hydropower)) (Sambo 2009; ECN 2005). Currently, 150 MW of small- and medium-sized hydropower projects are on-going in the country, but more needs to be developed considering the potential.

Hydropower technology has been developed and used in Nigeria since the 1960s. In addition, no transformers, high tension lines, or reservoirs are needed for distribution if small hydropower is used. The displacement of inhabitants, however, is a major side effect. This can be mitigated through informed consent from local communities along with economic compensation.

Biomass Energy in Nigeria

Nigeria's biomass resources include agricultural residues, forest biomass, municipal solid waste (MSW) and animal dung. The country's vegetation arrangement dictates the availability of these resources. The major forms of vegetation in Nigeria are savannahs and forests, with the former occupying approximately 80% of Nigeria's total area (Sambo 2009; Akinbami *et al*. 2003). Substantial land areas are cultivatable in the northern part of the country where agricultural products, animal dung and modest quantities of fuel wood are produced, while large quantities of wooden biomass are produced in the south. Traditional biomass has proven to be an alternative source of energy to the scarce petroleum products despite the fact that Nigeria is a major producer of crude oil. The rate of consumption, particularly of FWC, is alarming, and there is a pressing need for modernising the use of this energy source to prevent depletion of the resources.

Nigeria biomass resources can generate electricity up to 68,000 GWh/year at 30% availability. However, biomass-effective supply chains and overall affordability will ultimately decide its viability for electrical generation. This is mainly because biomass resources have to be procured. In addition, residues, particularly forest biomass, have low density and low value, where transportation costs are high/energy units (Evans *et al*. 2010).

Geothermal Energy in Nigeria

There are two locations of geothermal energy that exist in Nigeria: Ikogosi warm spring and Wikki warm spring in Ondo state and Bauchi state, respectively. Similarly, the tendencies of high geothermal gradient are identified in the Lagos sub-basin, Auchi-Agbede, Okitipupa ridge and also the Abakaliki anticlinorium (ECN 2005).

The problems of this energy source include the lack of discovering of commercial proportion in the country and perhaps the lack of records. However, the situation may change if commercial quantities from this source are established, which may eventually allow it to be enlisted among the energy supply mix in the country (ECN 2005).

Ocean Energy in Nigeria

Nigeria is bordered by the Atlantic Ocean in the southern part of the country, with the coastline extending from Bakassi to Badagry with a distance exceeding 850 km. This gives Nigeria the opportunity to produce electricity using ocean energy technologies if the availability of the resources is confirmed.

The wave energy potential of the West African coast (including Nigeria) has the poorest resources in Africa, with an energy regime of 10 KW/m. According to ECN (2005), *"Nigeria does not seem to have significant tidal energy resources"*. However, OPEC (2004) estimated that Nigeria has 150,000 TJ/annum of wave and tidal energy resources.

Furthermore, even if Nigeria has adequate resources from this energy source, the technology is still developing, along with high capital costs, long gestation periods and low load factors. Hence, it is not commercially viable at the moment even at the global level, l*et al*one in a developing nation like Nigeria

ASSESSMENT OF RET USING SWOT ANALYSIS

Based on the data collected from the systematic review and the results of a pilot study, a SWOT analysis has been carried out to assess the potential of various RETs (see Table 1). This was followed by ranking various technologies according to various sustainability criteria to identify the best options for utilisation in rural communities. This is summarised in Table 2. Sustainability criteria included sustainable development objectives and resource criteria. This is because RET may not be sustainable if resources (e.g., water, materials, land) are constrained (Manish *et al*. 2006).

In ranking each technology, a scale of 1-3 is used to rate individual RETs in relation to each sustainability criterion used, with 3 and 1 being the highest and lowest marks, respectively. For example, where the RET resource is continuously available, it scores 3, while partly available is 2 and intermittently available is 1. As shown in Table 2, the total score of each RET was achieved by adding up these individual ratings (shown in brackets). These total scores are then used to rank various RETs

