HYBRIDIZING RENEWABLE ENERGY SYSTEMS IN NIGERIA: A CONTEXTUAL FRAMEWORK FOR THEIR SUSTAINABILITY ASSESSMENT

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ABSTRACT

Humans cannot do without one form of energy or another. Energy is needed to lighten our environment, power our homes, schools, hospitals, offices, businesses, and for industrialization. It is also a known fact that the economic growth of a nation depends on electrical power supply. However, Nigeria has severe electric energy supply problems. Various efforts made by the governments at addressing the problems including privatization of its energy agency are yet to yield desirable outcomes. This study considered independent municipal-based hybridized renewable energy supply system as a feasible alternative. This is premised on the fact that Nigeria is blessed with abundant sunshine all year round. There is also a large vegetative cover all over the country. Although there is no data on the amount and variability of wind in Nigeria, there is a belief that there is also a lot of potential for energy generation from wind. This article is assessing the possibility of hybridizing the various renewable energy sources in Nigeria and evaluating the sustainability of such hybridization. In this study we explored various sources for Nigerian biomass, solar and wind data. We are also examining efforts being made at utilizing these renewable sources for energy production in Nigeria. Furthermore, we are researching various attempts made to hybridize these energy sources for different types of application. We are assessing the sustainability challenges and benefits of hybridizing the various combinations of the renewable energy sources that are abundantly available in Nigeria. We are evaluating these combinations in order to determine the best combination for the region. The study is in progress and it is expected that we will be able to give a good picture on the sustainability of hybridized renewable energy production system in Nigeria.

Keywords: Hybrid energy system, Renewable energy, Sustainable energy.

INTRODUCTION

Humans cannot do without one form of energy or another. Energy is needed to lighten our environment, power our homes, schools, hospitals, offices, businesses, and promote industrialization. It is a known phenomenon that the economic growth of a nation depends on electrical power supply. While telecommunication market in Nigeria has recorded advancement and stability, the electricity market in Nigeria is faced with myriad of problems. These problems include slow growth in generation capacity, market deregulation process interference by government, electrical transmission lines and distribution equipment vandalism, poor maintenance of existing electrical facilities and corruption. These and other characteristics of Nigerian energy problems are illustrated in Figure 1. Nigeria should not be different from global electricity market trend which focuses on building a cleaner, more diverse and more sustainable energy mix. That is electricity market investment system that is of quality, affordable and of proven security. This paper focuses on the challenges facing sustainable electricity market in Nigeria and possible ways by which the nation can builds a sustainable electricity market.

Current Electric Energy Supply Situation in Nigeria

There are currently 23 grid-connected generating plants in operation in the Nigerian Electricity Supply Industry. Twenty of them are thermal while the remaining three are large hydropower plants. The thermal systems installed capacity is 8,457.6 MW while the three hydropower plants accounts for 1,938.4 MW of total installed capacity (KPMG, 2014; Vincent and Yusuf, 2014). Less than 50% of about 170 million people are hooked to the electric power supply system. Majority of the power generating plants are owned by the Federal Government while the rest are owned by some State Government and Oil and Gas Companies. Figure 2 shows the installed capacity and available capacity of each category of Nigerian energy generating power plants. Incessant vandalism of the gas pipelines and other problems highlighted in the previous section has made the average available power supply to be about 4000MW (Barber, 2014; Iwayemi, 2008; Oyedepo et al., 2012). 40 to 60 per cent of power generated is lost due to technical faults and inefficiencies in transmission and distribution, occasioned by inadequate investment and poor maintenance culture (Okere, 2015). This has made the distribution companies to rationalize power supply to the extent that some households and businesses receive only about 2 hours of electric power in a day. This situation has forced many businesses to invest in polluting diesel and petrol fueled electric generating sets. This has in turn caused increased cost of doing business, reduced productivity, inability of locally manufactured goods to compete with foreign goods, and folding up of some businesses. Furthermore, about 80 percent of the Nigerian rural population is without grid access at all. According to Barber (2014), "In many rural areas, "self-generation" using diesel generators is the norm, estimated at around 6,000 megawatts. In fact, Nigeria is reported to be world's largest importer of diesel generators." But a solution must be found to the problem. A credible solution will need to consider the nation's energy resources endowment and the extent of their utilization.

