BENEFITS OF SOLAR POWER IN NIGERIAN RURAL COMMUNITIES

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1 author:

Ismaila Haliru Zarma
Egypt-Japan University of Science and Technology

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[1]Zarma I. H, [2]Dioha I. J, [2]Tijjani N., [3]Alhassan M.
[1]Department of Energy Resources Engineering, Egypt – Japan University of Science and Technology
[2]Department of Renewable Energy, Energy Commission of Nigeria
***corresponding Author:** ismail.zarma@ejust.edu.eg, ismailzarma@yahoo.com

Abstract

There is considerable potential for solar-powered energy service provision in Nigeria's rural communities, in the form of solar photovoltaic (PV) or solar thermal power. Nigeria lies within a high sunshine belt and, within the country; solar radiation is fairly well distributed. The annual average of solar radiation varies from about 12.6MJ/m^2 per day (3.5kWh/m^2) in the coastal latitudes to about 25.2MJ)m^2 per day in the far north. This gives an average annual solar energy intensity of 1934.5kWh/m^2 per year; thus over a whole year, an average of 6,372,613PJ/year (≈1,770,000TWh/year) of solar energy falls on the entire land area of Nigeria. In the recent years solar power has crept into power generation agenda in Nigeria, but mainly in the form of small mini grid solar power plant for residential electrical applications. Although central power plants are still in the scene, a fast revolution is possible through power generation on site, in a distributed fashion, locally nowhere farther then our residential buildings. Solar power is becoming increasingly important in Nigeria, as the energy consumption is getting higher due to the population growth, urbanization and today's energy dependent society and industry. The use of fossil resources is causing an irreversible climate change and damage to nature due to high levels of greenhouse gas (GHG) emissions. In a round figures residential buildings cause 40% of the total GHGs and the residential buildings consume 70% all the energy produced across the world among all types of buildings. The Energy Commission of Nigeria - has published renewable energy policy and renewable energy masterplan for Nigeria in an attempt to fasten the penetration of solar energy utilization especially in rural communities. Several solar PV mini grid has been established in many rural communities powering residential buildings electrical appliances. This paper shall introduce available solar mini grid power plants and clarify all the benefits provide by the presence of such plan in residential rural buildings in Nigeria.

Keywords: Energy Solar, Rural, Residential

1.0 Introduction

Nigeria is naturally endowed with abundant renewable energy resources especially solar irradiation. A lot of potentials exist which can be adequately harnessed into useful energy. Moreover, a large percentage of the Nigerian populace lives in rural areas with very little energy access. This translates to absence of basic social amenities and the resultant effect being a constant exodus from such areas to urban centers where there are social amenities. This drift occurs in every part of the country. However, this trend is not economically healthy to our country as the urban areas tend to be over populated and over stretched in their facilities with other attendant consequences whereas the rural areas, where basic or primary production takes place is depleted in population leading

to a drop in this aspect of production, with the greatest sector affected being the agricultural sector. Consequently, renewable energy technologies can be adopted and applied in the rural areas where the national grid has not yet been extended to. Rural electrification, community water projects and other things can be achieved with the use of renewable energy technologies. This will increase energy access in such areas and improve the standard of living thereby discouraging and curbing migration from such places to the urban areas. Furthermore, the use of renewable energy technologies like solar energy does not only increase energy access and aid in providing social amenities, it also has capacity to generate employment opportunities which will culminate in curbing rural-urban drift in Nigeria.

In Nigeria, most solar PV projects are designed for street lighting, water pumping and general stand-alone/mini grid rural electrifications. However, several solar PV projects being installed in various parts of this country fail to meet the minimum life-span due to a number of limiting factors. These include poor or improper fundamental design, use of sub-standard components, adoption of poor installation procedure by inexperienced personnel, bad construction/civil works among other factors. This has become a problem in the country and many are beginning to feel disgusted with solar PV projects as the heavy investments in such projects do not seem to be commensurate with their performances and satisfactions derivable. We believe that if power projects are designed and executed properly by experienced technical experts, using the appropriate components and best technical procedures, standard PV projects with maximum performance output could be achieved.

It is over eleven decades ago since electricity was introduced into Nigeria. The country has an installed generating capacity of about 6000MW from 60kW within this period but only about 40% of the population has access to grid-connected electricity supply. A per capita electricity consumption of 72kwh per annum was estimated in the year 2000. Utilization of the existing generation capacity has also been estimated at 30% to 40% for the same year [1].The supply of electricity in the country is sparse and inadequate; the spread favours the urban areas with about 80% accessibility by households in 1992 [2]. Most rural grid-connected households have blackouts of up to 20 hours a day.

