A Survey Of Solar Energy Utilization For Sustainable Development In Nigeria

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***Abstract*—Access to clean, affordable, and environmentally friendly energy is a condition for attainment of sustainable development. This paper discusses how Nigeria can exploit and utilize solar photovoltaic (PV) in her journey towards sustainable development. The Solar PV is a renewable source of energy that offers clean, everlasting, and environmentally friendly energy that can be used in households, education, health, agriculture, social, communal, commercial and industrial sectors of the economy. Practical applications of solar PV includes for lighting, water pumping, cooking, phone charging, vaccine preservation, dairy refrigeration, egg incubation, crop and manure drying, as well as fish and poultry production. The paper enumerated the benefits derivable from utilization of solar PV to include employment generation, increased agricultural production, access to large pollution-free energy source among others. The paper concluded that if the identified constraints to exploitation and utilization of solar PV are tackled and the recommendations adhered to, Nigeria will be on her way to attaining sustainable development by increasing the energy accessibility of her citizens through utilization of solar PV.**

Keywords - Solar PV, renewable energy, sustainable development, energy utilization.

I. INTRODUCTION

The importance of energy in achieving sustainable development cannot be over emphasized. Energy availability has been found to be closely related to sustainable development of a country [1]. Real sustainable development is about the ability of a society to meet the needs of the present without compromising the ability of future generations to meet their own needs. These need include access to functional, affordable health care and educational systems, access to nutritious food, living in a comfortable house with the basic necessities of life, and living in a friendly environment or planet, to mention just but a few. To meet these needs, energy availability is central. It is required to drive the socio-economic and industrial development of a nation. For example, energy is used in the agricultural sector for irrigation and preservation; in the household sector for lighting, heating, refrigeration, and cooking; in the industrial sector for turning raw materials into finished goods; and in the transportation sector to power cars, trucks, trains, airplanes, etc. Energy contributes in multiple ways to the Gross National Product (GNP) of a country [2].

Nigeria, located in West Africa is bordered by Cameroon to the west, Niger to the north, Benin Republic to the west and Atlantic Ocean to the south, lies within latitudes 4.32^{o}N and 14^{o}N and longitude 2.72^{o}E and 14.64^{o}E has a land area of about 924,000km^2 and a population of 165million people [3]. Nigeria is blessed with abundant energy sources, both renewable and non-renewable. Nigeria has an estimated reserve of 36 million barrels, which is about 4.9 billion ton of oil equivalent (toe), 5210 billion m^3 of natural gas as of 2006, about 4.1 billion toe of tar sands, and 1.52 billion toe of coal and ignite. This place Nigeria among the 10th largest crude oil producer in the world, and among the top 10 countries with the largest gas reserves globally [3,4]. Exploitation and utilization of these non-renewable energy sources has not been able to meet the country's energy needs as Nigeria is still plaque with epileptic power supply and still imports about 70% of her petroleum products. This is why in the last few years, efforts have been geared towards exploiting and utilizing the abundant renewable energy source available in Nigeria.

The recognized Renewable Energy (RE) in Nigeria includes solar energy, hydropower, wind energy, biomass, and biogas. Exploitation and utilization of these RE sources will not only help Nigeria to meet her energy targets, ensure energy sufficiency, but it will also help in stemming the

tide of environmental degradation associated with exploitation of non-renewable energy sources.

Having established the unbreakable link between energy availability and sustainable development and the problems associated with exploitation and utilization of non-renewable energy sources, it is obvious the Nigeria's quest for energy sufficiency will be a mirage if RE is not given its rightful place in the country's energy mix. This paper examines the potential of RE, particularly solar energy, in achieving sustainable development in Nigeria. Possible areas of utilization and benefits accruable in exploitation and utilization of solar energy will be highlighted, while useful suggestions that will allow for achieving sustainable development will be offered.