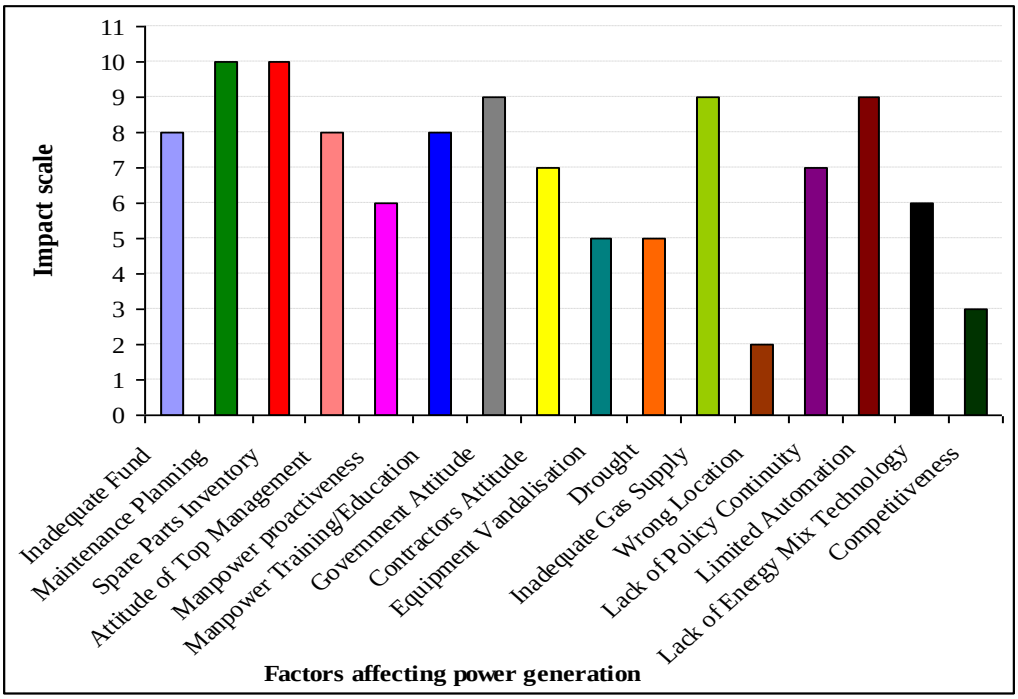

Figure 1 Ranking of Factors Affecting Power Generation in Nigeria
[Source: Emovon et al (2010). Power Generation in Nigeria: Problems and Solution]

