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***Review***

# Challenges of sustaining off-grid power generation in Nigeria rural communities

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**ABSTRACT**

The erratic supply of power by Power Holding Company of Nigeria has not only forced the urban dwellers that are presumed to have more access to the electricity than their rural counterpart to the similar fate of the rural dwellers. This made some state governments to take shot in off-grid option with the assistance of the international community such as World Bank to provide electricity for remote areas where grid extensions were difficult to reach. Nigeria was not lucky like other nations in this adventure as monumental failure were being recorded than the success from the technology. The problems range from lack of planning, technology gap and operational challenges which are fundamental bases for the abandonment of many of off-grid power projects in Nigeria. This paper elucidates with clarity the remedies to these challenges such as proper planning before commencement of off-grid installation, government participation among others. It is belief that better result is ahead if the recommendations are considered by stakeholders of electricity in Nigeria.

**Keywords:** Off-grid technology, rural electrification agency, grid connection, rural communities.

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## INTRODUCTION

Off grid technologies offer affordable decentralized energy to homes, villages, dispersed settlements islets etc as Solar Home Systems, wind systems, biogas digesters, biogas gasifiers, micro-hydro power plants, etc. Alliance for Rural Electrification (2013), opined that this technology is the most adaptable, flexible and easy to use technologies for isolated communities, especially rural areas.

In the last decade, electrifying rural area with off-grid plant using renewable energy sources (RES) has become a common option for settlement where grid connection is neither available nor feasible in the near future (Rohit, 2013). The off-grid technology has been found very relevant and appropriate for the rural electrification project. Countries with many islets have been exploiting this technology due to the difficulties attached to operating a single main grid. East Asia and Pacific Countries have recorded a milestone in this technology. Nigeria has little islets (such as Bonny in River State, Brass in Bayelsa, Banana and Bishop Kodji in Lagos) but many villages that are sparsely distributed especially in the northern part of the Country. This necessitates the need for taken sort in off-grid option. As part of the Republic, every rural settler is entitled to the electricity irrespectively of location. According to Ajeiigbe et al, 45% of Nigeria has access to electricity, 10% of rural dwellers have access to electricity. In the same vein, Usman (2013), opined that Nigeria is the most populous black nation on earth, and despite its huge abundant natural resources, it is still one of the poorest in the world with an estimated Gross Domestic Product (GDP) per capita of $2,162 with 50 to 90% of current population of 170 million people living in rural areas lack access to electricity.

Efforts are often made to alleviate the condition of the rural dwellers but the program either ended in policy stage, lack of fund or abandonment of the project by the contractors. Consequentially, Nigeria has begun to see mass rural urban transit in the last two decades than ever before. Besides petroleum which account for over 80% of the National Revenue and GDP, the next resources is agricultural products. The World Bank (2010) reveals that the percentage of rural population in Nigeria significantly reduced from 76% in 1971 to 50.1% in 2009, largely due

**Table 1.** Nigeria population growth.

| Population parameter | 2011 | 2012 |
|---|---|---|
| Population density (people per sq. km) in Nigeria | 161.4 | 165.4 |
| Population in largest city in Nigeria | 9,466,458.0 | 9,831,147.0 |
| Population in the largest city (% of urban population) in Nigeria | 13.5 | 13.5 |
| Population in urban agglomerations of more than 1 million (% of total population) in Nigeria | 14.6 | 14.7 |
| Population in urban agglomerations of more than 1 million in Nigeria | 21,413,926.0 | 22,186,169.0 |
| Rural population growth (annual %) in Nigeria | 1.1 | 1.1 |
| Rural population (% of total population) in Nigeria | 52.4 | 51.6 |
| Rural population in Nigeria | 76,943,793.4 | 77,803,783.0 |
| Urban population growth (annual %) in Nigeria | 4.0 | 4.0 |
| Urban population (% of total) in Nigeria | 47.6 | 48.4 |

Source: World Bank 2012 Report (http://www.tradingeconomics.com/nigeria/population).

