# A SUSTAINABLE SOLAR POWER SYSTEM FOR THE UNIVERSITY OF NIGERIA, NSUKKA USING MICRO INVERTERS.

Nathan David
Senior Lecturer
nathan.david@unn.edu.ng
+234 8036686028
Department of Electronic Engineering
University of Nigeria.

## ABSTRACT

Nigeria is faced with a number of problems in the power sector, where about 50% of the population currently live without electricity, leading to a majority of 77% of the population relying on alternative power sources. These power sources are fuelled by petrol or diesel leading to a rise in the Carbon footprint through its emissions. In Nsukka, the average power consumption of electricity is about, 19,000 KW/hr., out of this the University of Nigeria consumes about 3,000KW/hr., though only a fraction of this power is supplied from the local power provider resulting in load shedding. The University due to a special agreement is given special consideration and receives a majority of this power with minimal load shedding paying as much as about $100,000/month. This deprives the local industries of power during the day, leading them to use alternative power sources thereby increasing their cost of production and making a negative impact to the environment through the carbon emissions. Harnessing solar power is a viable cleaner energy source where the economic and environmental impact of the solar powered system clearly reduces the carbon footprint, leading to virtually zero emission, clean and green sustainable system. However, the cost of this system is immense, with a major cost being storage with an estimated rate of $400 dollars per kilowatt hour (kWh). Taking this into consideration a design to set up a solar farm for the University using micro inverters is proposed that would be able to provide AC power during the day. Here, each panel, has its own micro inverter attached to the back side of the panel. The panel still produces DC, but is converted to AC on the roof, and is fed straight to the electrical switchboard. AC electricity is sent to the switchboard where it is directed to the various circuits and appliances in the University at the time. Any excess electricity produced would be sold to the electricity grid. The main objective is to reduce the Carbon footprint, as the power from the generation companies no longer required by the University during the day could be used to supply the local industries reducing their overhead cost of production while also being less dependent on fuel generators. The huge cost of power bills to the University would also be reduced, since the load is more during day, where the increased load of air-conditioning and lab equipment would be compensated. This system will ensure that the University over a period of time would eventually be self-sustaining in terms of its power needs producing a clean sustainable energy system.

## 1.0 INTRODUCTION

Like many developing countries in Africa, Nigeria has experienced a significant increase in its electricity needs as it is developing. Since coal is one of the sources of its energy for power generation. Its combustion process has led to an increase in pollution and environmental destruction (David, Abioye 2013). In Nigeria, electricity is in short supply where users are either connected to an overloaded national grid that is prone to erratic power failures, or not supplied power at all. For majority of the populace, the only alternatives are inefficient petrol or diesel generators that contribute to Green House Gas (GHG) emissions. In should be noted that 70% of the GHG emissions come from fossil fuel combustion from electricity generation (David 2017). Electricity losses abound in the transmission and distribution system of Nigeria's power network. Nigeria's power grid has a total transmission and distribution loss of 40% (Anumaka 2012). On average, the monthly cost for the fuel to run these generators adds an additional $48 to a household's bill. That is three times the cost of direct supply (NOI Polls, 2017). It is estimated that Nigerians spend about five billion dollars yearly to fuel their generators (Dogara 2017).

The erratic power supply and frequent outages in the electric power grid has compelled a large percentage of the populace to rely on petrol/diesel power generator as alternative means of power generation. These generators have sustained its usage as a reliable means of generating electricity in remote and grid isolated areas of Nigeria. Availability of fuel makes it an economic option. However, the avocation for the adoption of solar photovoltaic systems as an alternative source of electricity generation has gradually increased in Nigeria, due to its reliable, affordable and clean energy source.

