Techno-Economic Evaluation of Solar-Powering of the Department of Electrical-Electronics Engineering and Civil Engineering - Ebonyi State University, Abakaliki, Nigeria

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***Abstract*: Energy is the most basic need of all the people in the world, and it is similar to food in its basic characteristics as a global commodity. There is no absolute shortage of energy in the real sense, but severe deficiencies exist in its availability and distribution to large portions of the population, especially in developing countries. The continuous increase in population and industrialisation in almost every country in the world, has been very responsible for the ever growing or increasing energy demand. The solar panel is used to cushion the increasing energy demand as we investigated.**

***Keywords*: Energy, Energy Crisis, Solar Panel, Solar Energy**

1. Introduction

In Nigeria, less than 40% of the country is connected to the national electric grid and less than 60% of the energy demand by this group is generated and distributed. The Energy-induced environmental degradation is already prevalent in the country (Sambo, 2009).

This is characterized by deforestation as a result of falling of trees for fuel wood and charcoal production, air pollution in urban areas arising from vehicular emission and burning of traditional fuel for traditional cooking in household, noise pollution from use of small generators to provide electricity due to inadequate supply from the national grid, land and water pollution from oil spillage in the oil producing communities (Bala *et al. 2008*). This has led Nigeria and indeed the world to look for alternative power supply such as solar energy among others. Unfortunately utilization and development of solar energy is rising in other parts of the world but encountered with low pace of development and utilization in Nigeria. This low pace of development is due to the associated problems such as purchasing power, technology of installation and fabrications, awareness, governmental policy and politics, culture, Nigerian factor, among many other variables (Whitefield, 2000). In Nigeria, more than 75% of Nigerian populations are rural dwellers (Okonkwo, 2007). Less than 20% of Nigeria is connected to the National grid and more than 70% of Nigeria's population of about 140 million live in more than 80% of land mass of Nigeria which is not connected to the national grid. Since the energy production level of any community dictates her pace of development and hence her poverty level. Hence, the development of every country has a direct relationship with the energy supply and distribution. These are in turn indices of the standard of living of any country. The major useful quality or advantage of energy is facilitation of the provision of those things which are necessary for the welfare of human existence: health, heat, food, light, clothing, shelter and transport, etc. Energy availability improves the standard of living. Solar energy, an energy obtained from the sun, is the world's most abundant and cheapest source of energy available from Nature. It is free and automatically renewable everyday. In the world over, emphasis has shifted from the use of hydro and fossil-powered electricity generation to renewable energy such as solar source.

Solar energy is available in two forms, namely Solar Thermal and Solar Photovoltaics (PV).

Solar thermal is the direct application of solar energy to produce heat. This is dated back to ages, exemplified by sun drying and so on, common in the equatorial region where people have programmed themselves to sun drying of personal effects such as clothing and drying of agricultural commodity, resulting to various researches in solar thermal equipment like cabinet dryers, oven, hatchery, water heaters among others. In Nigeria, solar thermal have been developed for various applications; some of these are solar cookers, chick brooding devices (Okafor and Joel-Uzuegbu 2010). Regarding the drying of Agricultural produce, there are four major drying techniques namely: open air drying, fire wood/fuel drying, electrical drying and solar drying (Nwoke *et al.*, 2008) while Solar PV is the conversion of solar radiation to electricity using solar cell. These include Water Pumping for Irrigation in the Rural Areas, lightings and other proposes. The energy demand in Nigeria was estimated in 1993 as 11GW and it has risen sharply since then. See the component or make up as at 2011 in Figure 3 below.The review done revealed that as at 2015, the total grid capacity was 7,139.60 MW where 3,572.6 MW was peak generation, 3,091.8MW was the lowest generation, 80,308.49 MWH was energy recorded, 49.232 Hz being lowest system frequency, 51.18 Hz was highest system frequency, 347 KV was highest voltage recorded, 300 KV was the lowest voltage recorded.

1.2 Statement of the Problem

Emphasis in this work is to investigate the possibility of the use of solar PV System in power generation in Departments of Electrical / Electronic Engineering and Civil Engineering, Faculty of Engineering and Engineering Technology (Ugwuachara Campus), Ebonyi State University, Abakaliki, Nigeria as an alternative renewable energy source and problems associated with the installation and operation. Since the energy crisis has become increasingly more serious, the importance of research on high efficiency PV systems cannot be overemphasized. Such evaluation are still very few in Ebonyi State, Nigeria.