II. AVAILABLE RENEWABLE ENERGY IN NIGERIA

The Federal Government of Nigeria (FGN), through the Federal Ministry of Power and Steel, enacted the Renewable Electricity Policy Guidelines in 2006, to pursue the vision of RE in the power sector to achieve an accelerated sustainable development through increased share of renewable electric power to the national electricity supply. The policy guidelines recognized only four forms of renewable energy, namely hydropower, solar, biomass, and wind. Table 1 presents the estimated RE resources in Nigeria while Figure 1 shows the energy mix in Nigeria. This shows that RE utilization in Nigeria is still abysmally low, and that the abundant RE potentials in Nigeria are still untapped. However, with the persistent failure of PHCN despite its unbundling and the recurrent unrest in the Niger Delta region of Nigeria, government had increased the exploitation of RE in recent years.

Table 1: RE resources in Nigeria.[5]

Energy Sources	Capacity
Hydropower, large scale	10,000 MW
Hydropower, small scale	734 MW
Firewood	13,071,464 hectares
Animal waste	61 million tonnes/yr
Crop Residue	83 million tonnes/yr
Solar Radiation	3.5 – 7.0 kWh/m^2/day
Wind	2 – 4 m/s (annual average)

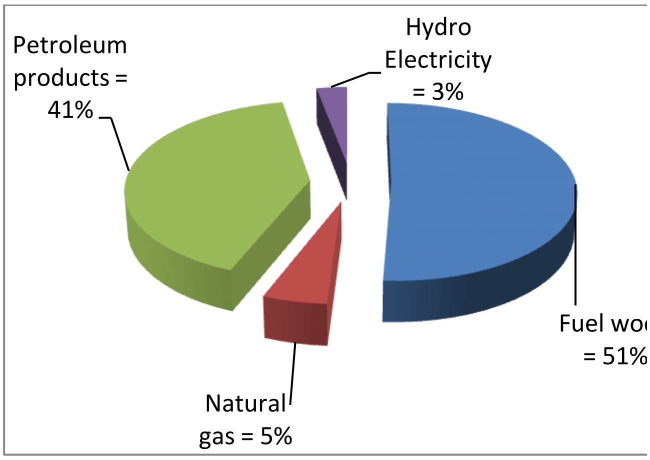

Fig. 1. Energy mix in Nigeria. [6]

Renewable Energy Master Plan (REMP) of 2009 provides a roadmap for the effective implementation of the RE and articulates Nigeria's vision for achieving sustainable development in energy. Through this roadmap, government set up the Nigeria's Renewable Energy targets as follows [1,7]

- 18% electricity from renewables by 2025
- 20% electricity from renewables by 2030
- 100 MW small hydro capacity by 2015 and 760 MW by 2025
- 300 MW solar PV capacity by 2015 and 400 MW in 2025
- 40 MW wind capacity by 2025
- 5 MW biomass fired capacity by 2015 and 30MW by 2025

These national electricity targets are expected to be met through the following strategies:

- Grid-based extension for proximate areas;
- Independent mini-grids for remote areas with concentrated loads where grid service is not economic or will take many years to come; and
- Standalone renewable electricity systems for remote areas with scattered small loads.

These targets are too low when compared with other Africa countries targets as shown in Table 2.

Table 2: RE targets in Africa. [8]

Country	RE targets	Target year
Cameroon	50% /80%	2015/2020
Cape Verde	50%	2020
Ghana	10%	2020
Madagascar	75%	2020
Mauritius	65%	2028
Niger	10%	2020
Nigeria	7%	2025
Rwanda	90%	2012

However, there is no doubt that there is an increased awareness about the potentials and benefits of RE as a veritable means of meeting Nigeria's energy need among various levels of government with the active collaboration of the private sector and other development agencies. Citizens are also adapting to the change and are embracing the new energy source. In summary, available statistics put the renewable energy potentials in Nigeria as follows:

Hydroelectric energy: The total technically exploitable hydropower in Nigeria is about 20,000MW out of hypothetically approximated potential of 30,000MW [9]. Small hydropower's (SHP) potential capacity is 3,500MWin about 277 sites, 12 states of Nigeria and in 4 river basins authority nationwide out of which only 30MW is being exploited currently [3,10].