As key pointer to economic prosperity and strength of a nation, power generation capabilities can at no time be understated. A nations access to a clean, sustainable and efficient (in all ramifications) electric power generation system goes a long way in determining that nations destiny. However, being products of nature ourselves it is only natural that our major sources come from nature itself (David et al 2013). In the modern world there is hardly a house, a street, a business or a transport facility that does not make use of electricity. Although electricity is often seen as a panacea for all environmental ills, a lot depends on how the electricity is generated (David, Abioye 2013). Solar power enhances energy diversity and borders against the price unpredictability of fossil fuels, thus stabilizing costs of electricity generation in the long term. The avocation for the adoption of solar photovoltaic systems as an alternative source of electricity generation has gradually increased in Nigeria, due to its reliable, affordable and clean energy source.

## 1.1 ELECTRICITY SITUATION AT UNIVERSITY OF NIGERIA, NSUKKA

Two urgent energy issues in Nigeria today are rural electrification and development of renewable energy sources. The University of Nigeria, Nsukka (UNN) consumes approximately 3000KWh, which amounts to about 26MWh annually. A survey was carried for a period of six months from January 10$^{th}$ to July 10$^{th}$ 2018 to determine the number of hours of power supply supplied to UNN, as shown in Figure 1. A similar graph illustrated in figure 2 shows the amount of power received between 8:00 - 17:00 hours, (sunshine period for the region). From the graph it could be clearly seen that there is indeed a dire need to support the grid supply with an alternative source of energy.

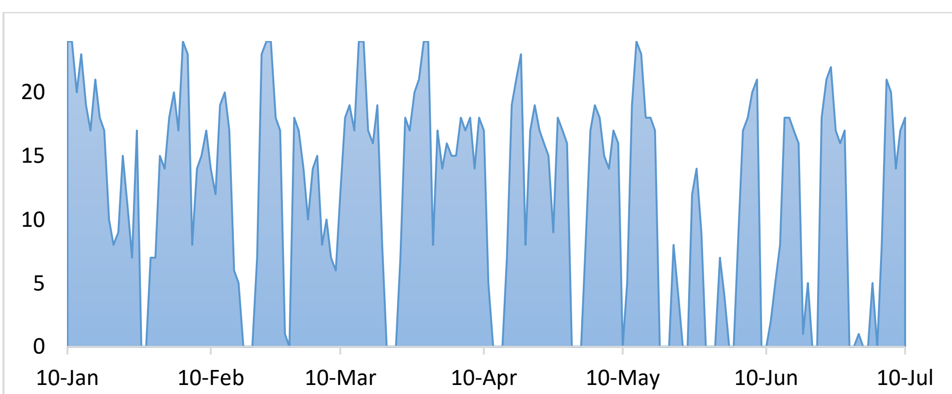


*Figure 1: Number of hours of electricity supplied daily for the period 10/01/18 -10/07/18*

Total number of hours of supplied electricity = 2200 hours
Percentage of electricity supplied = 50%

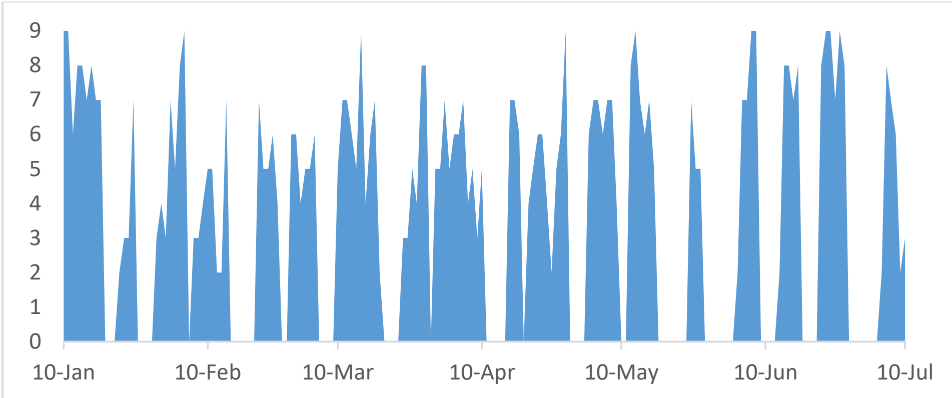


*Figure 2: Number of hours of electricity supplied between 0800hrs – 1700hrs (10/01/18 -10/07/18)*

Total number of hours of supplied electricity between 0800hrs and 1600hrs = 675 hours
Percentage of electricity supplied = 41%

It could therefore be observed that UNN receives approximately only 50% of electrical energy from the National Grid, approximately 13MWh annually. A similar study was done in 2015 and there does not seem to be much improvement in the Electricity supply (David 2015). Therefore, with the evident erratic power supply, the necessity for an alternative power supply is a necessity; UNN uses Diesel Generators therefore, increasing the Carbon footprint. The cost of running these generators averages about ₦ 15 million per month.