**Table 2.** Nigeria energy resources.

| Resource | Capacity | Remark |
|---|---|---|
| Large hydropower | 11,500 MW | Only 1972 MW exploited |
| Small hydropower | 3,500 MW | Only about 64.2 MW exploited |
| Solar | 3.5 kW/m/day – 7.0 kW/m/day | Refer to solar radiation map |
| Sunshine hours | 4 - 7.5 h/day | - |
| Wind | 2 - 4 m/s at 10 m height mainland | Electronic Wind Information disk (WIS) available |
| Biomass | Fuel wood | 11 million hectares of forest and woodland |

Source: Renewable Energy Development in Nigeria.

to rural-urban migration. The trend that follow suite in the 2011 and 2012 Nigeria population (Table 1). The population census revealed that most of the rural dwellers are subsistent farmers. These people are capable of putting a superlative performance out-put that will collaborate with government effort in food production if their villages are electrified.

One of the factors leading to dwindling of rural population is due to lack of social amenities many of which are powered by electricity. Although, the cost of supplying and maintaining electricity in rural area is high, off-grid power generation is considered most suitable in places where national grid extension is not feasible or not economical, in terms of bad geographical location and; if profit is not the objective. Although, this option has few associated challenges which include fuelling cost as for diesel/gas generating plant, maintenance of solar PV panel and charging of batteries; these amongst other made the option not economically viable. It is very clear from the report of Nigerian resources assessment data (Table 2) that energy resources are not Nigeria problem but how to exploit and harness it economically.

## THE OFF-GRID TECHNOLOGY

Off-grid mean not connected to the grid. Supply of electricity before reaching the end users normally passes through three stages: generation, transmission and distribution stages. Electric power could be generated by solar, water, biomass, thermal etc. the generated power when produced in large amount are not directly supply for consumers consumption, but rather first wheeled to “reservoir” from where it is transmitted for distribution which are used directly by consumers. This type of technology is refers to as “grid system”. On the other hand, off-grid technologies are objectively focused on manufacturing a required power for immediate consumptions. Off-grid electricity is commonly used for small community. At times it comes as a mini and micro grid. Apart from community, many individual has also resulted to the system without depending on the public utilities for electricity. Many Third World citizens have never had the chance to go on the grid. Current estimates data revealed that 1.7 billion people live off-grid worldwide (Perez, 2006). With off grid, individual is automatically become the power manager of his/her domain. But the effectiveness and efficiency of this option depends on the capability of the owners to maintain the facilities.

Grid extension is often the cheapest and easiest way to connect new users located not too far from existing networks and it is relatively easy to implement. Off-grid electrification, mini-grids or individual systems — is

suitable in remote areas which are unlikely to be connected to the grid in the foreseeable future, provided that sustainable supply is guaranteed (World Bank, 2010).

## OFF-GRID AND RURAL ELECTRIFICATION IN NIGERIA

The Rural Electrification Agency which is a product of the ESPR Act 2005 was inaugurated in 2005 to promote rural electrification in Nigeria; set up and manage the Rural Electrification Fund as well as to coordinate rural electrification activities in the Country. However, the agency was short lived, as it was closed down by the Federal Government. Unfortunately, the Agency has never achieved its responsibility before it was closed down in September 2009. The issue bothering on corruption was responsible for its closure. In late 2011, the Federal Government, directed opening and appointed a new MD for the Agency, Mr. Kenneth Achugbu. However, no provision was made for the body in the 2012 budget. In 2013 budget, a sum of ₦6,456,217,274 (FRN Budget, 2013) was voted for the body out of the ₦ 74,262,379,894 budgeted for the power ministry representing 8.69% of the total power budget.