Wind Energy: Wind speed has been found to range from 4.0m/s to 5.12m/s in the extreme northern Nigeria, while in the southern Nigeria, wind speed varies from 1.4m/s to 3.0m/s. Available information showed that at 25m height, annual wind energy of 1680.50kWh is achievable in 22 sites spread across 17 states of Nigeria. For example, in a site in Sokoto, a wind turbine can generate up to 197.68kWh/year while 93.91kWh/year, 49.78kWh/year, 49.98kWh/year and 101.10kWh/year is estimated possible in Enugu, Ibadan, Port Harcourt and Maiduguri respectively at 25m height [3,11].

Biomass: Nigeria's biomass resources (fuelwood, agro waste, saw dust, municipal solid waste) have been estimated at 8 x 10^2 MJ which can be used as fuel, fermented as biogas and as paper products. 80million m^3 of fuelwood with energy content of 6 x 10^9MJ is used annually for cooking and other domestic purposes in Nigeria [3, 10].

Biogas: Though biogas is not yet listed in the energy mix in Nigeria, but researchers have identified economically feasible feedstock to include dung, water hyacinth, cassava peels, rice husk, water lettuce, saw dust, banana peels, sewage, wood shavings, etc [12,13]. Nigeria is estimated to produce 227,500tones of fresh animal wasted daily and 20kg of municipal solid wastes per capital is produced annually. About 0.03m^3 of biogas can be produced from 1kg of fresh animal wastes, thus Nigeria can produce 6.8million m^3 of biogas/day. It has also been discovered that a 6.0m^3 family-sized biogas digester can generate 2.7m^3 of biogas/day to satisfy the cooking need of a family of 9 persons [3].

Solar Energy: Energy radiated from the sun is about 3.8 x 10^{23} Kw per second, which is equivalent of 1.082 million ton of oil equivalent (mtoe) per day [2]. Nigeria has an average of 1.8044.851 x 10^{12} kWh of incident solar energy annually based on Nigeria land area of 924 x 10^3km^2 and an average of 5.535kWh/m^2/day. As shown in Figure 2, solar radiation is well distributed throughout the country by virtue of Nigeria's location on the globe. The sun shines on the average for 5.5hr/day. The annual solar energy value is about 27 times the country total fossil energy resources in energy unit and is over 115,000 times the electric power produced. This means that only about 3.7% of Nigeria's landed area is required to collect an amount of solar energy equal to the country's conventional energy reserves [3,4].

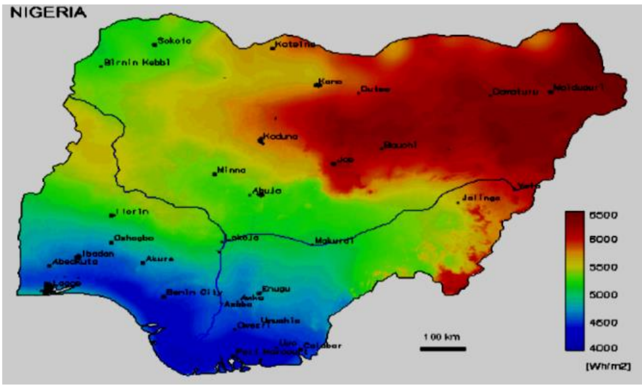

Figure 2: Solar radiation map of Nigeria.[5]

III. SOLAR POWER GENERATION

Power generation is the process of converting energy from an available source to electrical energy in a form that is suitable for distribution, consumption and storage. Sun radiations are converted into electricity through photovoltaic (PV) cells. PV cells are composed of layers of semiconductors such as silicon. Energy is created when photons of light from the sun strike a solar cell and are absorbed within the semiconductor material. This excites the semiconductor's

electrons, causing the electrons to flow, and creating a usable electric current. The current flows in one direction and thus the electricity generated is termed direct current (DC) [14, 15, 16].