The University is a major consumer of electricity for the Nsukka region and since the electricity provider is a beneficiary from this consumption in terms of financial payments, special consideration is given to ensure the demand is met.

However, a major hindrance to the poor electricity supply apart from the general problem's facing the country is the corruption factor. In this case, staff of the University collide with the power officials to ensure that there is an irregular supply of electricity. This is attributed to what is commonly known as 'diesel runs'. Since it is mandatory for the University to have electricity for certain periods of the day, the general power supply is often cut during these periods in order to ensure that there is a steady flow of diesel.

In the process of providing electricity to the University, the drawbacks are that the local industries are hit by inconsistent supply and very often have to revert to carbon emitting generators to fill in the void. In addition to increasing the carbon footprint, their overheads too are increased which is thrown onto the consumer thereby creating inflation.

## 1.2 LOCAL INDUSTRY POWER SUPPLY

In September 2017 a survey was carried out and involved interviewers with 3 broad categories of respondents; Traders, Customers and Residents, thus enabling a rounded view of current performance from key actors within these categories (REA 2017).

The socioeconomic surveys used a random sampling across all cluster sections to assess the current state of affairs in the markets from a variety of users of the space. Census surveys were carried out for the Energy Audits, as all shops within the project scope were enumerated. The enumeration was carried out in this manner in order to accurately capture generation, consumption and energy demand data. The analysis of captured data allows for reliable recommendations for the most suitable energy solution for each of the economic clusters.

From the markets surveyed, the expected power requirement is approximately 4.3MW, however over 70% of these traders use alternative sources of energy, these are fuel generators that produce carbon emission's raising greenhouse gases. About 50% of traders suggested that they would expand their shops if they were given a reliable power supply as shown in figure 4.