Nigerian Rural Electrification exploits both grid connection and off-grid connection just like other nations' rural electrification project. Albeit, several factors usually determines the choice of the option of power generation technology, which include: geographical location of the settlements, security of the extension power line, cost of connecting with the national grid and availability of the energy resources in the environment; literatures revealed that most of Nigeria rural areas were connected to the national grid far more than off-grid power generation. The ₦ 33,849,634,011 (2013 Budget) proposed for transmission sub-sector which amount to 45.58% of total amount budgeted for power is a clear indication of the nation's choice of grid extension ahead of the off grid option.

Off-grid technologies which majorly has a link with the renewable technologies such as solar and hydro is not been pronounced in Nigeria like East Asia and Pacific countries (Papua, New Guinea, Solomon Island, Japan, China, etc). For example, Bangladesh, worked for over a decade with the World Bank, to install 1.4 million rural solar home systems (the figure as of mid-2012). Peru recently announced that the first phase of its national home electrification program will equip a half-million off-grid homes with PV (Roney, 2013). The dearth of electric power supply, high cost of connecting a dispersed settlement with national grid, recurrent vandalism of the transmission lines, and challenge of maintenance of distribution facilities such as transformers, ring main unit fuse (RMU) necessitate the provision of electric power through off-grid option for people living at remote far from national grid. This option is popular in developing and under-developed nations in which Nigeria is included. According to World Bank Energy fact, over 1.2 billion people (20% of the world's population) are still without access to electricity worldwide, almost all of whom live in developing countries. This includes about 550 million in Africa, and over 400 million in India. However, Indian is making a great leap to push this huddle behind them as they are curious of becoming a developed nation. The development recorded in the Country in the last one decade courtesy of information technology was based on the effort made by the government to electrify the nation's rural communities exclusively. These were not based only on the connection of the entire nation with the national grids but also building of mini, micro and stand alone power plants. This sterling option gives the Nation a better energy output.

Due to the insufficient power generated and supply to the national grid, and the geographical location of sum communities, building of the off-grid power generation becomes inevitable. This has being the practice across the world and most of these technologies are attached to the renewable and majorly supported by the international organization largely the United Nations. The United Nation commitment to renewable energy (off-grid especially) is not unconnected with their campaign for the reduction in the carbon and environmental pollution which is the major bye product of most of current power generation technologies. This among other reasons, made the United Nation Secretary General to lunch "Sustainable Energy for All" project in 2009

The erratic supply of power by Power Holding Company of Nigeria has forced the urban dwellers that are presumed to have more access to the electricity than their rural counterpart to the same fate with the rural dwellers. This reason made some state government to take shot in off-grid option with the assistance of the international community such as World Bank to provide electricity for some government services centers such as Hospital and some remote area within their states. However, it is pathetic, that most of these off-grid power generations such as solar PV power generations turned to waste of resources and subsequently sabotage the commitment of government. One of such cases was Solar Plant located at Onisowo Village Bishop Kodji Island, Lagos State.

This monumental failure in the off-grid technology prevents further investment in the technology by some state governments and private investors in Nigeria. In the past five years, only forty solar off-grid plant was put in use in Nigeria rural communities according the Rural Electrification Agency as shown in (Figure 1) (Achugbu, 2012). This is evidence that the technology is not working in Nigeria. In Malawi biomass and solar power were used to provide power for poor subsistence-farming households and schools in 321 communities with better performance results. The technology which is expected to