The current approach to involve independent power producers in boosting grid electricity supply via thermal plants has also been focused to cities and towns in the country with rural areas alienated. As of year 2000, less than 10% of electricity generated in the country goes to the rural area which is rather too inadequate to meet the developmental objective of the rural areas of Nigeria[3].Since the availability of energy is an important precondition for developing the rural economy and improving the people's living standards, it is imperative therefore that the extent to which the country could meet the growing demand for energy in the rural areas in a sustainable way will significantly affect its economic growth and well-being of its rural dwellers. It is therefore essential to access what alternatives exist for supplying electricity in a sustainable manner to rural households to meet their energy requirement. And potentially, one of such options is solar energy photovoltaic device. This paper therefore reveals the importance of using solar power to Improve Energy Access in rural areas and also contribute to the industrial and economic growth of Nigeria.

2.0 Solar Energy Potentials in Nigeria

Solar energy is the term used for the heat and light which the sunlight contains. Sunlight reaches to earth in the form of photons. Photons are energy packets that contain light in it. Solar energy is considered as a renewable energy source because it does not destroy our ecological system and is present naturally in the environment. There are basically three ways that we can use the sun's energy. The first is by solar cells in which photovoltaic or photoelectric cells are used to convert light directly into electricity. The second is solar water heating in which the heat from the sun is used to warm the water in glass panels on the roof therefore no longer requiring gas or electricity to heat the water. The third is solar furnaces which use mirrors to capture the sun's energy into a congested place to produce high temperatures.

Solar radiation incident on the earth's surface varies in intensity with location, season, day of the month, time of day, instantaneous cloud cover and other environmental factors. The incorporation of efficient storage devices in solar energy conversion systems will take care of this intermittent nature of the availability of solar radiation. Nigeria lies within a high sunshine belt and, within the country, solar radiation is fairly well distributed. The annual average of total solar radiation varies from about 12.6- 28MJ/m2-day in the coastal latitudes to about 25.2 MJ/m2-day [4]in the far North,(Figs.1 and 2) and (Table1). Solar energy is renewable and its utilization is environmentally friendly. Consequently, when the availability and environmental costs of the utilization of other forms of energy are considered, the competitiveness of solar energy in comparison with these other forms becomes very evident, particularly for low to medium power applications. Solar radiation conversion technologies are generally either of the solar-thermal type (solar heating, cooling, drying, thermal power plant, etc.) or of the photovoltaic type (direct conversion to electricity). Areas of application of solar thermal technologies are crop drying, house heating, heating of process water for industries, hospitals etc, air-conditioning, preservation of foods and drugs, power generation, etc. Photo-voltaic (PV) power may be utilized in low to medium power applications and in remote areas, in such uses as communication stations, rural television and radio, water pumping, refrigeration etc, which require power of the order of 1-10 kW. It may also be used for power supply to remote villages not connected to the national grid. It is also possible to generate PV power for feeding into the national grid. Most solar-thermal technologies can be supported by the technical expertise existing within the country.

However the industrial infrastructure needs to be strengthened for effective utilization of the energy resource. Photovoltaic system components require more sophisticated technologies for their manufacture, particularly as regards the photovoltaic cells. Apart from traditional open air drying, solar energy technologies are not much used in Nigeria. Nevertheless they have tremendous potentials. Much work needs to be done in the development and popularization of applications equipment and systems, solar and environmental data acquisition and development of standards for materials, design and equipment manufacture. There is considerable potential for solar-powered energy service provision in Nigeria's rural communities, in the form of solar photovoltaic (PV) or solar thermal power. Nigeria lies within a high sunshine belt and, within the country; solar radiation is fairly well distributed. The annual average of solar radiation varies from about 12.6MJ/m^2 per day (3.5kWh/m^2)[5] in the coastal latitudes to about 25.2MJ)m^2 per day in the far north, (Table 1). This gives an average annual solar energy

intensity of 1934.5kWh/m^2 per year; thus over a whole year, an average of 6,372,613PJ/year (≈1,770,000TWh/year) of solar energy falls on the entire land area of Nigeria (Fig. 2). The major energy-consuming activities in Nigerian households are cooking, lighting and use of electrical appliances – in that order. Cooking accounts for a staggering 91% of household energy consumption, lighting uses up 6% and the remaining 3% can be attributed to the use of basic electrical appliances such as televisions and pressing irons [6]. Table 2 shows the Renewable energy Utilization Level-Solar energy.