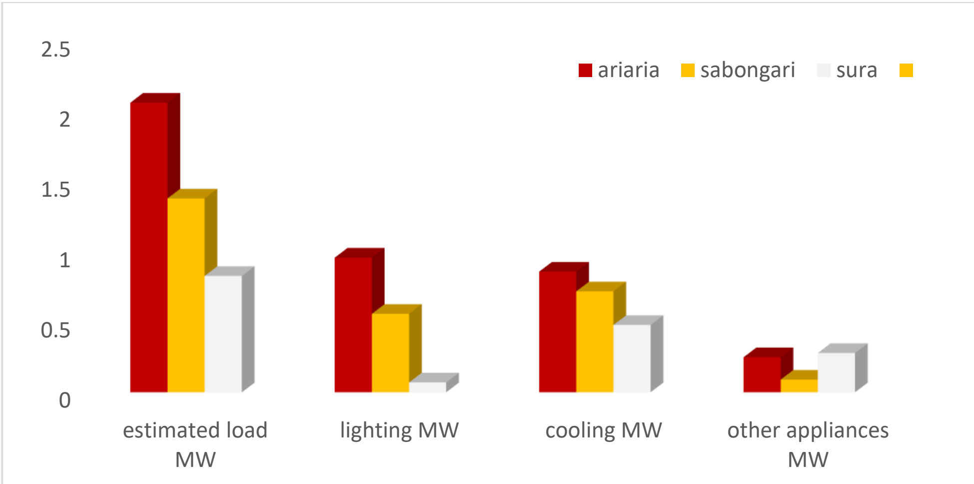


*Figure 3: Energy audit for the three markets*

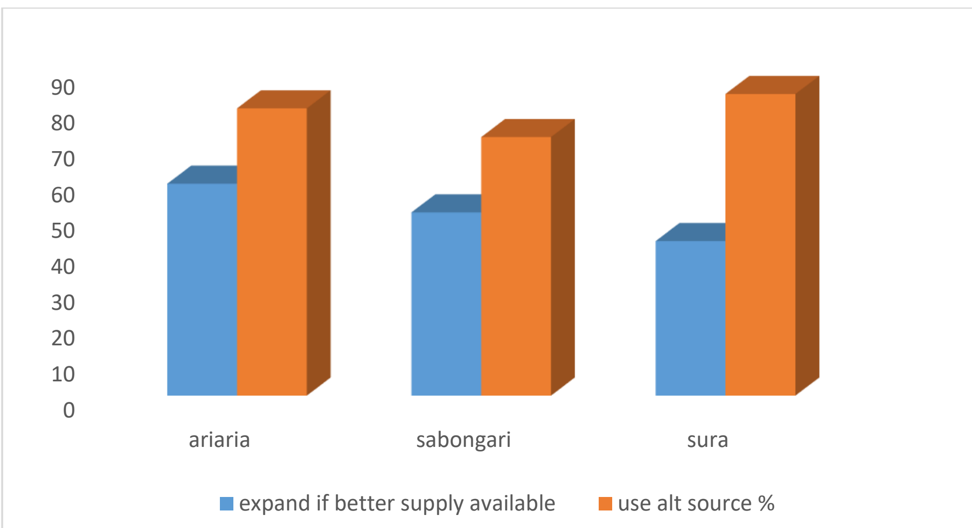


*Figure 4: Energy effect on the three markets*

The Rural Electrification Agency (REA) in Nigeria, has developed an Off-Grid Electrification Strategy with the primary objective of increasing electricity access to rural and undeserved areas (REA 2017). This strategy is designed to complement the national grid supply by developing a decentralized approach to power generation. However, this would come with an added cost which would be spread across the consumers.

A study conducted for the market at Nsukka town show that majority of the shop owners use electricity for illumination while a few for refrigeration. On the other hand the timber shed in Nsukka have to rely on generators daily for their machines. A number of other small scale entrepreneur's also rely on generators for their work. The cost of running these generators is then spread on the customers creating inflation.

It is obvious that the cheapest source of electricity is from the grid. It is therefore the interest of this study for the University to complement this cost so as to enable small entrepreneurs have a cheaper source of electricity, which would increase their productivity and processing thereby reducing inflation. Majority of these identified consumers require power between 0800hrs and 1700hrs; and from figure 2 we have observed that the supply to the University is only 41% of the demand. The University is in a better position to go Green as it is easier to absorb the financial implications than throw it onto small scale enterprenuers.

Solar electricity is therefore an appealing solution since there is no need for fuel and little need for maintenance. This energy is widely available and can contribute to reduced dependence on energy imports, as it entails no fuel price risk or constraints, it also improves security of supply. Solar energy has constantly helped in decreasing the greenhouse effect and global warming.

## 1.3 ENERGY EFFICIENCY CHALLENGE

It has been illustrated that the energy supply at UNN is insufficient relative to the demand. Hence, this limits the productivity of staff as well as students. For instance, in an office/classroom where major dependency for power supply is on the grid, when there is an interruption of power supply, either of these two scenarios take place:

- A Diesel generator is turned on which incurs more cost in addition to increasing the Carbon footprint
- There is no available generator which leads to lectures being conducted without any interactive or multimedia system, lack of Internet etc.

In the case when generators are turned ON for lectures/practical, students are often surcharged for the cost of the fuel for the stipulated period. This procedure that is very common leads the students to feeling exploited. During the night, in the absence of electricity from the grid, the University provides electricity by running generators and provide electricity to ONLY student's hostels between 1900hrs and 2200hrs. From 2200 hrs till daybreak the hostels are in darkness and students are left to fend for themselves. It is therefore imperative that an alternative source of electricity be provided for a conducive studying environment. Only two departments at UNN currently use an alternative source of energy out of about 64 departments, with a third currently setting up a 40KW system. It is also increasingly becoming popular in residential areas where a number of staff have installed smaller systems ranging from 1KW to 2.5 KW systems. These systems are standalone systems and are limited to the amount of storage capacity which is a major contributing factor that limits the system to low energy consuming devices.