1.3. The Aim and Objectives of the Study

The general aim and objective of this paper are:

(a) Determine the problems in the utilization of the 1.2MWp PV System in the Faculty of Engineering (FE), Ebonyi State University Abakaliki,

(b) Carry out Techno-economic evaluation using payback period and offer solution to those problems associated with the solar energy stand alone installations in Ugwuachara Campus, EBSU, Nigeria in general.

The Specific Objectives Include:

1. To investigate the various practically encountered post installation problems in EBSU, Abakaliki.
2. To give solutions with more attention being paid to Techno-economic evaluation of the installations in FE, EBSU, Abakaliki.

1.4 Significance of the Study

Electricity is most conventionally generated by using coal energy, hydro energy or Nuclear energy. Apart from energy waste, there is also environmental pollution associated with these conventional sources of energy or electricity. The study will show how cost effective the use of the installed PV Systems is, determine the post installation problems and offer solutions.

1.5 Justification of the Study

Power supply from the mains, NEPA or PHCN or EEDC has been erratic and the study is timely and appropriate now that the Ebonyi State Government and the University Management are ready to help cushion the effect of the epileptic power supply by installing some solar panels that are yet to work.

1.6 Scope of the Study

The scope of this study includes:

(a) Estimation of the load demand of the Departments in the Faculty of Engineering,

(b) Selection of the accessories for a workable photovoltaic system,

(c) Carrying out a techno-economic analysis on the installed system and determine the payback period.

(d) Determination of post installation problems and provide solutions

1.7 Limitations of the Study

The major limitations of this work are time constraints and relatively high cost of the materials for research work.

2. Literature Review

2.1 Solar Cell

The contact between two semiconductors for electricity production under the photovoltaic effect is called solar cell (Kagkarakis, 1992). A solar cell converts photon power into electrical power and delivers this power to the load (Islam, 2006). It is a p-n junction device with no voltage applied directly across the junction. The cost of a solar cell is given per unit of peak electrical power. Manufacturing costs necessarily include the cost of energy required for manufacture. Solar-specific feed in tariffs vary worldwide, and even state by state within various countries. Such feed-in tariffs can be highly effective in encouraging the development of solar power projects.

The equivalent solar cell circuit is shown in Figure 1 below:

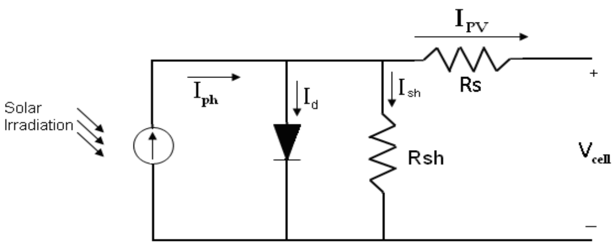

Fig. 1: Circuit Diagram of a Solar Cell

From Fig. 1:

I_{PV} = photovoltaic current of the solar cell

I_{sh} = current through the shunt resistor

I_d = p-n junction current that behaves like diode current, it moves in one direction

and

$I_{PV} = I_{ph} - I_d - I_{sh}$

Where: Iph is the generated current due to sunlight irradiation. The technology behind Solar panels has varied widely throughout the five or six decades and while Solar cells were the true origin of modern solar panels, today researchers are shifting to new platform and approaches to gathering energy from sunlight which including crafting solar cells from silicon semiconductor configured to trap and convert sun energy which are coated in an anti-reflective coating and contained under a glass cover plate to protect the cell from the elements.

Solar cells represent the fundamental power conversion unit of a PV System. They are made from semiconductors like diodes, transistors and integrated circuits (Adegbenro, 2011).

2.1.1 Types of Solar Cells

A lot are already in the market and some are under development. The producers are concerned with making it give maximum power at least cost.

Crystalline Silicon cells are dominant in the market. To reduce cost, multi-crystalline materials are now used for its production. Crystalline Silicon cells have long life span. And their efficiency is approaching 18% (Sambo, 2008).

Another type of Solar cell is the amorphous thin films which are less efficient and are used to power consumer products like solar watches ellsand calculators. A variety of compound semiconductors like cadmium telluride and copper indium can be used to make thin film cells. These are cheap. A highly specialized and efficient cells are made of gallium arsenide and indium phosphide. They can be used to power satellites and systems under high intensity concentrated sunlight.