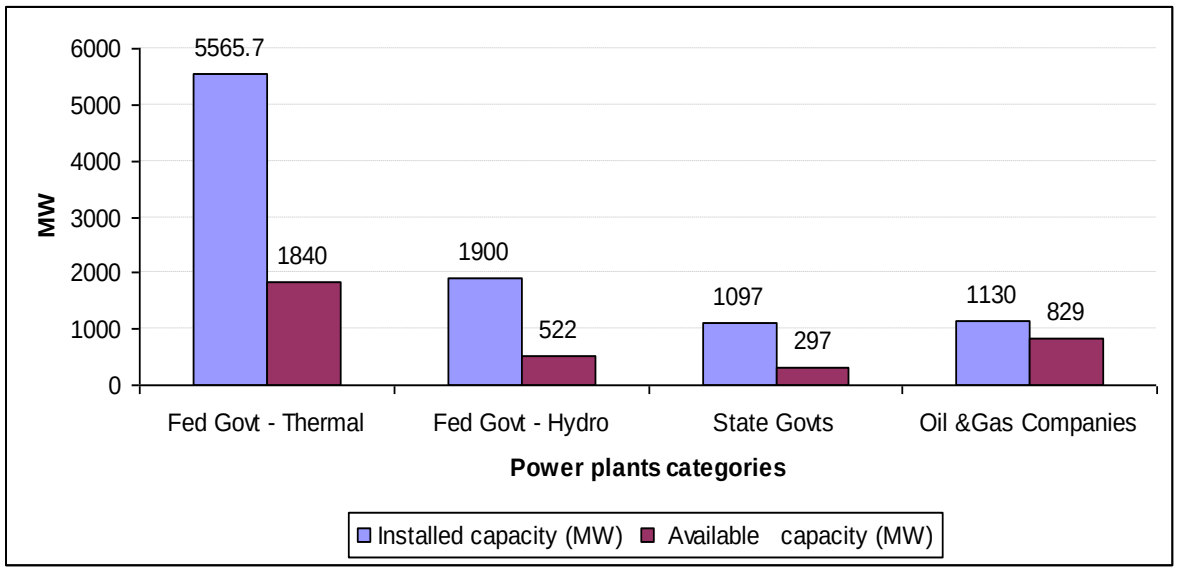

Figure 2 The State of Nigerian Electricity Supply System

Nigeria's Energy Resources Endowment

Nigeria is endowed with abundant energy resources. There are abundant varieties of both renewable and nonrenewable energy resources. For example, Nigeria is Africa's top fossil fuel producer and holds the world's seventh largest gas reserve [Barber, 2014). According to Iwayemi (2008), Nigeria has an estimated reserve of 35 billion barrels of crude oil, 185 trillion cubic feet of natural gas and 2.75 billion metric tonnes of coal. In addition, Nigeria, especially the Western region, is blessed with abundant renewable energy resources in the form of solar radiation, biomass, wind and significant body of surface water that could be harnessed for small hydro energy supply. It was estimated that Nigeria has 14,750 MW hydro resources, 3.5-7.0 KW/m^2 per day of solar radiation, 2.0-4.0 m/s wind energy at 150,000 TJ/yr and biomass at 144 million tonnes per year [Iwayemi, 2008]. Simonyan and Fasina (2013) estimated the Nigerian biomass resources from residues and wastes to be 47.97 MTOE. Despite these abundant energy resources, Nigerians are suffering from epileptic energy supply. What should be done to address the situation? Municipal based integrated electrical energy system from a mix of renewable sources is proffered as a suitable approach to solving the energy supply problem. Some of the questions that should be asked is will it be workable and will it be sustainable?

ENERGY SOURCES HYBRIDIZATION EFFORTS IN NIGERIA

Hybrid energy system refers to combination of two or more energy conversion devices/energy sources in an efficient way to ensure generation and supply of stable electric energy at a geographical location or region. There are several possible combinations that could be made. It could be a combination of a number of non-renewable energy sources, a combination of non-renewable energy with non-storage renewable energy sources, a combination of non-renewable energy sources with storable renewable energy sources, a combination of non-storable energy sources with storable renewable energy sources, or a combination of non-renewable energy sources, non-storable renewable energy sources with storable renewable energy sources. The bottom line is that the chosen combination should be based on the locally available abundant energy resources. However, the preference would be a combination of renewable energy sources. According to Lal et al (2011), "The concept of hybridizing renewable energy sources is that the base load is to be covered by largest and firmly available renewable source(s) and other intermittent source(s) should augment the base load to cover the peak load."

Currently, there is no widespread use of hybridized energy systems in Nigeria. Although the Nigerian Federal government is attempting to solve the energy crisis by the use of integrated energy system approach which involve a combination of non-renewable with renewable energy systems to provide grid energy supply. However, they are mega projects plagued with politicking and vandalism. There are also many state governments that have signed memoranda of understanding with local and foreign energy companies to assist with energy generation from renewable sources especially solar (Barber, 2014).