Table (1): SWOT analysis of RET

	WIND ENERGY		
STRENGTHS	**WEAKNESSES**	**OPPORTUNITIES**	**THREATS**
Reduces GHG emission by ~98% when	-Experience intermittency and idleness	-High turnover-US$ 75 billion in 2012 as	-Landscape distortion
compared with coal	-Good resource location restriction	as against US$ 3.9 billion in 2000	-Bird deaths and displacement
Major source of RET after hydro source	Many experience high transmission line	-Uses of flown turbines (Kites) as wind	-Noise
Cost competitive with fossil fuel source	cost because good resources are located	speed at jet stream are high	-Growth decline in the last 3 years
Zero fuel utilisation	far from energy demand centres	-Use of Aluminium conducting secure	-Installation error
Generally available	-Low energy efficiency (24-54%)	anchored in space generating wind power	
Contributing over 3% of global power energy	-Low capacity factor (21%)	Installed capacity doubling every 3 years	
Use in about 100 countries	-Cannot produce base load		
	SOLAR ENERGY		
-Reduces GHG emission by ~95% when compared with coal	-Experience intermittency and idleness	-Experience unit cost priced reduction (between 20-30%) in 2012 alone	-Removal of incentives in 2008 in some European countries such as Spain
-Extremely modular	-Most expensive among RET sources	-Proposed advance application of	-General policies uncertainties
-Require little/no maintenance cost	-Low energy efficiency (<22%)	satellite and ground solar farm (such as	-Saturation of local grids particularly in Europe
-Zero fuel utilisation	-Low capacity factor (19%)	satellite power system, Desertec)	-Market saturation
-Contribute around 100GW of global electricity energy in 2012	-Cannot produce base load		-Fierce competition (over 100 organisations closed up between 2011-2013)
-Generally available	-Deployment is quite small considering global		-A lot of Companies went bankrupt
-Highest global energy potential capacity (170,000 TWh/year)	potential		
	HYDROPOWER ENERGY		
-Reduces GHG emission by ~96% when compared with coal	-Partially intermittent especially tropical and Amazonian reservoirs	-Can be started and stopped at any time and are modular in nature	-Declining hydro dam construction because of resistance from habitats and pressure
-Largest source of RET (contributing over 16% of global total electricity generated in 2012)	-May be responsible for earthquake	-More new electricity generation from BRICS and other developing countries as witness in 2012	-Effect on biodiversity
-Cheapest form of RET/unit of electricity	-Location specific		-Effect on water quality and hydrological regimes
-Zero fuel utilisation	-Displacement of populations		-Climate change effect
-Most available, reliable and flexible form of RET	-Declining fisheries		
-Can provide base load and peak load	-Low energy efficiency (24-54%)		
-Most energy efficiency among RET (>90%)	-Partially Low capacity factor (20-70%)		

	GEOTHERMAL ENERGY		
-Continuous available energy source	-Resource tapping is unsustainable	-Electricity generation is expected to rise	-Rivers and lake pollution
-Has the highest capacity factor (>90%)	-Lowest energy efficiency among RET (10-20%)	because of improved technology	-Cause land subsidence
-Cost competitive with fossil fuel sources	-Growing capacity is low	(Enhanced Geothermal System) by 2015	-Operation can induce micro seismic
-Can provide base load and peak load	-Lowest global potential among RET		
-Can provide 17% of global electricity needs	-Location specific		
	-Low potential for further expansion–using convention geothermal technology		
	-Highest source of GHG emission among RET		
	(6 times that of wind energy)		
	BIOMASS ENERGY		
-Generally available	-Deforestation (as result of land-used expansion)	-Arid land plantation can increase soil carbon	-Could worsen global climate change
- Carbon neutral (Reduces GHG emission by ~95% when compared with coal)	-Application causes food price increase –Huge water utilization/KWh electricity (around 150-260 kg/KWh)	-Develop international policy mechanism for sustainable land use	-It is not naturally available (majority of the resources have to be sought)
-Good capacity factor (60-70%)	-Food usage for energy generation	-High priority to none/less land bioenergy	- Continuous expansion leads to displacement of
-Cost competitive with fossil fuel source	-Highest land utilization among RET	- Strengthen sustainability requirements and	communities
-Continuous source of energy		certification schemes	-Water scarcity
-Generate more employment than fossil fuel energy source/TJ energy	-Low return on investment when biomass is used for energy production		
-Good energy efficiency particularly if its gasification techniques (60-70%)			
	OCEAN ENERGY		
-Generally available	- Location specific	-Enjoying policy support particularly in Europe	-Experiencing pressure from environmental campaigners
-Energy potential more than humans' needs	–Low capacity factor (23%)	-Has no significant impact on environment	-Ecological concern
-Highly dependable and predictable	-Lowest total installed capacity among RET		-Effect on ocean wild life
–Continuous energy source	(only 0.53 GW in 2012)		
-Reduces GHG emission by ~95% when compared with coal	-Most expensive after solar energy form of RET/unit of electricity		
-Good energy efficiency particularly if its gasification techniques (60-70%)	-Faces Engineering challenges		