2.2 Photovoltaic Systems (PV)

Photovoltaic (PV) is the conversion of energy that comes from the sun into electricity through a phenomenon known as the photoelectric effect. Energy from the sun as light is transformed into electricity when it touches a solar cell. Many homes particularly in the developed economies are today powered by photovoltaic systems. In homes that are far from utility grids, photovoltaic systems are frequently the most cost-effective sources of power. Even if utility grid is closed by, some home owners choose PV systems because it gives them more autonomy and provides a way of minimizing the effects of increase in utility rate. PV system is an attractive alternative energy to conventional sources of electricity for many reasons: it is safe, silent, non-polluting, renewable, its fuel is free, and highly modular in that its capacity can be increased incrementally to match with gradual load growth, reliable with minimal failure rates, it contains no moving parts, it requires no special training to operate and it has projected service life times of 20 to 30 years. A typical PV system is shown in Figure 2 below.

2.2.1 Applications of Solar PV

Solar photovoltaic electricity is used for many purposes (to power electrical appliances) and is either used as direct current electricity (DC) or alternating current electricity (AC). Photovoltaic solar power is one of the most promising renewable energy sources in the World. Compared to nonrenewable sources such as coal, nuclear gas and oil, the advantages are clear:

(a) Generates free energy from the sun.
(b) Has no moving part to break down thus requiring minimal maintenance.
(c) Non-polluting energy reduces emissions (has no direct impact on the environment).
(d) Photovoltaic cells are modular, giving room for expansion from small systems
(e) Systems have a long life and durability. Cells last up to 25 years.
(f) Grid-Tie systems allow you to sell excess electricity back to the utility

Solar photovoltaic electricity is used in the following areas: lighting, water supply, communications, healthcare, agriculture, satellites, transportation, rural electrification, demonstration projects.

2.3 Types of PV Systems

(a) There are three general types of electrical designs for PV power systems:
(b) Off-grid stand alone systems
(c) Mini-grid systems
(d) Grid-tie systems (some have battery backups and others have not).

2.3.1 PV system components: A typical solar PV system consists of the following components: solar panel, charge controller, battery and inverter.

3. Practical Example And Applications

3.1 Materials

(a) Lead Acetate, Pb $(CH_3\ COO)_2$
(b) Iron (II) Chloride Dehydrate ($FeCl_2\ 2H_2O$)
(c) 5 No voltage regulators
(d) The system voltage - 48 V DC as the total AC-load is greater than 5,000 W.

(e) The battery type used was VRLA with capacity 325 Ah. The battery bank capacity was 5,200 Ah.

3.2 Methods

The Techno-Economics of Solar Energy in present FE - Abakaliki, Nigeria and Power estimate of the requirement of the Faculty were done. The Faculty of Engineering, EBSU comprises many departments but two departments and Deans Office were chosen for the analysis; Electrical/ Electronic Engineering and Civil Engineering. The appliances assessed were AC appliances. The load and balance of system were investigated using their rating as guideline. The electrical appliances (loads) available at the Faculty of Engineering (FE) were first itemized with their power ratings and time of operation during the day to obtain the total energy demand and consumption in Watt-hour per day. The total energy demand obtained was then used to size the stand alone photovoltaic system. The daily energy demand for all the departments in the FE was done by itemizing all the appliances, their rated power, the quantity, hours used per day. The system voltage selected was 48Vdc as the total ac-load is greater than 5000W. The method used includes a module for the calculation of the energy delivered by the PV system and a module for the economic evaluation of the PV system.

3.3 Power Estimation of FE and Individual Departments

Faculty of Engineering EBSU comprises departments and Dean's Office, Electrical / Electronic Engineering, Civil, CPE, Finance, etc. Tables 1.0 to 3.0 shows the summary of the estimated total energy demand per department in KW, daily energy demand by Department of Electrical / Electronic Engineering and estimated total energy demand per appliance per department. All the appliances assessed were AC appliances. Appliances were itemized and from the rating the power estimate for the selected department and Faculty were done. These were shown in tables 1 to 3 above. The Detailed Power requirement or estimation of energy demand for Other Departments in the Faculty were made and for Electrical / Electronic Engineering is 18.999 KW, Civil is 24.855 KW, CPE is 33.339 KW, Finance is 20.749 KW and Dean's office is 11.303 KW.