A. STRUCTURE OF A SOLAR CELL

Solar PV cells are made of special materials called semiconductors such as silicon, which is most commonly used. Basically, when light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor. The energy knocks electrons loose, allowing them to flow freely [14]. A typical solar cell is as shown in Fig. 3.

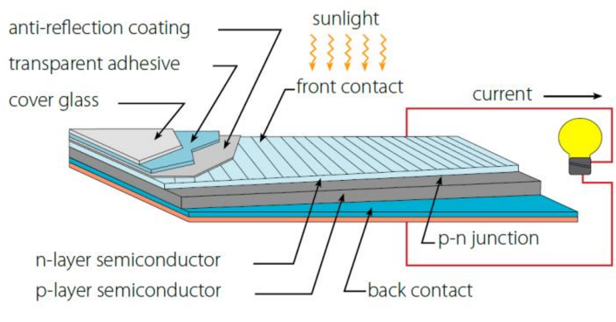

Figure 3. Components of a solar cell. [15]

Solar cell is a multi-layered unit consisting of the following parts [15]:

Cover - a clear glass or plastic layer that provides outer protection from the elements.

Transparent Adhesive - holds the glass to the rest of the solar cell.

Anti-reflective Coating - this substance is designed to prevent the light that strikes the cell from bouncing off so that the maximum energy is absorbed into the cell.

Front Contact - transmits the electric current.

N-Type Semiconductor Layer - a thin layer of silicon which has been mixed with phosphorous to make it a better conductor (i.e dopin).

P-Type Semiconductor Layer - This is a thin layer of silicon which has been mixed or doped with boron to make it a better conductor.

Back Contact - transmits the electric current.

One PV cell produces only one or two watts which is not much power for most uses. In order to increase power, photovoltaic or solar cells are bundled together into what is termed a module and packaged into a frame which is more commonly known as a solar panel. Solar panels can then be grouped into larger solar arrays as shown in Fig. 4.

Fig. 4: Arrays of solar panels

B. SOLAR PANEL PLACEMENT AND ORIENTATION

The solar panels can be arranged on the ground, mounted on a pole or mounted on the roof where it will not be shaded by trees or buildings but exposed to the direct rays of the sun. For the

solar panels to be effective, they must be arranged and installed where the direct rays of the sun can strike it. Solar panels should also be inclined at an angle as close to the area's latitude as possible to absorb the maximum amount of energy year-round. Fig. 5 shows the mounting angles for solar PVs at different locations around the continent.

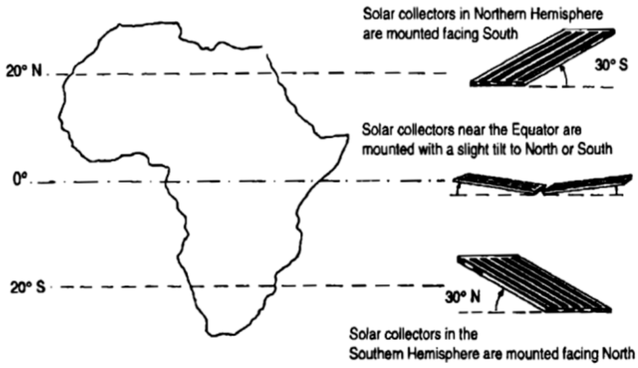

Fig. 5: Mounting angles for fixed solar collectors [14].

Optimally, the panels must be installed where it will enjoy the most exposure to direct sunlight. The caveat is that the optimum angle which depends on latitude must be maintained. To determine the optimum angle for solar panel, the following instructions are to be adhered to [14].

i. Calculate latitude using a global positioning system, GPS, map, atlas or even from Google Earth. An easy to read sun map with key information such as the number of hours of sunshine, its intensity and so on is created. This will be used to calculate the optimum angle

ii. Add 15 to the calculated latitude (This is the rule of thumb for even production throughout the year).

iii. Ratchet systems can be installed to raise or lower the angle so that the panel can be adjusted manually.