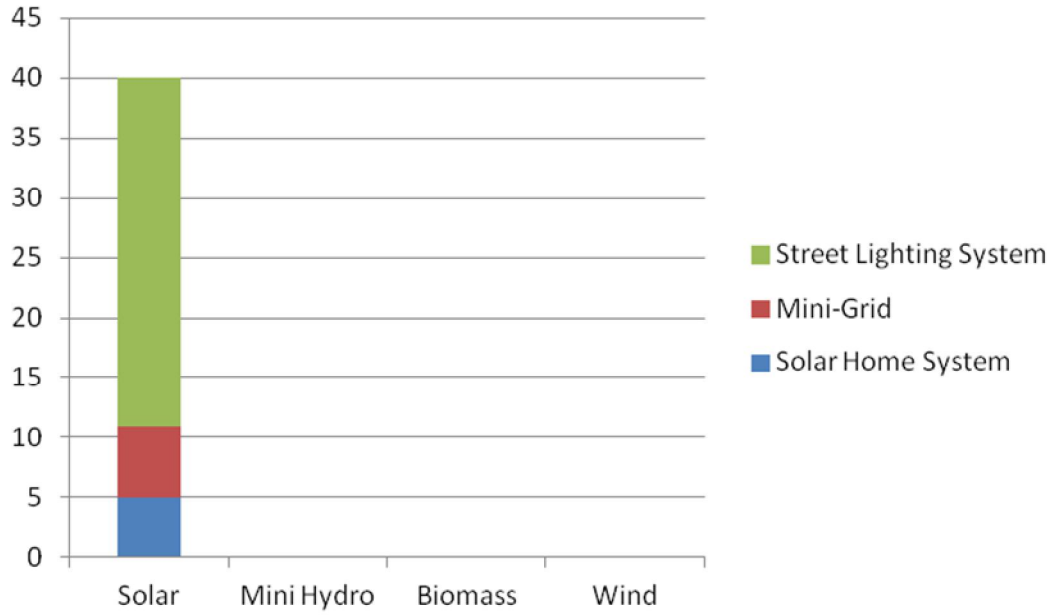


**Figure 1.** Nigeria Rural Electrification Agency 2006 -2009 Off-Grid Status. Source: Frame work for Off-Grid Power Generation: Status Report and Plan for 2013 – 2015.

bring a basic amenity and as well power that will support the infrastructures such as schools, health centers and pipe-borne water in rural areas had turned to mere experimental specimens.

The future of off-grid technology is still not defined in Nigeria. Despite the support receive from the international bodies on energy and relevant body for rural electrification, Nigeria is yet to have breakthrough in the using the technology. The pressure and condemnation that the past leaders received from the people may have formed the bases of some states governments not venturing into the technology. Within year 2011 and 2013, Osun State of Nigeria was said to have devoted a lump sum of ₦1,059,427,861 on rural electrification for about 77 projects across the village. The sum was spent on connection of the villages with national grids and maintenance of the bad distribution facilities (Faturoti 2012; Ige, 2013).

When Northern States were enlighten about the abundant solar energy resources in the region, many of them were motivated to generate power through solar PV, however, the monumental failure in the project discouraged many from continuing with the off-grid option. These failures were recorded in state like Sokoto, Borno, Nasarawa, and some Southern States like Bayelsa and Lagos. Sokoto State project was abruptly terminated and the people were advised to be patience until the government has muscle to musty the funding for national grid connection which would cost roughly $22million and take decades according to Alhaji Garba Umar Kyadawa, special adviser to the Sokoto State Governor on rural electrification (Omisore, 2011).

## CHALLENGES FACING OFF-GRID TECHNOLOGY IN NIGERIA

The current challenges and the likely ones that may still confront the usage of the technology are as follows:

### Lack of proper planning and designing challenges

The lack of proper planning is one of the reasons responsible for most of the failures recorded in the off-grid power generation in Nigeria. The success by other countries proved this. The diagnosis of the cases of some failures also attested to this. In the country like Bangladesh and Vietnam where off-grid option were considered for their rural electrification, better results were recorded. Planning and design proceed any sustainable off-grid power generation. This step goes beyond the type of technology to be utilized. Some rural communities are very rich in renewable energy resources but may not be economically viable. There could be abundant water and sun with government readiness to provide the off-grid facility but the community may not be matured enough to handle the maintenance and management of the facility provided by the Government. It is even worse when government or non-government organizations that installed the facility do not plan to handle the maintenance of the plant after commission. The consequence of which is abandonment of the project in a short while.