## 2.0 OVERVIEW OF UNIVERSITY OF NIGERIA, NSUKKA

The University of Nigeria is located at Latitude 6.8683 and Longitude 7.4093 with an approximate elevation of 550m. It receives ample sunlight all around the year. The solar PV modules could easily be installed on the roof tops of the existing buildings, and also be integrated with new buildings. The University has enough surface area to encompass these panels with NO effect to the environment.

Each Faculty at UNN has its own building complex that would be able to house all the necessary equipment required to install the required energy source. At present the Faculties are run on 100KW Diesel generators with the Administration building and students hostels with a 500KW diesel generator. However, many of these generators are not run regularly due to the absence of diesel or run for a brief period. During the periods that these generators are run a number of heavy appliances, (there are exemptions), are not powered to reduce the overall load.


*Figure 3: Aerial view of University of Nigeria, Nsukka (excluding staff quarters) © Google maps*

The principle of solar systems is quite simple as it consists of solar PV modules connected in series and parallel depending on the specified configuration. Theoretically, in order to set up a system of 100 KW we would require 400 panels of 250 W each; a 250W module occupies 1.6m$^2$ of area, so 1.6m$^2$ * 400 = 640m$^2$. Figure 3 shows an aerial view of the University excluding the staff residential quarters that has a surface area of over 6 km$^2$. It could also be observed that majority of the buildings are not obstructed by trees and are ideal to place the panels, minimizing the impact on the environment.

## 2.1 OFF-GRID OR STANDALONE RENEWABLE ENERGY SYSTEMS

Stand-alone systems are renewable energy systems that are not connected to the electricity grid. Stand-alone systems are more cost effective in isolated areas than extending a power line to the electricity grid which is more expensive. A successful stand -alone system reduces cost, minimizes inconvenience by taking advantage of a combination of techniques and technologies.

In addition to buying photovoltaic panels, there is need to invest in additional equipment called "balance-of-system". The equipment could include, batteries, charge controllers, safety equipment etc. However, in order to install a small renewable energy system, reducing the electricity loads is a necessity.

## 2.2 GRID CONNECTED INVERTER

Multiple solar modules connected in series and parallel provide 200 - 400 V output and 10 – 50 A. Combination of these panels are then connected to a single centralized inverter to yield the output voltage of 110/220VAC at medium power levels. Since the system is connected to the grid power lines, it is therefore known as a Grid tie Inverter system.

In this option the customer utilises the power that he requires and excess power not used is sold back to the power company during the day. This power is then bought back from the power company during the night. The grid connected inverter is an option when a costly storage system is not desirable. The Cochin International Airport in India stepped into tapping of solar energy with the commissioning of 1.1 MW solar plant in 2013 and it was the first MW scale solar power plant in Kerala. The airport has been operating green since the solar system was fully operational producing as much as 12MW of electricity (Sreenath & Sudhakar 2017).

## 3.0 MICRO INVERTERS

A solar micro-inverter, is a device used in photovoltaic systems to convert direct current (DC) generated by a single solar module to an alternating current (AC). They contrast with conventional inverters, which are connected to multiple solar modules or panels of the PV system and are used to generate electricity that is supplied to the electricity grid. In this process, electricity generated through solar system is fed into the consumer's line while excess electricity not consumed is 'sold' to the electricity grid. This electricity is then 'sold' back to the consumer when there is no sunshine. In a majority of cases the electricity; bills are reduced enormously.

Micro inverters have several advantages over conventional inverters. The main advantage is that small amounts of shading, debris or snow lines on any one solar module, or even a complete module failure, do not disproportionately reduce the output of the entire array. Each microinverter harvests optimum power by performing maximum power point tracking (MPPT) for its connected module (Zipp 2011). Simplicity in system design, lower amperage wires, simplified stock management, and added safety are other factors introduced with the microinverter solution.