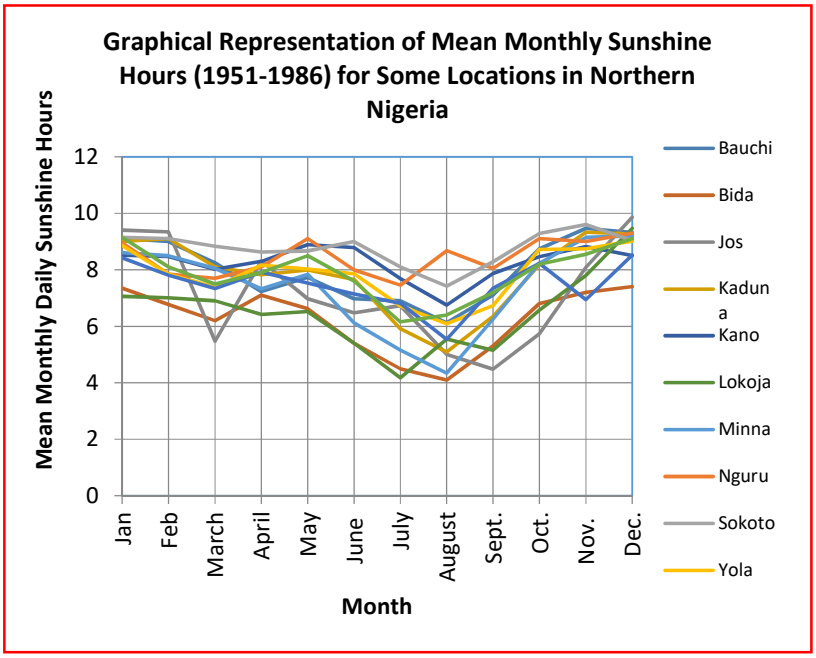

Fig. 1: Monthly Mean Daily Sunshine Hours (1951-1986)

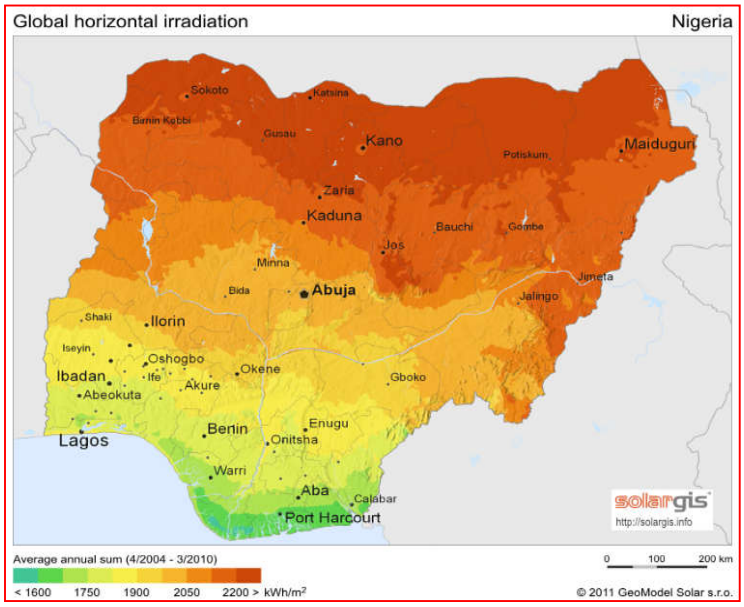

Fig. 2: Map of Nigerian solar irradiation

Table 2: Renewable energy Utilization Level-Solar energy

S/N	Resource		Reserve	Utilization Level
1	Large hydro power		11,250MW	1,900MW
2	Small Hydro power		3,500MW	64.2MW
3	Solar Energy		4.0 kWh/m^2/day 6.5kWh/m^2/day	15MW solar PV stand-alone No solar thermal electricity
4	Wind		2-4m/s at 10m height	2x2.5KW electricity generator; 10MW wind farm in Katsina
5	Biomass	Fuel wood	11 million hectares of forest and woodlands	43.4 million tonnes of firewood/yr
		Municipal waste	- 18.3 million tonnes in 2005* & about 30 million tonnes/yr now	-
		Animal waste	- 243 million assorted animals in 2001	-
		Energy Crops and agric waste	- 72 million hectares of Agricultural land	28.2 million hectares of Arable land only 8.5% is cultivated

Table1: Monthly Mean Daily Sunshine Hours (1951-1986)

	Stations	Jan	Feb	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
1	Bauchi	9.1	9	8.24	7.23	7.73	6.98	6.9	6.12	7.1	8.74	9.46	9.32
2	Bida	7.35	6.77	6.2	7.1	6.62	5.4	4.5	4.1	5.3	6.8	7.2	7.4
3	Jos	9.4	9.34	5.47	8.3	6.97	6.47	6.73	5.01	4.48	5.73	8.09	9.86
4	Kaduna	9	9.1	8.1	7.83	8	7.66	5.91	5.09	6.35	8.18	9.33	9.26
5	Kano	8.52	8.47	8.02	8.29	8.89	8.78	7.69	6.75	7.87	8.47	8.82	8.51
6	Lokoja	7.06	7.01	6.9	6.42	6.52	5.4	4.18	5.55	5.15	6.57	7.8	9.47
7	Minna	8.6	8.5	8.05	7.33	7.84	6.12	5.16	4.35	6.25	8.23	9.15	9.2
8	Nguru	8.95	7.85	7.7	8.1	9.1	8	7.45	8.68	8.05	9.1	9	9.3
9	Sokoto	9.15	9.1	8.83	8.62	8.67	9	8.1	7.42	8.28	9.28	9.6	9.03
10	Yola	8.86	7.85	7.38	8.17	8.03	7.86	6.72	6.09	6.73	8.72	8.74	9.02
11	Yelwa	8.42	7.81	7.34	7.91	7.53	7.15	6.82	5.54	7.35	8.23	6.94	8.52
12	Zaria	9.15	8.1	7.5	7.9	8.5	7.6	6.15	6.4	7.2	8.2	8.55	9.1
Average		**8.63**	**8.242**	**7.476**	**7.767**	**7.867**	**7.202**	**6.359**	**5.925**	**6.676**	**8.02**	**8.556**	**8.999**