Moreover, a number of corporate organizations especially telecommunication companies are investing in hybrid energy systems in order to reduce their dependence on diesel fueled energy system that costs them about $53 million per month. For example, MTN Nigeria (a telecommunication company) currently have a number of hybrid energy infrastructure involving a hybrid of diesel fuel powered generating systems, solar power and batteries. According to Africatelecomit (2012), MTN Nigeria network has already connected over 250 low-cost solar powered Base Transmission Stations (BTS), covering 319 communities, where transmission has been provided using satellite mesh technology to optimise backhaul and guarantee latency of call. And, in line with its ongoing network modernization and swap-out exercise, additional 200 solar-powered base stations are expected to be integrated into their network soon.The company planned to have about 4000 sites on hybrid power system by the end of the year, up from the current 2,000 sites.

In the same vein, Airtel Nigeria (another telecommunication company) has also invested in solar-powered equipment. The company has solar power systems at 250 of its cell sites across the country. Furthermore, Hybrid Energy Solutions and Airtel, along with Hybrid's local partner called 'Eureka Power', are investing about $50 million to upgrade and optimise the power supply to Airtel's Nigerian network in order to provide an efficient, reliable and cost effective means of resolving the off grid and bad grid challenges that Airtel faces in Nigeria (Africatelecomit, 2012; Corcoran, 2013; Jern, 2011). According to Jern (2011), "the goal is to help the company cut down energy costs, ensure a reduction to a considerable level of CO_2 emissions and prevent network outages associated with inconsistent power supply."

Moreover, there are also a number of research projects by scholars on possible hybridization of some energy sources to solve energy problems in Nigeria. Some of the reported hybrid energy research projects in Nigeria include the work of Ani et al (2012) on "Energy Optimization at Datacenters in Two Different Locations of Nigeria". Using optimization approach, the group was searching for "the best" possible option from combinations of grid supply, diesel generator, wind turbine and solar photovoltaic cell power generation. Their results showed that grid is the best choice economically while Hybrid Solar-Grid power is the best from environmental point of view. Furthermore their results showed that the Datacenter could save (9,731kg; 8,536kg) of CO_2 emissions annually in Abuja (FCT) and Nkanu-West (Enugu State), respectively by removing backup Diesel Generators and by using Solar-Grid as a power source. Another work on hybrid energy was that of Anayochukwu and Nnene (2013). They were evaluating the suitability of solar - photovoltaic (PV) - diesel hybrid power generation system for Global System for Mobile communication (GSM) base station site. They made use of Hybrid Optimization Model for Electrical Renewables (HOMER) software. They evaluated savings associated with conversion of the diesel powered system to a PV/diesel hybrid power system. In another project, Anayochukwu et al (2013) examined the potentials of optimized hybrid system in powering off-grid macro base transmitter station site. Their goals were to assess the possibility of hybridizing the diesel generator source system with renewable energy sources and to demonstrate the possibility of utilizing renewable energies to reduce both the operating cost and the quantity of different air pollutants. Ekpenyong et al (2012) also reported a 1.5kVA hybrid power supply in Calabar (South Eastern Nigeria). The project also used HOMER software to model "a 1.5KVA grid connected solar power

supply system using a combination of PV array, charge controller, inverter, battery bank, A.C load and installation accessories which work complementarily to capture the best feature of the energy resources and provide the grid-connected location with the highest electricity network quality and reliability."

All these pilot projects revealed the potentials for improved energy supply from utilization of hybridization of energy sources. Reports on combination of renewable with non-renewable energy sources both grid-connected and off-grid projects showed that hybridization of various energy sources have a great potential in solving the long standing energy problems in Nigeria. However, none of these pilot projects have taken a holistic approach to assess the sustainability of such hybridization. This study examined the sustainability of the few existing hybrid energy projects, articulated potential challenges of hybrid energy systems development in Nigeria and suggests a pathway to developing a sustainable hybrid energy system in Nigeria

SUSTAINABILITY OF HYBRID ENERGY SYSTEMS IN NIGERIA

Sustainability is a concept aimed at achieving a "balance between human concerns (such as cost, health, comfort) and environmental concerns (such as resource use, ecological degradation) (Stanford University, 2005). So far, there is no formal sustainability analysis of the few existing hybrid energy systems in Nigeria. There are only some pronouncements by the few hybrid energy developers in Nigeria. Some of the statements include reports that the system has helped them reduce their energy cost, enable them provide stable services and reduce their carbon footprints. However, sustainability evaluation goes beyond vague attribution of a system's perceived benefits. There are some initiatives aimed at resources conservation like recycling that ends up having more negative impacts on the environment contrary to its intended purpose. The net impact would not be would not be observable without a comprehensive analysis of the system. It is therefore necessary to have a critical and quantitative analysis of hybrid system in a way that would enable stakeholders to have a good understanding of the extent to which the system is sustainable.