The primary disadvantages of a micro inverter include a higher initial equipment cost per peak watt than the equivalent power of a central inverter since each inverter needs to be installed adjacent to a panel (usually on a roof). This also makes them harder to maintain and more costly to remove and replace.

Typically, micro-inverters are a sub classification of the small inverter classification and range in output power of 100W to 350W. This is the typical range of output power for a single solar panel module.

## 3.1 SOLAR FARM

Solar farms have no storage thus a solar farm is totally dependent upon the sun to supply power directly to the inverters. There is a misconception that a solar farm cost more than a coal fired, diesel fired or nuclear power plant. This is not true. When you take the cost of fuel out of the calculation and high cost of a coal fired power plant a solar power plant cost less and it more reliable than any other form of electric power generation. The next best thing is a hydro power plant. The water behind the dam is stored energy, same as a bank of batteries (Gozuk 2017).

## 3.2 DESIGN OF THE SOLAR FARM USING ENPHASE MICRO INVERTERS

Solar panels may be on top, but it's the inverter that does all the real work, therefore choosing an inverter technology is the most critical decision when going solar. Taking into consideration the average demand for electricity daily and the process of developing an alternative power source, a simple design using Enphase micro inverters is proposed. These are suitable for small estimated loads; table 1 shows a costing for a 334 Panel 100 KW Enphase Solar System which would cost about $95,000 (Enphase 2018).

These micro-inverters have significantly improved the safety of installing a solar panel system by generating standard AC power instead of dangerous DC power. They have a plug and play feature with each solar PV module connected to it forming an AC solar module with inbuilt MPPT and are usually connected to the AC line eliminating DC cable loss, thus improving system efficiency. The plug and play feature allows one to have as few or as many panels as you like and to easily expand the system later. Installation is simplified allowing the monitoring of each module independently. Since each panel is an individual system they maximize the power output from each panel resulting in an average 15% increase in power generation per panel.

Briggs suggests that applying high power solar modules to micro inverters leads to greater lifetime performance, lower installed cost per watt, and ultimately, the highest return on investment for the end-customer (Briggs et al 2012).

*Table 1: Cost of setting up a 100 KW solar system using Enphase IQ7 micro inverters*

| ENPHASE 100 KW Solar Sytem | | | | |
|---|---|---|---|---|
| Component | Quantity | Cost | Ext Cost | |
| Enphase IQ7+ | 334 | 124.00 | 41,416.00 | |
| Enph Trunk Cable Port | 24 | 13.10 | 314.40 | |
| Enph Branch Endcap | 24 | 14.20 | 340.80 | Assuming 24 strings |
| Enph Envoy Gateway | 1 | 420.00 | 420.00 | Works up to 600 Micros |
| 300 W PV Panels | 334 | 140.00 | 46,760.00 | |
| Miscellaneous | | | 5,000.00 | |
| **TOTAL** | | | **94,251.20** | |

It is the intention to set up a number of 100KW installations across the Faculties in the University to supplement the irregular supply of Electricity. Energy not consumed could be sold back to the grid. It should be noted that out of the 3000KW energy requirement, half of this is supplied to the staff residential areas and hostels. So, the design is looking at setting up a solar farm using micro inverters with the combined capacity of approximately 1500 KW to supply uninterrupted power to the administrative and academic areas. Other areas not covered initially could later be incorporated and benefit from the system as it grows.

The system would be in use from 0800hrs 1700hrs, the period the sun is up. During this time the electricity from the grid could be diverted to the market and the small scale entrepreneurs who would benefit immensely from the supply of electricity. This would also curtail the use of fuel generators thereby reducing the Carbon footprint. There is also a provision whereby if storage is required at a later stage it could easily be implemented.

## 4.0 CONCLUSION

Currently, there is a view that grid-extension is a large risk to off-grid energy enterprises. However, clearer policy around grid interactivity could make off-grid solutions a way of supporting the grid. Given the right incentives and policy environment, off-grid energy can become an important component in the overall energy selection rather than being seen as only a stop-gap solution.