3.0 Solar Energy Policies in Nigeria

Nigeria has a national energy policy document [7];[8]whose overall thrust "is the optimal utilization of the nation's energy resources for sustainable development." A critical assessment of the document however may place it as a well-crafted "energy policy guidelines " since it captured a large spectrum of government vision with respect to the energy sector in Nigeria but fails to deliver specific targets that are both measurable, predictable and achievable as well as timelines reminiscent of a sustainable energy policy system. Nigeria is naturally endowed with abundant renewable energy resources especially solar irradiation. A lot of potentials exist which can be adequately harnessed into useful energy. It is in this regard the energy policies take in consideration of solar energy development and articulated in it below policies, objectives and strategies.

3.1 Policies

i. The nation shall aggressively pursue the integration of solar energy into the nation's energy mix.
ii. The nation shall keep abreast of worldwide developments in solar energy technology.

3.2 Objectives

i. To develop the nation's capability in the utilization of solar energy.
ii. To use solar energy as a complementary energy resource in the rural and urban areas.
iii. To develop the market for solar energy technologies.
iv. To develop solar energy conversion technologies locally.

3.3 Strategies

i. Intensifying research and development in solar energy technology.
ii. Promoting training and manpower development.
Iii.Providing adequate incentives to local manufacturers for the production of solar energy systems.
Iv.Providing adequate incentives to suppliers of solar energy products and services.
v. Introducing measures to support the local solar energy industry.
vi. Setting up extension programmes to introduce solar technology into the energy mix.
vii. Providing fiscal incentives for the installation of solar energy systems.
viii. Setting up and maintaining a comprehensive information system on available solar energy resources and technologies.

4.0 Types of Solar Energy Systems

There are three general types of electrical designs for PV power systems:

- Off-grid stand-alone systems
- Mini-grid systems
- Grid-tie systems (some have battery backups and others have not).

4.1 Off-Grid Stand Alone Systems

Off-grid stand-alone operates independent of the electrical grid. Stand-alone PV (photovoltaic) systems are used when it is impractical to connect to the utility grid. Common stand-alone systems include PV-powered fans, lights, water pumping systems, portable highway signs, and power systems for remote installations, such as cabins, communications repeater stations, and marker buoys. Stand-alone systems also often incorporate battery storage to run the system under low sun or no sun conditions. Most solar PV projects in Nigeria are in this category (stand-alone)[9].

4.2 Mini-Grid Systems

A solar-PV-based system supplying a mini-grid would generate electricity and store it in a battery bank in a central location and then invert it to alternating current (ac) to supply consumers. A mini-grid system is a distribution network usually operating only at low voltage and providing electricity supply to a community. It can provide steady community- level electricity service, such as village electrification, offering also the possibility to be upgraded to either more capable systems or through grid-connection in the future. It has a total installed power of up to 100 kW (according to IEC) with distribution line in low voltage operating in either single or three phase distribution system. There are handful numbers of mini-grid solar PV projects in the country (used for rural electrification).

4.3 Grid-Tie Systems

A grid-tied PV system is a photovoltaic system interacting with the utility. It can be with or without batteries. A valuable feature of grid-tie or grid-connected photovoltaic systems is the ability to connect with the existing power grid and sell excessive electricity back to the utility with a plan known as "Net Metering"[10]. This system is yet to be installed in any part of the country.

5.0 Advantages of using Solar Photovoltaic electricity over other non-renewable energy sources

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:

- Generates free energy from the sun.
- Has no moving part to break down thus requiring minimal maintenance.
- Non-polluting energy reduces emissions (has no direct impact on the environment).
- Photovoltaic cells are modular, giving room for expansion from small systems.
- Systems have a long life and durability. Cells last up to 25 years.
- Grid-Tie systems allow you to sell excess electricity back to the utility
- Can be installed and operated anywhere including areas of difficult access and remote locations
- Make no noise and give off no exhaust
- Allow the use of electricity in remote areas where it would be expensive or impossible to run power lines
- Have electrical power during blackouts

Solar photovoltaic electricity is used in the following areas: lighting; water supply; communications; healthcare; agriculture; satellites and transportation.