Assessing the Sustainability of Hybrid Energy System

To enable stakeholders have a good grasp of the extent to which the system is sustainable, the assessment of a hybrid energy system would need to be approached from a lifecycle perspective (Dunmade, 2010; Dunmade, 2014). It would have to start with identification of various stages in the lifecycle of the hybrid system and followed by articulation of appropriate evaluation criteria.These criteria can be divided into four broad categories, namely: technical, economic, environmental and social (Dunmade, 2002; Dunmade, 2014; Tugnoli et al, 2008). Figure 3 shows an articulated criteria and procedure for hybrid energy decision making in Nigeria context. A combination of conjunctive and simple additive weighting approaches would be suitable for the utilization of these criteria in the evaluation of the system at each stage of its lifecycle and for ranking various decision pathways which would culminate in the choice of an optimal pathway at the end of the process.

Challenges of Hybridizing Energy Systems in Nigeria

Although results of the few cases of hybrid energy supply projects showed great potential as a solution pathway to addressing Nigerian energy supply problem, there is a need to determine at what scale it would be sustainable. There is a need to identify what the potential challenges are what should be done to preempt the potential problem in order to ensure a smooth running of such infrastructure throughout its lifecycle. Understandably due to locational differences and differences in the characteristics of various combinations, it is impossible to identify all the problems that could be encountered in the course of developing and operating all types of hybrid energy systems. However there are some sustainability issues that would need to be considered regardless of

locations and peculiarity of combinations. One of the major challenges of hybridizing combinations of energy sources is how to integrate the system in a way that will ensure availability of sufficient amount of energy on a continuous basis. Another issue is ensuring that the system is simple enough in its design such that the system can be maintained and even upgradable by the locally available technicians.