IV. BALANCE OF SOLAR PV SYSTEM

A PV installation needs several components other than the PV panels. These components are jointly referred to as the Balance of Systems (BoS) and include batteries, battery charge controller, inverters, supporting structures required for mounting the PV panels, etc. [17]. The basic components of the BoS are:

i. Batteries: Battery is an electrochemical device that converts the chemical energy contained in its active material directly into electrical energy and vice versa by means of oxidation-reduction reactions. Batteries are used for storing energy and as a backup source when solar insolation is fluctuating, during cloudy conditions or at night. Commonly used batteries for solar PV include Lead-acid batteries, and Nickel-Cadmium (Ni-Cd) batteries [17]. Deep Cycle Batteries store electricity to provide energy on demand at night or on overcast days. They are designed to be discharged and then re-charged. These batteries are rated in amp hours usually at 20 hours and 100 hours. Like solar panels, batteries are wired in series and/or parallel to increase voltage to the desired level and increase amp hours [14].

ii. Inverters: Inverters are required to convert the Direct Current (DC) power produced by the PV module into Alternating Current (AC) power. Most solar power systems generate DC current which is stored in batteries while nearly all lighting, appliances, motors and so on, are designed to use AC power, so it takes an inverter to make the switch from battery-stored DC to standard power (120VAC, 60Hz). Also, the grid connected applications require that the DC is converted into AC before power can be fed into the grid [14, 17].

iii. Charge Controllers: A charge controller monitors the battery's state-of-charge to insure that when the battery needs charge current it gets it, and also insures the battery is not over charged. In applications, where batteries are used, it is critical to prevent over-charging or deep discharging for the batteries to preserve their life and ensure good performance. This is achieved using a charge controller. Connecting a solar panel to a battery without a regulator seriously risks damaging the battery and potentially causing a safety concern [14, 17].

V. AREAS OF UTILIZATION OF SOLAR PV

Over the years, Nigeria has joined other parts of the world to utilize the energy available from the sun. This might be due to the unreliable nature of electric power generated and supplied from other non-renewable sources. Apart from the traditional sun drying method which has been in use from time immemorial, solar energy has been exploited for various purposes all over the country. Some of the where solar PV has been used include households, agricultural productivity, off-farm productive uses (rural and cottage industry, commercial services and small business development), social and community services, and other productive activities, namely: billboards/advertising etc.

A. SOLAR PV FOR HOUSEHOLD USE

Solar PV utilization at the household level in Nigeria has been found to contribute to sustainable development over the years. The Solar Home System (SHS) is the dominant application of PV in rural areas of developing countries including Nigeria through provision of basic lighting service for the improvements in quality of life at the household level. Solar energy has also been adapted for other purposes including heating and cooking purposes, charging of phones, etc.

The quality of lighting output coming from well-designed SHS is much higher than the lighting from kerosene lamps. The SHS has been found to increase social welfare, quality of life and contribute to sustainable development through [17]:

- extended housework schedule;
- time and labour savings;
- increased reliability and convenience in energy use;
- decrease in indoor pollution;
- decrease in accidental fire;
- improved health and hygiene;
- improved education;
- increase in leisure time activities.

The exploitation of solar PV has been found to lead to better recreation possibilities, better health conditions, more time for homework in the evenings, more pride/self-esteem, more time for women for household shores, possible use as a mosquito repellent power supply, elimination of the use of primary cell batteries, etc. The use of solar PV as a means of providing power for household use for lighting, fan, and television has been well acknowledged the only constraint in this regard is the cost of the solar PV system. However, it has been discovered that though solar PV is costlier than generators powered by petrol or diesel fuels in the beginning, but on the long run, investing and using solar PV for household is a worthwhile and more beneficial venture [19].

B SOLAR PV FOR SOCIAL AND COMMUNAL SERVICES

Solar PV can be used to impact and improve social and community services, especially through improved health facilities, education and community centres. It is a veritable means of powering public lightings like traffic light, religious centres (churches and mosques), telecommunications, drinking/tap water (including water pumping, purification and desalination), veterinary services, etc to enhance social life in communities.