6.0 Applications of Solar Energy in Rural Areas

Solar energy in rural areas of developing countries has made significant inroads for household lighting and entertainment. Although electricity certainly provides improvements in the quality of life through these household applications, it is the "productive uses" of electricity that can increase incomes and provide development

benefits to rural areas. As incomes increase, rural populations are better able to afford greater levels of energy service, which can allow even greater use of solar energy. The major emerging productive uses of solar energy in the rural areas include the following:

- Rural electrification
- Rural water projects
- Battery charging
- Health care delivery
- Agriculture
- Education
- Cottage industry
- Community Services
- Domestic Uses

6.1 Rural Electrification by Solar Power

Renewable Energy technologies like solar PV power can be used in implementing rural electrification projects[11]. There are cases where more than one source (hybrid systems) (Fig. 3), which can also be utilized to execute such projects. Solar energy PV power projects have been implemented in many countries of the world and they have proven to be very efficient. They are either be used to power dc appliances alone or utilize inverters to enable the use of ac loads. In cases like this, the entire community is supplied from a centralized source or sources as the case may be (Fig 4-8).

Fig.3: 4Kw Wind power integrated with 10kW Solar power in Danjawa Sokoto

Fig. 4: 5kWSolar PV Plant in Nassarawa state

Fig. 5: 3kW Solar PV Plant at Gassol LGA in Taraba State

Fig. 6: 3kW solar PV mimi-grid in Talasse General Hospital, Balanga LGA, Gombe State (2013)

Fig. 7:3kW Solar PV mini Grid for Electricity at Igu Community Bwari, FCT, 2012,

Fig.8: Village electrification with solar power Bank of Industry Project at Ebonyi

Rural electrification policies and programs using solar energy continued to emerge and progress. New rural electrification programs using solar energy for mini-grid access started in pilot project by the Energy Commission of Nigeria (ECN) [12] and is now spring up by private sector and international donor especially UNDP, UNIDO, GIZ. ECN- GIZ has recently rollout a program called "Electricity for living with dignity" targets rural homes, with a goal to increase the electrified rural population percent especially those from remote Village. Electrification Program continued to achieve steady progress. By early 2009, a cumulative total of installed capacity of PV is recorded in Nigeria. Rural applications of solar PV in Nigeria has increased to more especially in home lighting systems, also many solar lanterns distributed, and solar-power water pumps were installed (Figs. 9-10). There were some hand full of solar cookers in use and mini- off-grid power generation in rural areas in Nigeria Fig. 10. Nigeria recently proposed to augment cooking, lighting, and motive power with solar energy in rural villages by reasonable percentages by 2032, starting with remote un-electrified villages the project is under taken by Federal Ministry of Power, Works and housing [8].

Fig.9: Solar powered borehole at Arimgoria, Ogun State

Fig.10: Solar PV powered Water Borehole in Abule Kajola, Akute, IFO LGA, Ogun State

6.1 Domestic Uses

The use of solar energy for cooking and other domestic purposes has a lot of positives effects both on the environment and on the users. Solar energy application has made it possible to replace that means of cooking with inefficient stoves that utilize from biomass.

6.1.1 Lighting

Lights for several applications are powered by solar PV. From our homes to the streets and roads, parking lots etc. Anywhere light is needed, solar PV can be used to supply the needed energy to power such lights (Figs. 11-12).

6.1.2 Cooking

There were some hand full of solar cookers in use (Figs. 13-14).

Fig.11: Solar PV Street light in Ido Oyo State,

Fig.12: Solar PV Street light, Yola, Adamawa State

Fig.13: Solar Cooker

Fig.14: Solar Cooker

6.2 Rural Water Projects

Water is an essential basic requirement for life. Its availability however is a serious issue in our country especially in the rural communities where many have to go long distances in search of consumable water. Solar powered community water projects (boreholes) provide a solution to this problem of water scarcity in rural areas. Many solar project has been installed in many part of Nigeria (Figs. 15-16). Water is a basic

essential life need which is a problem to developing countries like Nigeria. Provision of potable water is a difficult task for our governments. Solar PV can be used to supply energy to pump water in the various water supply works. A lot is being done in this line in the country by the Energy Commission of Nigeria and other government and private organizations- the use of solar-powered boreholes[13].

6.3 Battery Charging

Solar modules can be used to charge batteries that the users take home to power appliances providing different services (lighting, entertainment, etc). Photovoltaic Battery Charging Stations (PV BCS) are small power plants run by PV modules designed to charge batteries. This will not only provide charging points, it also has the capacity to generate employment as many people can depend on battery charging as a means of livelihood (Fig. 17).