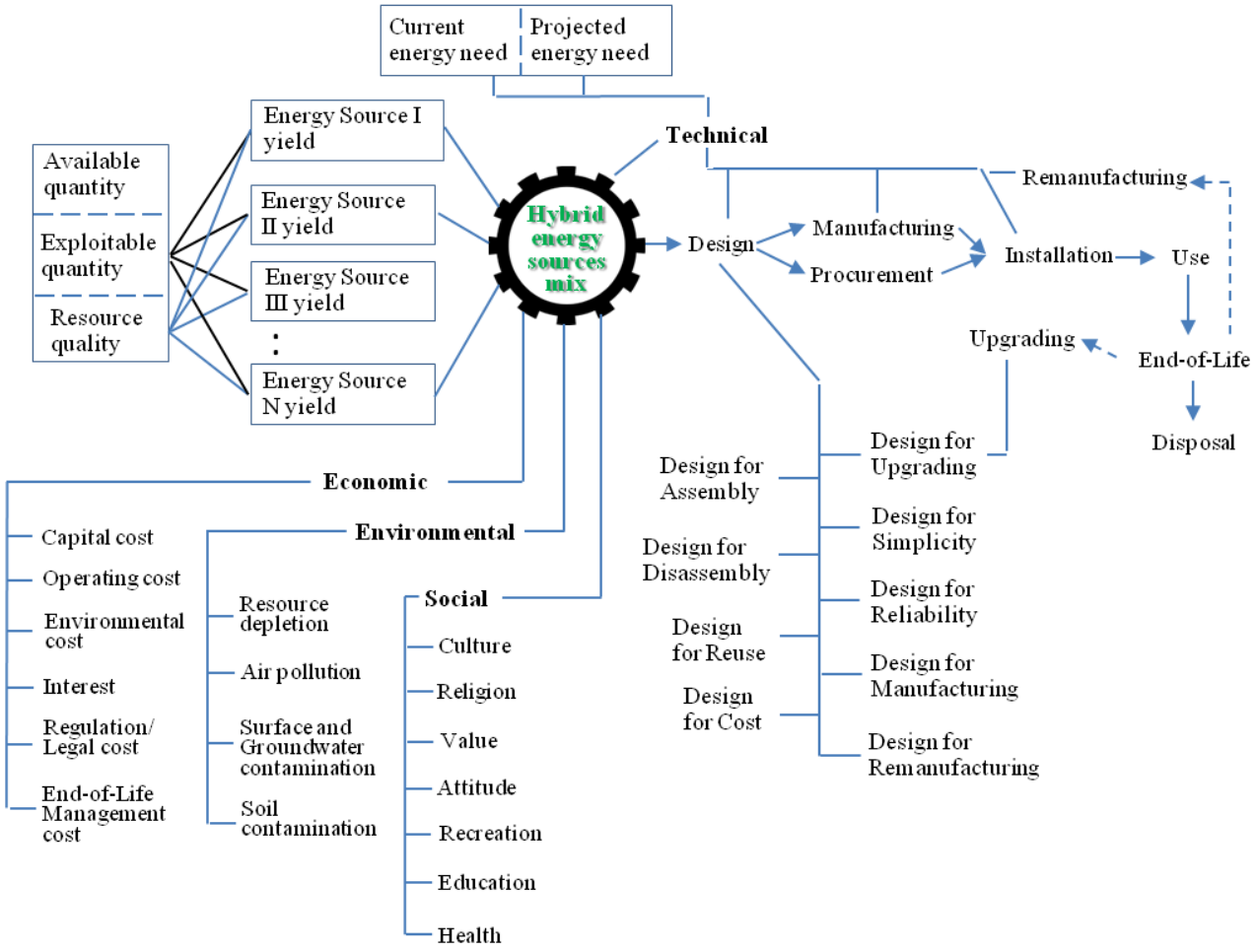

Figure 3 A contextual based criteria for hybrid energy development

Potential Benefits of Hybridizing certain Combination of Renewable Energy Sources

Although there are a number of potential challenges that are confronting sustainability of hybrid energy systems, there are several benefits to hybridizing renewable energy sources. One of them is the fact that it provides assurance of steady supply of energy because when one is not available in sufficient quantity the other one is available to compliment it. Another benefit is that since the hybridization is premised on the abundant local resources, the problem of depending on external supply for energy generation which could be disrupted by vandalism is eliminated. Furthermore, it can be utilized at remote locations and terrains where grid connections are difficult or expensive. In addition, such projects would require members of the local communities to provide requisite services for its operation and thereby boost business opportunities and increase employment in the locality which in turn would reduce rural urban migration. Moreover, steady supply of electric energy would eliminate the need for expensive and polluting fossil fuel powered generators and thereby reduce business operating cost, reduce idleness, increase productivity, enable locally manufactured products to compete on the market, make local businesses to flourish, increase employment opportunities, reduced social vices, promote peace and stability, reduce pollution that causes health problems, and improve standard of living.

CONCLUSION

This study showed that the development of hybrid energy systems in Nigeria is at an embryonic stage. Hybrid energy systems based on a mix of locally available abundant energy resources seems to be a good solution to the persistent Nigerian energy supply problem. However, it is necessary to get it right at the first time. Getting it right would require a balance of human concerns with environmental concerns. This study provided balancing criteria for evaluating the sustainability of a proposed or an existing hybrid energy system. The next stage of this study would involve case studies that utilized the set of proposed criteria in evaluating the sustainability of a number of hybrid energy systems in Nigeria. Hybrid energy systems investors, regulators, researchers and developers would find these criteria useful in their decision making regarding the choice of a hybrid energy system option from various options that are at their disposal.