1) Solar PV for health care

Vaccine refrigeration and ice-pack freezing are the best-known and most common applications of PV in rural health clinics. This equipment is used in immunization programmes around the world. Failing reliable refrigeration (along the whole chain: from manufacturing to transport to the point of use), the potency of vaccines is lost and endangering immunization programmes even more. In the most remote health clinics ice-pack freezing is also necessary to carry the vaccines to remote villages in coolers. Other medical appliances that can be run on solar PV systems are nebulizers, centrifuges, sterilization and water treatment equipment. Electric lighting greatly improves accessibility and quality of (emergency) care at night [17].

2) Solar PV for drinking water supply

Water is a basic necessity and a reliable supply of clean water can reduce the amount of water-borne diseases (especially in children); it can contribute to an increase in health, hygiene and convenience and can help liberate time for other activities, especially for women.

The supply of drinking water is often one of the top priorities of villagers lacking such services. Solar PV can be applied for water pumping projects to supply reliable water to the communities. Available statistics confirm that most of the solar PV usage in Nigeria is in the area of water pumping [20].

3) Solar PV for schools, community and other public buildings

Solar PV are being used to enhance the quality of education for powering audio-visual aids, computers, internet for distant learning methods for adult education, extend the learning time as well as providing electricity for night study. Basic lighting in the evening can also facilitate after-dark activities like community reunions, religious activities and festivities.

As in the health care sector, basic lighting and audio-visuals can also help professionals working in remote areas to increase their standard of living and motivate them to stay. Also it allows them to prepare classes at night and stay informed, through radio and TV, which should have their effect on the quality of teaching and learning. Other social and communal use of solar PV system includes public and street lighting, powering telecommunication base stations, etc.

C. SOLAR PV FOR OFF-FARM PRODUCTIVE USES

Off-farm productive activities can be classified in cottage industry, commercial sector and in the service sector, that is, the activities related to recreational services and utility services (electricity delivery, communication services).Solar PV can be used to power retail shops, restaurants, bars, cinemas, mobile phone shops, sewing shops, repair shops, battering charging, and hotels. Benefits accruable from the use of solar PV for off-farm productive uses include employment generation, allowing longer working and opening time, creates new business opportunities, more marketable products through handicrafts, higher productivity, better quality products, more sales, better quality services, more attractive business through provision of light music, cold drinks, etc [18].

D. SOLAR PV FOR AGRICULTURE

Solar PV has been used for agriculture over the years in Nigeria. This has enhanced agricultural practice, production and preservation of agricultural products. Some of the notable usage of solar PV in agriculture includes:

a) Poultry Production

Egg incubation: Solar PV has been used for large scale and commercial hatching of eggs away from the chicken, since the temperatures required are low and can easily be achieved. Design provision must, however, be made for humidifying the air. The components of the hatcher consist of a solar air heater, glazed with a single thin PVC corrugated sheet. The humidified heated air is made to the egg chamber [20].

Chick brooding: Young poultry are unable to survive under their self-generated body heat for the first few weeks of life i.e. during the brooding period, which is normally 0 - 4 weeks. Solar energy may be used to provide the required heat through air or water solar heaters or by direct heating of the brooder space. The temperatures required are low and so can be handled with non-concentrating flat plate collectors.

b) Solar PV for crop, fish and manure dryer

Solar PV crop dryers are mechanized methods of using solar radiation to dry agricultural crops that excludes the traditional method of open to sun or air drying. Different types of solar dryers have been developed by agencies like the National Centre for Energy Research and

Development (NCERD), Nsukka, Sokoto Energy Research Centre (SERC), Sokoto, and tertiary institutions for maize, rice, beans, vegetable, pepper, melon, fish and manures, for example, solar dryers for fish and grain have been developed at the Mechanical Engineering Department, Ekiti State University, Ado Ekiti. A typical solar dryer is as shown in Fig 6.The solar dryers are more efficient, enhance complete drying and longer storage compared to open-air drying [21].