Fig.15: Solar water Borehole

Fig.16: Solar water heater

Fig.17: Solar Battery Charging

6.4 Health Care Delivery

Rural health service is an important national and international priority. It is said that health is wealth; however, the availability of electricity to support proper rural health services is less than adequate in Nigeria[14]. Consequently the use of renewable energy

will make it possible to enhance provision of vaccines and other basic health care services in remote areas. Such energy will power lighting, fans, solar refrigeration, radio and telecommunications, medical appliances (such as microscope, centrifuge nebulizer, oxygen concentrator etc), sterilization, and water treatment for such health centres (Fig. 18-20). Solar PV can be used in health centres either as the main source of energy or as back-up. Especially in areas where there is no grid, Solar PV serves as the source of energy to help power DC refrigerators that are used for the storage of vaccines and other drugs that need such condition. Sterilization can also be done using this source of energy. In places where, Solar PV is used as back-up, it helps in cases of emergency, for example, when surgical operations are being carried out and there is a power failure, the solar system switches on automatically (depending on the connection).

Fig.18: Pilot Water Heater at UDUTH by SERC, at Maternity Hospital, Sokoto

Fig.19: Solar-Powered Refrigeration for drugs in clinic

Fig. 20: Solar Water Heater installed at the Sokoto State Governor's House by SERC

6.5 Agriculture

Agricultural activities characterize the people living in rural areas in the country and renewable energy can be used to boost such. For example irrigation can be made easier with the use of solar-powered irrigation pumps which will definitely have a positive effect on productivity. Also, in food production renewable energy can be employed for water pumping for animals[15], electric livestock fences, and aeration pumps for fish and shrimp farms, egg incubators, and refrigeration for storage. In addition, in the aspect of food processing, renewable energy is useful for meat and fish drying, plant/seaweed drying, spice drying and cereal grain processing, coconut fiber processing, grain mills[16]. Furthermore, lighting of farm settlements can be powered

using renewable energy systems. Irrigation and other farm energy needs can be supplied with the use of Solar PV. This makes solar PV very relevant in agricultural applications because mostly farms are located away from the reach of grid lines hence the necessity of applying solar energy to cater for the energy needs of the farm centres (Figs. 20- 24).

Fig.21: Rice dryer

Fig.22: solar dryers

Fig.23: Rice dryer

Fig.24: solar dryers

6.6 Education

Education is another sector that employs the use of renewable energy technologies. One of the ways of improving the education of the rural dwellers is the use of Information Technology Education (Computer Education)(Fig. 25). This will expose them to the use of computer and other related devices in information technology. Solar PV can be used to supply the needed power by these computers and will even lead to the establishment of cyber cafes in the rural areas. As well, locating solar PV technology on schools is an excellent way to raise energy awareness in a community. Schools are community gathering places, and locating a renewable energy project in such a centralized location can improve the profile of renewable energy and conservation in general.

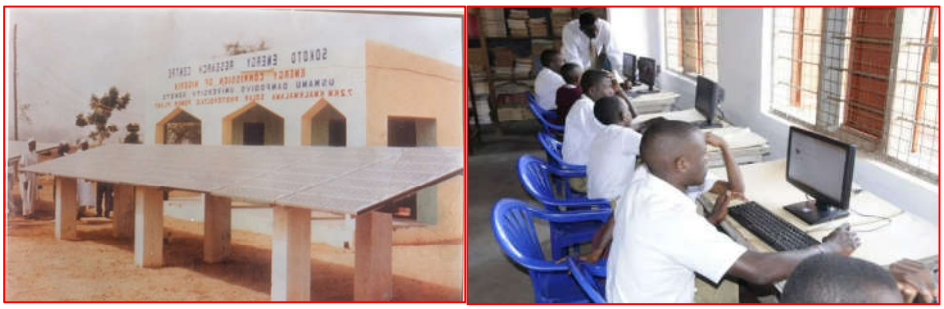

Fig 25. 7.2 kWp Village Electrification Solar-powered computers at School in, Sokoto State

6.7 Cottage Industry

Solar Energy can be applied in cottage industry in places like bakeries (oven), brick making, carpentry (power tools), electronic repair (soldering irons), handcraft production (small electronic tools) and sewing. See fig

6.8 Community Services

Streetlights, town halls and other residential houses can all be powered by renewable energy source. Either as stand-alone or mini-grid systems. Renewable energy in rural areas of developing countries has made significant inroads for household lighting and entertainment. Broadcast media, village cinema, and fax can all be powered with the use of renewable energy (Fig. 26).

Fig 26.The Church at Night: Members listening to the Pastor's Message via Solar PV Driven Satellite Dish.

6.9 Communications

Base Stations of mobile communication companies can be powered using Solar PV. The good thing here is that it will supply continuous energy without the fear of blackout or fuel finishing. Furthermore radio communications can be powered using solar PV.