Table 2: Sustainability Indicators of RET in Nigeria Rural Areas

CRITERIA	Wind	Solar	Hydro	Geothermal	Biomass	Ocean (Tidal)
ENVIRONMENT						
Green house emission (g/kwh)	25 (3)	90 (2)	41 (3)	170 (1)	70 (2)	41 (3)
ECONOMY						
Price -cost/kwh (US$)	0.07 (3)	0.24 (1)	0.05 (3)	0.07 (3)	0.06-0.08 (3)	0.12 (2)
Energy Efficiency (%)	24-54 (2)	4-22 (1)	>90 (3)	10-20 (1)	60-70 (2)	55-75 (2)
SOCIAL						
Visual, displacement, Noise, Pollution, Seismic etc	Visual, Noise & Bird strike (3)	Toxins & Visual (3)	Displacement health, Agric & Earthquake (1)	Seismic, Noise, pollution, odour (1)	Food shortage, biodiversity loss, more labour used (2)	Effect on marine life, visual (2)
RESOURCES						
Water consumption(Kg/KWh)	1 (3)	10 (3)	36 (2)	12-300 (1)	150-260 (1)	28-40 (2)
Land use/TWh	72Km^{-2} (2)	28-64Km^{-2} (3)	73-750Km^{-2} (1)	18-72Km^{-2} (3)	462Km^{-2} (1)	73-750Km^{-2} (1)
Continuity of resources	Intermittent (1)	Intermittent (1)	Partly Intermittent (2)	Continuous (3)	Continuous (3)	Continuous (3)
Resources availability type	Location specific (1)	General (3)	Partly Location specific (2)	Location specific (1)	General (3)	Location specific (1)
OTHERS						
Nigeria potential (TWh/year)	1 (1)	17,702 (3)	58 (3)	NER (1)	225 (3)	41.7 (1)
Capacity factor (%)	21 (1)	19 (1)	20-70 (2)	>70 (3)	60-70 (3)	23 (1)
Total Score	**20**	**21**	**22**	**18**	**23**	**18**
Rank	**4**	**3**	**2**	**5**	**1**	**5**

Legend - Numbers in the brackets represent (scores), other numbers/statements are raw data;
Coal -GHG emission = 850-900g/kwh, Cost $0.042; NER-No Existing Record

Biomass energy has been ranked first with the highest total score of 23 followed by hydropower, solar, and wind sources with total scores of 22, 21 and 20 respectively. The lowest technologies are geothermal and ocean energy with a total score of 18 each.

These findings are in agreement with previous research (e.g., Shaaban and Petinrin 2014; Mohammed et. al. 2013; Sambo 2009) that RETs have the potential of providing sustainable electricity to Nigeria rural areas. Biomass is the way forward for providing sustainable electricity for rural communities in Nigeria without supply chain problems. This research will be the first to optimise subset of RETs in Nigeria with a view to be affordable to rural communities.

CONCLUSIONS AND THE WAY FORWARD

Nigerians are experiencing a dearth of electricity that is affecting their socio-economic standing, particularly in the rural areas. Causes of Nigeria's electricity problems include power generation limitations, investment pattern limitations, and the economics of gridline networks and infrastructures. Decentralized RET is recognized to be the solution because of its strategic benefits in identifying when and where electricity is actually required. Various RETs have been critically reviewed with a focus on their availability and level of utilisation in Nigeria. Nigeria has abundant renewable energy resources, particularly biomass, hydro and solar energy sources, with good potential for providing sustainable energy to rural areas in the country. The level of RETs utilisation in the country is low. The main causes are a lack of implementable policy framework, government apathy towards RETs development, and the low purchasing power of the majority of citizens. In line with sustainability assessment of RETs in Nigeria rural areas, the following energy sources should be adopted by order of priority for sustainable electricity: Biomass, hydro and solar sources; this should be supported with robust and consistent policy framework for implementation. Also, there is the need to correct the government's preference for fossil fuels over RETs as a source for generating electricity.