REFERENCES

Africatelecomit (2012) *Africa Telecom & IT – NIGERIA*. Accessed on 17 March 2015 at http://www.africatelecomit.com/nigeria

Anayochukwu, E.A. and Nnene, E.V. (2013) Simulation and Optimization of Hybrid Diesel Power Generation System for GSM BaseStation Site in Nigeria. *Electronic Journal of Energy & Environment, 1(1)*, April, 2013.

Ani, V.A., Nzeako, A.N. and Obianuko, J.C. (2012) Energy Optimization at Datacenters in Two Different Locations of Nigeria. *International Journal of Energy Engineering, 2(4)*: 151-164

Barber, D.A. (2014) *Nigeria Moving Into Solar Energy to Spur Business Growth*. Accessed on 30 March 2015 at http://afkinsider.com/34905/nigeria-moving-solar-energy-spur-business-growth/

Corcoran, S. (2013) *Hybrid Energy Solutions signs deal with Airtel in Nigeria*. Accessed on 22 March 2015 at http://businessandleadership.com/exporting/item/43595-hybrid-energy-solutions/

Dunmade, I.S. (2002) Indicators of sustainability: assessing the suitability of a foreign technology for a developing economy. *Technology in Society 24 (4)*, 461-471.

Dunmade, I.S. (2010) Collaborative lifecycle design: A viable approach to sustainable rural technology development. *International Journal of Technology Management & Sustainable Development, 9(2)*, 149-158.

Dunmade, I.S. (2014) Issues in the sustainability of products designed for multi-lifecycle. *International Journal of Engineering & Technology 3 (1)*, 56-62.

Ekpenyong, E.E.; Bam, M.E and Anyasi, F.I (2012) Performance Analysis of an Installed 1.5kva Hybrid Power Supply. *IOSR Journal of Electrical and Electronics Engineering* 3(3), 20-27.

Iwayemi, A. (2008) *Investment in Electricity Generation and Transmission in Nigeria: Issues and Options*. Accessed on 12 February 2014 at https://www.iaee.org/documents/newsletterarticles/Iwayemi.pdf

Jern, S. (2011) *Airtel upgrades 250 diesel powered base stations in Nigeria with Flexenclosure's revolutionary 'green' energy solution E-site*. Accessed on 22 March 2015 at http://www.flexenclosure.com/airtel-upgrades-250-diesel-powered-base-stations-in-nigeria-with-flexenclosures-revolutionary-green-energy-solution-e-site/

KPMG (2014) *Overview of the Nigerian Power Sector: Industry Value Chain*. Korean Trade Delegation Advisory July 2014.

Lal, D.K., Dash, B.B. and Akella, A. K. (2011) Optimization of PV/Wind/Micro-Hydro/Diesel Hybrid Power System in HOMER for the Study Area. *International Journal on Electrical Engineering and Informatics 3(3)*, 307 - 325.

Okere, R. (2015) *BPE clarifies status of N213bn capital injection to power firms*. Accessed on 20 March 2015 at http://odili.net/news/source/2015/feb/12/4.html

Oyedepo, S.O., Adaramola, M.S. and Paul, S.S.(2012) Analysis of wind speed data and wind

energy potential in three selected locations in south-east Nigeria. *International Journal of Energy and Environmental Engineering 3:7 doi:10.1186/2251-6832-3-7*.

Simonyan, K. and Fasina, O. (2013) Biomass resources and bioenergy potentials in Nigeria. *African Journal of Agricultural Research 8(40)*, 4975-4989.

Stanford University (2005) *Guidelines for Lifecycle Cost Analysis – Land and buildings*. Accessed on 30 March 2015 at https://lbre.stanford.edu/sites/all/lbre-shared/files/.../LCCA121405.pdf

Tugnoli, A., Santarelli, F. and Cozzani, V. (2008) An Approach to Quantitative Sustainability Assessment in the Early Stages of Process Design. *Environ. Sci. Technol. 42 (12)*, 4555–4562.

Vincent, E. N. and Yusuf, S.D. (2014) Integrating Renewable Energy and Smart Grid Technology into the Nigerian Electricity Grid System. *Smart Grid and Renewable Energy 5*, 220-238.