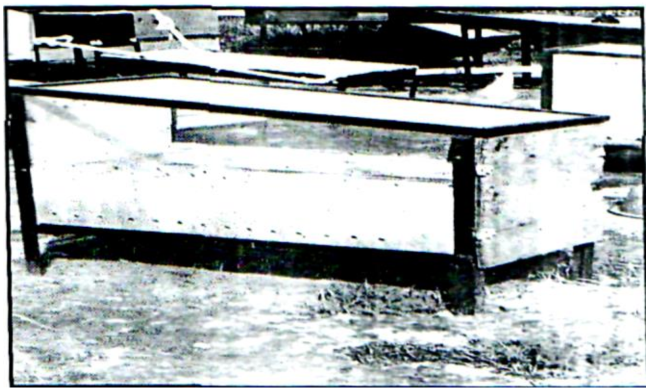

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Fig. 6: Solar crop dryer [21]

c) Solar PV for irrigation and water pumping

The use of solar PV has been demonstrated for pumping water from wells and bore holes especially in rural areas for providing the water requirements of entire communities for irrigation and for drinking by animals [21]. These have contributed to higher crop yield, increased production of vegetables and increased income for farmers.

d) Solar PV for aquaculture and fishing

For nearly 20 years, aquaculture has been one of the fastest growing food producing sector in the world, increasing from 1.45 kg per capita in 1984 to 4.9 kg in 1997. Since 1984, aquaculture production in developing countries, including Nigeria, has grown significantly. Solar PV has been developed to power aeration pumps for aquaculture purposes. Aeration of the water increase oxygen levels, which contributes significantly to productivity. Many of these farms are in remote, off-shore locations. Much of the power demand is at present provided by diesel generators, which are costly to operate and present an ecological hazard, especially close to vulnerable aquatic eco-systems. For small applications (aeration pumps) solar PV can be an economic solution. For higher energy consuming applications PV/diesel hybrid systems can be an option [18, 21].

e) Solar PV for electric fences

Livestock farmers in many remote areas need power for electric fences. In remote areas where the use of grid electricity is often too expensive due to the long lines to be extended, electric fences are often powered by stand-alone batteries. The addition of a solar panel extends the lifetime of the battery and avoids the costs for time, transport and charging [18].

f) Solar PV for poultry lighting

Solar PV has been identified to provide electricity for poultry (both meat and egg production). Electricity availability extends the day and increases the growth of poultry and the production of eggs. It also reduces the mortality rate of chicks.

g) Solar PV for pest control

Solar powered lanterns have been identified for use for trapping a specific pest (Red-Headed Hairy Caterpillar or RHC). Pesticides are often used to control pests, but with attendant harmful environmental effects and growing pesticide resistance, the use of solar PV is viable alternative. If lights are placed in the fields at night after a heavy rain, which is when the moths emerge in great numbers, most moths are attracted by the light, fall into the water and drown before laying eggs. Solar lanterns proved far more effective, economic and safer than extending a cable into the fields [18].

VI. BENEFITS OF SOLAR ENERGY

Solar energy is really energy for the moment. If the environment and the ecosystem is to be preserved for today and for the generations yet unborn, the clean and renewable energy which solar energy offers should be exploited and utilized. If this is pursued and implemented, the following are some of the benefits derivable [17, 22]:

i. Solar energy is an everlasting, renewable, clean energy source with no potential damage to the environment.

ii. Solar energy is free and large source of energy that does not cause pollution.

iii. Development of Nigerian made solar PV panels which will contribute to the Nations GDP. This will be the natural consequence since these panels will be exported and foreign exchange will flow into Nigeria's economy. The African market will be a major target for the solar PV cells.

iv. Patenting of new Solar PV products developed in the universities and research institutions. As the solar PV panels are being developed, other products used along with it will also be developed indigenously and both the solar PV panels and these by products will bring up the number of patents registered for Nigeria.

v. Human capacity building of those directly or indirectly involved with the project. Human capacity building of those involved directly in the project will stimulate an avalanche of technological know-how which will be required to both develop newer technologies and maintain the existing ones.

vi. Emergence of PV technology clusters and hubs in Nigeria which will stimulate Industrial growth through establishment of Small and Medium Scale Enterprises (SMEs) that produce and market Solar PV panels.

vii. Provision of a practical platform to harness renewable energy resources in Nigeria with all the attendant advantages it provides over fossil fuel.