Further work includes the application of whole life costing (WLC) to optimize the economic performance of biomass RET within its whole life cycle rather than during the construction phase only. This will be reported in a future paper

REFERENCES

Adenikinju, A F (2003) Electric infrastructure failures in Nigeria: a survey-based analysis of the costs and adjustment responses. *"Energy Policy"*, **31**(14), pp. 1519-

Adeoti, O, Oyewole, B and Adegboyega, T (2001) Solar photovoltaic-based home electrification system for rural development in Nigeria: domestic load assessment. *"Renewable Energy"*, **24**(1), pp. 155-161

Ajayi, O O, and Ajayi, O O (2013) Nigeria's energy policy: Inferences, analysis and legal ethics toward RE development. *"Energy Policy"*, **60**(0), pp. 61-67

Ajayi, O O (2007) Modelling the Wind Energy Potential of Nigeria. Covenant University, Ota.

Akinbami, J K (2001) Renewable energy resources and technologies in Nigeria: present situation, future prospects and policy framework. *"Mitigation and Adaptation Strategies for Global Change"*, **6**(2), pp. 155-182

Augustine, C, and Nnabuchi, M (2009) Relationship between global solar radiation and sunshine hours for Calabar, Port Harcourt and Enugu, Nigeria. *"International Journal of Physical Sciences"*, **4**(4), pp. 182-188

Bugaje, I M (2006) Renewable energy for sustainable development in Africa: a review. *"Renewable and Sustainable Energy Reviews"*, **10**(6), pp. 603-612

Eberhard, A and Gratwick, K N (2012) Light inside: the experience of independent power projects in Nigeria.

Energy Commission of Nigeria and United Nations Development Programme (ECN– UNDP) (2005) Renewable Energy Master Plan: Final Draft Report. Available from: (http://www.iceednigeria.org/REMP Final Report.pdf) (accessed 22.02.14)

Evans, A, Strezov, V and Evans, T J (2010) Sustainability considerations for electricity generation from biomass. *"Renewable and Sustainable Energy Reviews"*, **14**(5), pp. 1419-1427

Fagbenle, R O *et al*. (2011) Assessment of wind energy potential of two sites in North-East, Nigeria. *"Renewable Energy"*, **36**(4), pp. 1277-1283

Ibitoye, F and Adenikinju, A (2007) Future demand for electricity in Nigeria. Applied Energy, 84(5), pp. 492-504

Ikeme, J and Ebohon, O J (2005) Nigeria's electric power sector reform: what should form the key objectives? *"Energy Policy"*, **33**(9), pp. 1213-1221

Kaundinya, D P, Balachandra, P and Ravindranath, N (2009) Grid-connected versus stand-alone energy systems for decentralized power—A review of literature. *"Renewable and Sustainable Energy Reviews"*, **13**(8), pp. 2041-2050

Manish, S, Pillai, I R and Banerjee, R (2006) Sustainability analysis of renewables for climate change mitigation. *"Energy for Sustainable Development"*, **10**(4), pp. 25-36

Mohammed, Y S *et al*. (2013) Renewable energy resources for distributed power generation in Nigeria: A review of the potential. *"Renewable and Sustainable Energy Reviews"*, **22**(0), pp. 257-268

Ngala, G M, Alkali, B and Aji, M A (2007) Viability of wind energy as a power generation source in Maiduguri, Borno state, Nigeria. *"Renewable Energy"*, **32**(13), pp. 2242-2246

Ohunakin, O S (2011) Wind resource evaluation in six selected high altitude locations in Nigeria. *"Renewable Energy"*, **36**(12), pp. 3273-3281

Ojosu, J and Salawu, R (1990) Wind energy development in Nigeria. *"Nigerian Journal of Solar Energy"*, **9**, pp. 209-222

Oyedepo, SO (2012) On energy for sustainable development in Nigeria. *"Renewable and Sustainable Energy Reviews"*, **16**(5), pp. 2583-2598

Sambo, A S (2009) Strategic developments in renewable energy in Nigeria. International Association for Energy Economics, **16**

Shaaban, M and Petinrin, J O (2014) Renewable energy potentials in Nigeria: Meeting rural energy needs. *"Renewable and Sustainable Energy Reviews"*, **29**(0), pp. 72-84

Shunmugam, V (2009) Biofuels—Breaking the Myth of 'Indestructible Energy'? Margin: *"The Journal of Applied Economic Research"*, **3**(2), pp. 173-189

Sopian, K, Ali, B and Asim, N (2011) Strategies for renewable energy applications in the Organization of Islamic Conference (OIC) countries. *"Renewable and Sustainable Energy Reviews"*, **15**(9), pp. 4706-4725

World Wind Energy Association (2012) World wind energy report 2012. WWEA: Bonn