6.10 Satellites

Space satellites are powered with the use of Solar PV. PV has traditionally been used for electric power in space. We can remember that the Nigeria's satellite that disappeared in space had problem with its solar power systems. The use of solar PV to

6.10 Transportation

Solar PV is being used increasingly to provide auxiliary power in boats and cars. A self-contained solar vehicle would have limited power and low utility, but a solar-charged vehicle would allow use of solar power for transportation. Solar-powered cars have been demonstrated (Fig. 27).

Fig. 27 Solar car build by Student at UNN

7.0 The Role of Solar Power in Minimizes Rural-urban Migration

The application of renewable energy technologies in the rural areas has the capacity to halt the massive migration of people from such places to the urban centres. Some of the ways in which the use of these technologies positively affects the rural areas are discussed below:

7.1 Improving Standard of Living

Having looked at how renewable energy can be applied in the rural area, one paramount thing that catches our attention is that if technologies are deployed to the rural areas in the mentioned areas, the standard of living in such places will have changed drastically. Access to energy has a way of increasing the rate of development, therefore the more our rural areas have access to energy, the more their standard of living improve. The overall effect being the willingness of these rural dwellers to stay back at home without thinking of moving on to urban centres where they feel they can "make it". This is because people migrate to urban centres primarily for the reason of finding greener pastures and to live in a better way so once the things they rush to the urban centres to have are put in place in their remote communities, they will be encouraged to stay back and engage in productive activities bearing in mind that the cost of living in rural areas are by far less than that obtained in urban centres.

7.2 Women Empowerment

Poor women in rural areas of Nigeria generally have a more difficult time compared to men due to their traditional socio-cultural roles. They often spend long hours collecting fuel wood and carrying it back home over long distances. The time and labour expended in this way exhausts them and limits their ability to engage in other productive and income-generating activities. Their health suffers from hauling heavy loads of fuels and water and from cooking over smoky fires. Their opportunities for education and income generation are limited by lack of modern energy services and as a result their families and communities are likely to remain trapped in poverty[17].

Shifting to renewable energy will positively impact women's health as they will no longer be exposed to smoke and carbon monoxide when they cook as it is with wood and charcoal. Renewable energy will also alleviate the drudgery of fuel wood collection and promote women's empowerment. Shift to modern energy for lighting, cooking and productive activities will positively impact women's literacy, education and economic activities. Particularly, education of women is known to produce powerful effects on nearly every dimension of development, from lowering fertility rates to raising productivity to improving environmental management[18].

7.3 Employment Generation

Many businesses thrive only when there is availability of energy. In other words, energy access increases productive activities. This means a lot of people in the rural areas will engage in businesses that will make them gainfully employed. Examples include: battery charging business; solar installations maintenance; GSM business; Cinema business, cyber cafes and business centres; sewing, baking, etc will all spring up and

thrive. Businesses can now operate even to the night hours because there will be light to light up the business premises.

8.0 Present Utilization Level of Solar Energy in Nigeria

Solar energy has been utilized in Nigeria in various forms: namely, solar PV for rural electrification and solar pumping systems; solar thermal in form of solar cooker, solar crop dryer, solar manure dryer, solar water heating, solar chick brooders etc.
Notable solar projects in Nigeria include:

- Solar street lighting in various parts of the country.
- Village rural electrification projects of various capacities in some parts.
- Solar water pumping scheme of different capacities in various parts of the country.
- 5. 2-tonne Solar Rice Dryer, Adani, Enugu State.
- 7.2kWp village electrification at Danjawa Village, Sokoto State,
- 5.5kWp solar photovoltaic plant at Laje, Ondo State,
- 3kW solar PV mimi-grid in Talasse General Hospital, Balanga LGA, Gombe State (2013)
- 5kWSolar PV Plant in Nassarawa state
- 3kW Solar PV Plant at Gassol LGA in Taraba State
- 3kW Solar PV mini Grid for Electricity at Igu Community Bwari, FCT, 2012

Generally, about 36 states and the Federal Capital Territory, Abuja has one or the other impacted by solar projects either sponsored by the government (Federal or State) through the Energy Commission of Nigeria (ECN) or other relevant agencies. With the world attention now shifting towards renewable energy due largely to the environmental effects of the exploitation of the convectional energy resources and the restive nature of the Niger Delta youths, there is a very high prospect that solar energy will experience more patronage from the government in the nearest future. The major constraints to the expansion of solar utilization in Nigeria are:

- Cost: Solar energy technologies and its deployment are very expensive. The cost of importation of the various parts is also very high.
- Some of the parts are not locally available as they cannot be manufactured locally.
- Government policy on the deployment of renewable energy technologies is not comprehensive and investors friendly.