If planning is not properly done, execution of off-grid project may not stand a test of time. The incidence of the

Bishop Kodji Island in Lagos is an example. The project of 10 million naira (about $83,000) (Omisore, 2011) was eventually abandoned shortly after it was commissioned. It is often common in Nigeria that a government will just jump into an off-grid rural electrification project without blue print upon which the project will be run. The availability of the white paper will guide the execution and sustainability of the project. The most common off-grid technology in Nigeria is Thermal (diesel and petrol) generator. This option is costly, primarily due to the cost of running fuel. Although the cost of purchasing and technology of installation is very cheap yet its great disadvantages are cost of fuel and pollution of the environment from $CO_2$ released into the atmosphere. Failure to settle the means of fuelling most of the off-grid power plant at the planning stage made most of the projects unsustainable. However, it is pathetic that most of the off- grid projects that failed in Nigeria were due to the assumption on the side of the beneficiaries that government will take a full financial responsibility of what they consumes.

**Corruption**

Corruption is another impediment to the success of government on the off-grid power project. The 2006/2007 rural electrification project corruption saga is still fresh where about 1,946 projects were neglected (Okafor, 2012). Nigeria political holders do see Non-Government Organization's assisted fund (such as World Bank, United Nations etc) allocated for development including off-grid project as a way to compensate there cronies with a contract for the support enjoyed from them during their electioneering.

Some governments will commence the project toward the end of their tenures. The off-grid project inaugurated at the wee hour to the end of government tenures are usually for political reasons which is another way to siphon money for election through kick-back.

Most of the projects in this category are often left uncompleted and subsequently abandon after a change in government leadership.

**Political instability**

Political instability also poses a serious challenge to the off-grid project that depends on the government for operation. Most of the off-grid projects for rural electrification in Nigeria are often handle by the state government, some are provided by the United Nations, MGDs office in conjunction with the local government. Unfortunately, this people have eight or less years to be in Office. Some local government leadership because of the monitoring scheme put in place by the international donor/sponsor of the project ensures the delivery of the project but, after handing over, the United Nations sustainable power project turns to unsustainable power project due to lack of proper monitoring.

**Adulteration of the off-grid equipment and low off-grid technology**

A report from Compendium of Projects on Rural Electrification and Off-Grid Power Supply by German Society for Technical Cooperation, in 1993/94, revealed that the cost of Solar PV device was hardly a reflection of their quality. Among the most expensive devices, there were some of extremely poor quality, and several of the inexpensive devices belonged to the best quality achievable on the market today. Adulteration of the off-grid devices especially the mini/home in the market led to poor performance of some installed solar system in Nigeria. Most of the off-grid equipment ship to the country are of low quality and fake. Shortly after their commissioning, they stop functioning. Contractors are sometimes forced to shop for lower standard facilities in order to make profit as a result of large kick-back demanded from them by their client.

**Technology gap**

The challenge of low technology of off-grid is common to all African countries. The off-grid equipments produced in Nigeria are still at experimental stage. Such products if installed for people, only work for a while and then stop functioning. Government often refers to them as a project and part of their achievement but they are rather mere specimens. In July, 2013 Kyosera Solar Inc announced successful installation of 8.2 KW Solar Power PV off-grid at Colorado's Mountain. The device was the modules of the PV was adjudged to perform at 95 percent of their original rating in spite of the extreme environment at 8,500 feet above sea level, which involves the modules being buried under snow and enduring solar irradiance levels of roughly twice those of laboratory test conditions (Scottsdale, 2013). That is the technology gap that Nigeria must strive to close. Why in Nigeria, we have a Solar PV friendly climate yet most of installed solar PV Off-grid pack-up shortly after their installations.