The setting up of solar farms at the University of Nigeria would allow the diversion of electricity from the national grid to supply the market and other small scale entrepreneurs in Nsukka during the working hours. Traders in the markets surveyed strongly expressed a willingness to pay for reliable energy due to the high cost of self-generation. Their observations included concerns centered on the negative health impacts caused by noise and air pollution resulting from self-generation. They however did express concerns that reliable supply might increase the overall rent of their stores.

The University needs a stable electricity supply during the day to enable the running of offices and laboratories. The excess electricity could be sold back to the grid which would complement the period during which the University uses electricity from the grid. This would be during the night, the same time that the markets would be closed for the day. The impact of power supply improvements on the social and economic life of the University community as well as the traders is enormous. These impacts are measured and objectives achieved by increasing the standard of education as well as trade volumes, allowing greater participation of vulnerable and less active groups, and most notably, extending the productivity at the markets.

Whosoever invests in solar is looking for one of two things: keeping energy costs down and reducing their impact on the environment. The great thing about solar is: no matter the motivation, installing solar does both of those things.

The huge cost of power bills to the University which ranges around $100,000 per month would be reduced, since the major load is during day. At night the overall load is decreased as the climate tends to be cooler reducing the load of air-conditioning. This system will also ensure that after a given period the cost of the solar farm would be recovered in terms of reduced bills and would eventually be self-sustaining in terms of its power needs producing a clean sustainable energy system.

**REFERENCES**


Anumaka, M.C., "Analysis of Technical Losses in Electrical Power System (Nigerian 330kV Network as a case study)", International Journal of Research and Review of Applied Sciences, pp. 320-327, 2012.

Briggs, David; Williams, Dave; Steele, Preston; Reed, Tefford; Bigger is Better: Sizing Solar Modules for Microinverters, Enphase Energy Inc. SCRIBD, October 2012

David Nathan, Abioye Ayodeji Opeyemi, “Solar Power System: A Viable Renewable Energy Source for Nigeria”, Quest Journal of Electronics and Communication Engineering Research (JECER) Volume1:1, pp: 10-19, 2013.

David N, Nzewi O.N., Onuora K.C., Abioye A.O “Alternate power source: wind turbine”, Quest Journal of Electronics and Communication Engineering Research (JECER) Volume1:1, pp: 01-09, 2013

David Nathan, “*An economical solar PV system for home use: explained*”, International Journal of Scientific & Engineering Research, Volume 6, Issue 11, pp: 453-358, November-2015.

David Nathan, “The effects of Energy Theft on Climate Change and its possible prevention using Smart Meters: Case Study Nigeria”, IJSER January 2018.

Dogara, “$5bn spent on generators annually unacceptable – Dogara”, Vanguard Newspaper,July 18, 2017, accessed July 20, 2017.

Enphase Inverters https://www.anapode.com/products/50panel_15000w_15kw_Complete_Solar_Panel_Module_Kit_DIY

Gozuk, Inverter with battery bank in solar farm system, 2017. http://www.inverter.co/inverter-with-battery-bank-in-solar-farm-system-213029.html

NOI Polls, “Nigerians Are Spending Almost Three Times The Cost Of Electricity On Alternative Sources Of Power”, 4th August 2015, accessed June 27, 2017, http://www.noi-polls.com/root/index.php?pid=343&parentid=13&ptid=1

REA, Rural Electrification Agency, Energizing Economies- Baseline Survey and Energy Audit Report, V1.0, October 2017

Sreenath Sukumaran Sreenath, K. Sudhakar, Fully solar powered airport: A case study of Cochin International Airport, Journal of Air Transport Management, Elsevier 2017 https://www.researchgate.net/publication/316451680_Fully_solar_powered_airport_A_case_study_of_Cochin_International_airport

Zipp, Kathleen, Where Microinverter and Panel Manufacturer Meet Up, Solar Power World, US, 24 October 2011.