3.4 Techno-Economics of the Faculty of Engineering, EBSU, Abakaliki

As at 18th May 2018, a litre of petrol for running a generator was sold at N145 per litre. Bearing this cost in mind and the fact that 70% of the Nigerian population live in rural settlements, a cost estimate for solar powering a Electrical / Electronic Engineering Department and the entire Faculty of Engineering is presented in tables 1 to 3 below. From the table it can be shown that cost estimate for powering them with generator for 1 year in Abakaliki are shown in table 4 and 5 below

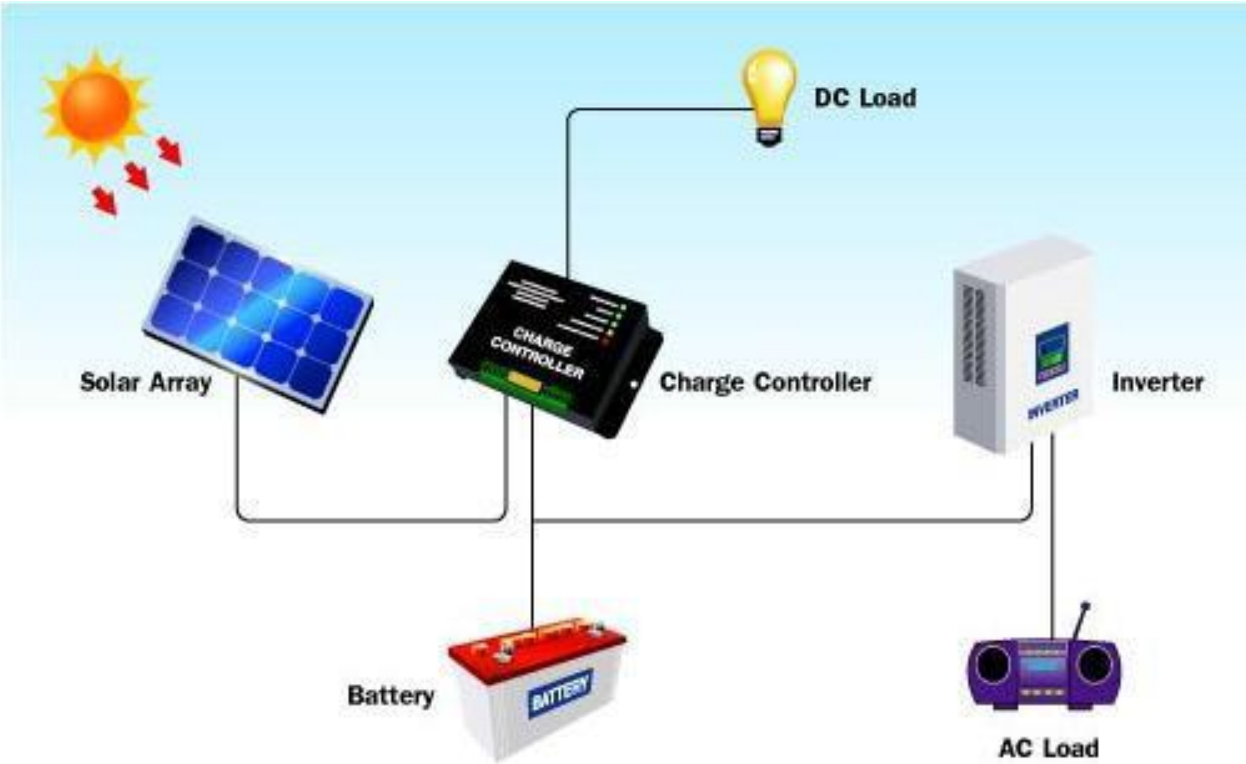

Figure 2: Schematic Diagram of a Typical Stand alone PV System
(Source: Jesuleye, A.O. and Siyanbola 2008)

Total Energy Consumption by Economic Sector in Nigeria between 2011-2014 (KTOE)