## REMEDIES TO THE CHALLENGES OF OFF-GRID POWER GENERATION IN NIGERIA

**Proper planning**

The onus of proper planning of electrify rural communities is on the government. To make it simple, it can be decentralized along Federal, State and Local Government in Nigeria. At the planning stage, government

at all level should ensure that their planning cover the life span of the proposed project. It should be a long time vision for the sake of achieving the sustainability of the project. To achieve this, the planning committee should be set-up for each community where the proposed off-grid project is to be used. The committee should include technical personnel (or consultants), the sponsors (government or NGO representative), and the representative from beneficiary (community should be involved through traditional leaders). Involvement of the community provides more security to the sustainability of the project than leaving it in the hand of government representatives only. World Bank Group Energy Sector Strategy in its 2010 report shows that electrification programs benefit greatly from local community participation. Involving local communities from the start can help improve the design, gain local support, mobilize contributions in cash or in kind, and increase local ownership, contributing to operational sustainability. The committee is to conduct various assessments on the feasibility and sustainability of the project for a reasonable period of time. And this must, however, premise the commencement of any off grid project for rural communities. The result of this assessment will reveal the type of off-grid power generation that is most suitable for the community or the off-grid generation that will not work at all. The project feasibility study will also reveal the economic viability and market response of the electricity over the forecasted period of time. The acceptability of such development will be known through the planning work. All these and other outcome of the planning work will form the recommendation of the planners for further consideration. If all other factors are satisfactory, except market, government may be advised to subsidize at certain percentage for the community. The report of the planners will also decide either to proceed with the off grid technology or to go for grid extension.

Thereafter a critical assessment on type of the technology to be chosen, financial viability of the benefactor to handle the project till the completion, economic viability of beneficiary community, long time maintenance scheme and finally the ownership must be institutionalized and legalized. The planning work includes assessment of the productivity of the off-grid power infrastructure facility in the community. This is also a test of sustainability of the off-grid power unit in the community. The revenue generated from the market can be used to maintain the facility. Such that if the government even, abandons the supervision, maintenance and renege subsidy assistance, the people could easily form a forum who will oversee the project for sustainability.

Nigeria may learn from country like Bangladesh, who established a Rural Electrification Board (REB) with clearly stated planning, administrative, and business procedures. The Board (of Bangladesh REB) that provided electricity to 500,000 new customers every year in the Country (World Bank, 2010)

**Government positive passion for technology development**

Government should invest in technology through setting up of power institution and as well encourage the technology company such as Siemen, GE Energy, Goldwind, Vestas and Enercon in the Country. Nigeria needs to learn from country like China. In China Solar power industry has grown tremendously. China currently boasts of over 400 photovoltaic (PV) companies. In 2012 China installed 5.0 GW of solar panel capacity. As of 2012, about 8.3 GW of photovoltaic contribute towards power generation in China (Solar Power in China, 2013). These power companies who specialized in solar, wind, thermal and hydro that are mostly used for the off-grid power generation should be encourage to invest in Nigeria so as to develop Nigeria power generation competency and as well provide a sustainable power for people. Today roughly 60 percent of PV is manufactured in China but in a decade ago, the country produced almost none. Easy assessment to bank loans and government subsidies attracted investors to China Power Industry. This policy has help China to displace other pioneers of the technology such as United States (in 2006) and Japan (in 2008) and now number three in solar PV power generation after Germany and Italy. Another country on the same track with China is India (Roney, 2013). This process will lead to technology transfer and improvement in competency development which will invariably address maintenance problem.

**Subsidy of the tariff and government commitment to the sustainability**

The planners will need to find answer to the mean for the cost of the fuelling the operation of the grid. The management board may be completely different from the financiers. However, mean of financing operational services which includes the technical officer's wages, purchasing of fuel if the off-grid is diesel or gas, maintenance and repairs may either come from the tariff collected from the consumers (the beneficiaries) or benefactor, if the project is totally based on subsidy, government or international assistances would be responsible for the funding of operations of the off-grid.