VII. CHALLENGES FACING UTILIZATION OF SOLAR PV IN NIGERIA

Despite the usefulness of energy from solar PV and the benefits derivable from its exploitation and utilization, Nigeria has not fully utilize the opportunities available in solar energy for sustainable development of her citizens. This may be due to some factors which include the following [23]:

i. Affordability: Deployment of solar-PV technology is still very expensive and unaffordable to majority of Nigerians particularly the rural dwellers. Because the parts are imported, the parts are still expensive. When compared with diesel or petrol generator, particularly for household use, solar PV is still expensive on the short run, though on the long run, solar PV may be cost beneficial.

ii. Financial constraints: A basic barrier to the development of solar energy technology in Nigeria as a developing country lies in high initial costs and long payback times. Due to the high cost of the parts and the fact that they are not affordable, financial constraints makes the technology not accessible to average Nigerian.

iii. Technological incapability: Though the technologies for harnessing solar energy are being developed in Nigeria, most components have to be imported which further pushes the investment costs higher. Nigerians still need to learn how to install, and maintain it. However in recent times, there has been lot of improvements in the technological know-how among Nigerian's engineers and technologists, a lot still need to be done to equip them with the requisite knowledge on the technology.

iv. Low level of public awareness: Awareness of existence of solar energy as a source of power supply is still very low in Nigeria. Those that are aware of it thought solar energy can only power few watt of lighting. They are not aware of the fact that solar PV is in modular form and can be connected in series and parallel to achieve the desired power output. Many

Nigerians are not aware of the environmental friendly nature of solar PV. Some still sees solar PV as an imported technology that cannot be implemented in Nigeria. They don't see solar PV has being capable of providing solution to their energy needs.

v. Absence of a Comprehensive National Energy Policy (NEP): There was virtually no comprehensive energy policy in Nigeria until very recently. Only sub-sectorial policies relating to energy exist. Even the existing NEP is not encompassing enough. For example, the targets set bet the NEP is too low and its realisation will not yield any fruitful improvements in the energy accessibility of Nigerians.

RECOMMENDATIONS

For effective and efficient utilization of solar energy in Nigeria, the following recommendations will be useful:

i. Government should subsidize the cost of importation of Renewable Energy Technologies (RET) most especially solar PV to bring down the high cost in Nigeria, and make it affordable.

ii. More research into the techno-economies involving the initial and subsequent costs of solar plants and their power efficiencies should be encouraged.

iii. Private individuals and organisations should be encouraged by appropriate authorities to invest in solar technologies in the country.

iv. Government should create more awareness on the advantages derivable from Renewable Energy Technologies (RET) such as solar technologies.

v. Government can also consider placing restrictions on the importation of diesel and petrol engine generators because of its adverse effects on the environment even as the global community gear towards clean (green) energies.

vi. Funding of solar technology researches and development initiatives in Nigerian Universities, Polytechnics and Research Institutes so as to develop solar PVs with increased efficiency that will be adaptable to our environment is advocated as is obtainable in developed countries.

CONCLUSION

This paper has once again confirms the immense potentials of solar energy in Nigeria. It has also confirms that Nigeria has enough solar radiation to solve her energy needs. With the many areas of utilization of solar PV cutting across household, education, health, agriculture, commercial, to mention just but a few, as well as the multi-faceted benefits derivable from exploitation and utilization of solar PV, there is no doubt that solar PV holds the key to bail Nigeria out of her perennial energy crises. The challenges enumerated above are surmountable with sincerity and consistent implementation of government policies. There is no doubt that Nigeria can attain sustainable development if solar PV is given its rightful place in Nigeria's energy mix.

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