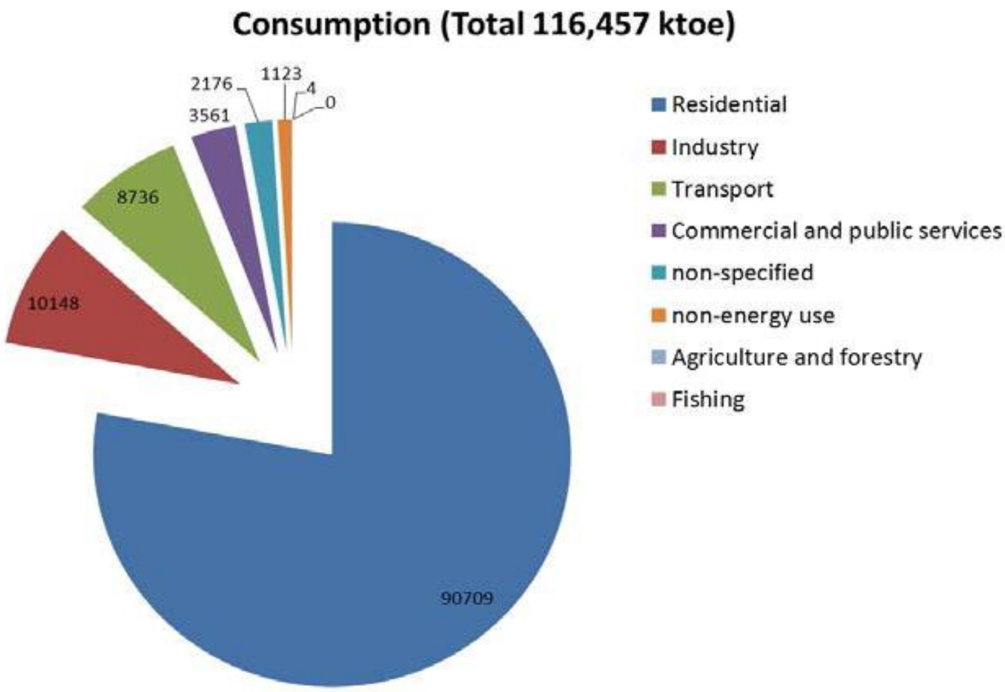

Figure 3. Source: The Nigerian Energy Sector, 2014

Table 1: Estimated Daily Energy demand for the Department of Electrical/Electronic Engineering

Appliance	**Quantity**	**Rated Power (W)**	**Total Rated**	**Hours used KWh/day**	**Power (KW) per day (h)**
Lighting bulbs	40	26	1.040	8	8.320
	24	36	0.864	8	6.912
	80	8	0.640	8	5.120
Fans	79	65	5.135	8	41.080
Refrigerators	17	15	2.550	8	20.500
Computers	50	75	3.750	4	15.000
Photocopying machine	1	1,200	1.200	4	4.800
Sumo/water dispenser	2	500	1.000	8	8.000
Electric Kettle	1	2,500	2.500	2	5.000
Printers	2	160	0.320	2	0.640
Total			**19**		**115.372**

Table 2: Estimated Daily Energy Demand for the Faculty of Engineering Tech. in KW

Appliance	**EEE**	**Civil**	**CPE**	**Finance**	**Dean's Office**	**Total**
Lighting Bulbs	4.271	15.260	5.058	17.556	4.620	46.771
Fans	5.385	1.170	3.990	4.180	0.960	31.370
Computer	3.750	3.500	5.880	6.800	1.050	41.960
Refrigerators	0.300	0.395	0.300	0.280	0.150	1.425
Photocopying Machine	1.200	1.200	1.200	1.200	1.200	6.000
Water Sumo	0.500	0.500	0.500	0.500	0.500	2.500
Electric Kettles	2.500	2.500	2.500	2.500	2.500	12.500
Televisions	1.000	-	1.000	-	1.000	3.000
Printers	0.320	0.320	0.320	0.320	0.320	1.600
Total	**19.216**	**24.855**	**20.759**	**33.349**	**11.313**	**107.685**

Table 3: Estimated Total Energy demand per Appliance per Department in KWh/day

Appliance	EEE	Civil	CPE	Finance	Dean's Office	Total
Lighting bulbs	20.352	21.080	80.472	123.472	16.984	262.360
Fans	43.080	2.000	43.800	2.000	7.680	97.840
Computer	15.000	14.000	20.000	15.000	1.400	65.400
Refrigerators	2.400	3.160	2.400	2.240	1.200	11.400
Photocopying Machine	4.800	4.800	4.800	1.200	4.800	20.400
Water Sumo	0.500	-	-	-	-	0.500
Electric Kettles	3.500	3.500	3.500	3.500	3.500	17.500
Televisions	8.000	-	8.000	-	8.000	24.000
Printers	0.640	0.640	0.640	-	0.640	2.560
Total	**98.272**	**49.880**	**163.612**	**147.412**	**44.004**	**501.960**