However, from the past experience and government incongruity in their policies, it is not advisable for the beneficiaries to depend on the government subsidy to avoid abandonment of the project.

There may therefore be a need to hand-over the project to the private investor to manage while government agency (National Electricity Regulatory Commission)

regulates their activities. This does not in any way presume that government subsidy should be omitted. The economic viability of the community should determine the percentage of the government subsidy for such community. A community with about ninety percent people living below poverty line should be given a higher priority at the planning stage for subsidy. The government commitment to eradicate poverty in conjunction with the Millennium Development Goal agenda, calls for a serious government to focus on the achievement of this goal and rather forget about making profit from people living below poverty line. The percentage of the subsidy to be given by the government here, also underpin the importance of proper planning.

## CONCLUSION

This paper presents the current challenges and possible solution of off-grid power generation in Nigeria. The literatures revealed that most of the precautionary measures necessary before embarking on the off-grid project are often been ignored. It critically reviewed the extent of the failures and at the same time reaffirmed that proper planning before commencing any off-grid power generation is the best way of getting sustainable energy from the off-grid technology. If this is done, time and resources would be saved. More also, the effort of government in putting end to the dearth of power supply would be reflected and appreciated.

In addition, the paper also suggested that priority be given to grid power generation than off-grid except in a case where it is extremely difficult to do so.

### REFERENCES


Achugbu KC, 2012. Framework for Off-Grid Power Generation: Status Report and Plan for 2013 – 2015; Retrieved on 10th May, 2013

Alliance for Rural Electrification, retrieved from http://www.ruralelec.org/17.0.html on April 14, 2013.

Faturoti G, 2012. Retrieved on 16th April, 2013 from http://dailyindependentnig.com/2012/12/osun-completes-77-rural-electrification-projects-in-two-years-aregbesola.

Roney JM, 2013. World Solar Power Topped 100,000 Megawatts in 2012. Retrieved on 21st August, 2013 from http://grist.org/article/world-solar-power-topped-100000-megawatts-in-2012.

Okafor C, 2012. Nigeria: Rural Electrification Agency to Complete Abandoned Projects. This day Newspaper. Retrieved on 23/3/2013 from http://allafrica.com/stories/201209030108.html.

Ige O, 2013. Osun Awards N1bn Contract for 24 Rural Electrification Projects. Nigerian Tribune Published on 4th February, 2013. Retrieved on 19th August, 2013.

Omisore B, 2011. Nigeria's Solar Projects Yield Both Failure and Success. National Geographic News. Published November 2, 2011, retrieved on April, 15 2013. http://news.nationalgeographic.com/news/energy/2011/11/111102-solar-power-in-nigeria/

Perez R, 2006. USA Today, Home Power Magazine. Retrieved: April 15, 2013.

Rohit S, 2013; Off-Grid Electricity Generation with Renewable Energy Technologies in India; an application of HOMER. Retrieved on 3rd May, 2013.

Scottsdale A, 2013. KYOCERA Solar Modules Prove Long-Term Reliability in Colorado Mountains. Wall Street Journal, Published on July 31, 2013. Retrieved on 21 August, 2013 from http://online.wsj.com/article/PR-CO-20130731-911557.html.

Solar Power in China, 2013, retrieved on 21st August, 2013 from http://en.wikipedia.org/wiki/Solar_power_in_China.

Usman M, nd. Rural Solar Electrification in Nigeria: Renewable Energy Potentials and Distribution for Rural Development. Centre for Energy and Environment, Gusau, Zamfara State, Nigeria. Retrieved on April 12, 2013.

World Bank Energy fact.

World Bank Group Energy Sector Strategy in 2010.

World Bank Population Report, 2012. http://www.tradingeconomics.com/nigeria/population-density

World Bank, 2010, Addressing the Electricity Access Gap; Background Paper for the World Bank Group Energy Sector Strategy; June 2010.