Table 4: Cost Estimate of Powering Electrical / Electronic Engineering Department for 1 Year Not Connected to the National Grid

Particulars	Description	Cost in Naira
Cost	Fireman Generator	85,000
Fueling	8 Hrs/day @ 8 Litres/day	424,560,000 (366 X 145 X 8)
Servicing		50,000/year
Total		**424,695,000**

Table 5: Cost Estimate of Powering Faculty of Engineering, EBSU, Abakaliki for 1 Year Not Connected to the National Grid

Particulars	Description	Cost in Naira
Cost	Yamaha Generator	300,000
Fueling	10 Hrs/day @ 12 Litres/day	636,840,000
Servicing		150,000/year
Total		**637,290,000**

3.5 Calculation

To determine how long the Faculty will break even, applying the payback formula, i.e estimated cost of power in the Faculty divided by estimated cost in one department = 637,290,000 divided by 424,695,000.

3.6 Effects of Unstable Power Supply

(a) Security problem
(b) Endangering of life
(c) Loss of satellite signal in area with highrise structures
(d) Inadequate initial information
(e) Access denial in some residential area
(f) Inability of institution to work adequately e.g. petrol stations cannot pump petrol without supply of electricity.
(g) High rates of accidents on the main roads due to ineffectiveness of traffic control signal as a result of power outage
(h) Inability to communicate effectively
(i) High death rate due to inability to power medical equipment required to save people in hospitals

3.7 Post Implementation Problems of the PV System in FE, Abakaliki

Communiqué reached in 2007 National Energy Forum (NASEF) among others, identified challenges to Solar energy development in Nigeria as: Cultural restriction on land use, Lack of appropriate institutional framework, Low level of technical expertise, Vandalization and theft of system component, and Lack of local manufacturing of system component - PV. In our study, the first post implementation problem is that the capacity is below the estimated load and other problems are listed below:

(a) Use of sub-standard components (Whitefield 2000).
(b) Affordability. It is still expensive (Sambo, 2008).
(c) Lack of Awareness**:** To many Nigerians on the street solar P.V. application seems more of science fiction than reality (Okafor and Joel-Uzuegbu, 2010).

(d) Technology of Equipment and Fabrication not in Nigeria.
(e) Environmental Problems and Climate Change.
(f) Payback period (Bala 2003)(Bala et al. 2008).
(g) Inability of PHCN to Meet Demand.

3.8 Some Solutions Offered to Problems of Solar Energy Installation in EBSU (FE)

(1) The identified problems of the installed PV systems are given the following solution, namely:
(2) Government and manufacturers should make it affordable to everyone.
(3) Creating Awareness of the importance (Jesuleye and Siyanbola 2008).
(4) The technology of energy mix and hybrid is recommended.
(5) Technology of Fabrication and Component within Nigeria should be encouraged.
(6) Preventing Theft and Vandalization of the existing systems.

4.1 Summary

The total Faculty load was 1,200 KW or approximately 1.2 MW. From the calculation above it can be deduced that in one and half years, EBSU utilizing solar Photovoltaic systems for power generation will break-even for her energy needs. The expenditure on energy will be reduced drastically and the reliance on NEPA / PHCN / EEDC will be a thing of the past and even though excess is produced, they can sell it. Enough power used for training students will be available and money can be realized as outsiders can patronize the commercial cyber cafe in the Electrical/ Electronic Engineering and Civil Engineering departments. The use of Photovoltaic systems (PV) are capital intensive but profitable and cheap in the long run.

4.2 Recommendations

For effective and efficient utilization of solar electricity in Ebonyi State, Nigeria, the following recommendations will be useful. More research into the techno-economies involving the initial and subsequent costs of solar plants and their power efficiencies is encouraged. Government should subsidize the cost of importation of Renewable Energy Technologies (RET) most especially solar PV to bring down the high cost in Nigeria. Government should create more awareness on the advantages derivable from Renewable Energy Technologies (RET) such as solar technologies. Ban on the importation of generators by government should be upheld (Adegbenro, 2011) (Whitefield, 2000).

Final recommendation among others include: financial package for solar energy projects, National Energy Master plan and Renewable Energy Master plan should be approved for the country (Akinboro et al. 2012).

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