Nigeria is blessed with abundant resources like the rivers and dams that have great potentials for hydro power generation. The two major rivers in Nigeria are River Niger and River Benue, of which there are others that have links with them in one way or the other and dam for electricity generation. The Nigerian government has established seven river basins along the major rivers in the country with each having hydropower potentials. Most of the potentials are however undeveloped. The Total Installed Capacity of the currently generating plants is 7,870MW, but the installed available capacity is less than 4,000MW. Seven of the fourteen generation stations are over 20 years old and the average daily power generation is below 2,700MW, which is far below the peak load forecast of7, 870MW for the current existing infrastructure [11]

and as a result, the nation experiences massive load shedding. Also, there is high potential for growth in sustainable energy development because of the opening of the energy sector for private sector participation from the ongoing reforms, particularly the electricity subsector which is backed by law. Likewise no hindrance to repatriation of profits as an incentives to investors and with some fiscal and financial incentives are available for sustainable energy development. Nigeria also, has a large local energy market as well as serves as a hub for the sub region

9.0 Why Solar PV Projects Fail In Nigeria

There is a noticeable high incidence of solar PV project failure in the country and a lot of factors are responsible for that. This has become a problem in the country and many are beginning to feel disgusted with solar PV projects as the heavy investments in such projects do not seem to be commensurate with their performances and satisfactions derivable Several solar PV projects being installed in various parts of this country fail to meet the minimum life-span due to a number of limiting factors. These include:

- Poor or improper fundamental design
- Use of sub-standard components
- Adoption of poor installation procedure by inexperienced personnel
- Bad construction/civil works
- Poor maintenance culture

9.1 Poor or Improper Fundamental Design

Just as the foundation of a building is very important to that building, so is design to solar PV project. If the foundation of a building is faulty, then the building will definitely have problems. In like manner, if the design process of a solar PV project is wrongly or improperly done, the project will experience performance problem after execution. Before designing a solar PV system, basic information (data) are required: solar irradiation for that site; and the load estimate. Common mistakes associated with design include: overestimation of irradiation figure; under-sizing PV panels; insufficient battery capacity or wrong battery type selection; and underestimation of energy demand.

9.2 The Use of Sub-Standard Components

One thing commonly observed with Nigerians is cutting of corners. This has led to so many badly executed projects in the country not only in the solar aspect. Instead of going for internationally accepted products, some contractors and project executors prefer to save cost by arranging for system components with low quality. One wonders why some products are only manufactured for sales in Africa and not in EU countries. So the use of poor quality system components will adversely affect the performance of that system once it is commissioned. No wonder some of the solar PV projects we see around pack up almost immediately after completion of installation and commissioning. We need to beware of some products manufactured from China.

9.3 Adoption of Poor Installation Procedure by Inexperienced Personnel

Another cause of failure in solar PV projects in this country is the adoption of poor installation procedures by personnel many of which lack the technical capability to carry out such installations. One important factor to be taken into consideration while carrying out a solar PV project is the determination of the angle of inclination of the panel. This is very fundamental as it determines the amount of insolation the panel receives. Many ignore this and you see a lot of panels placed flat without tilting to an angle (corresponding to latitude of that point) and this hampers the performance of such panels. The use of compass is a must in this regard albeit some of those carrying out installation either do not have or cannot even use them. Furthermore, setting of charge controllers is another problem that inexperienced personnel cause to Solar PV projects. Once there is a problem with the charge controller setting, it will affect the entire system performance. These are problems that make solar PV systems to perform abnormally and ultimately fail.

9.4 Bad Construction/Civil Works

Another issue bedeviling solar PV project implementation in Nigeria is the attitude of constructing poor support and bad civil foundation for these projects. Irrespective of the mounting type, every solar panel needs a very strong support structure that will hold it up high the absence of which threatens its safety. For example, when executing solar street light projects, if the foundation and the poles are not strong, they can easily be uprooted by wind storms or careless drivers. This is a common scene because in order to minimize cost, contractors prefer doing foundations and steel support structures that will maximize their profit thereby executing projects that easily fail (collapse).

9.5 Poor Maintenance Culture

Maintenance is another serious issue with Nigerians. Some solar PV projects fail due to this attitude exhibited by us. When there is no adequate and proper maintenance of such a project, then it will definitely perform less than expected. In case of Solar PV projects, the maintenance activities are actually light, for example, cleaning of panel surface, and replacement of used-out components. However, such activities are hardly carried out thereby leaving these projects appearing as failed-projects.

10.0 How to Implement Standard Solar PV Projects

It is very possible and easy to execute solar PV projects in Nigeria that will be of international standard and lasting as specified. From stand-alone to mini-grid and grid-tie systems, execution can be done in Nigeria like in any other developed country. If things are done the right way, without cutting corners then we are sure of implementing solar PV projects that will be to the delight of every one. In this regard, there are basic things that must be put in place in order to get a standard solar PV project implemented. They include the following:

- The use of technically sound personnel
- Gathering design data (solar irradiation and load)
- Comprehensive system design

- Use of high quality system components
- Use of high quality support structure and good civil work
- Following standard installation procedure
- Proper maintenance

10.1 Technically Sound Personnel

There is basic technical knowledge required in the implementation of Solar PV projects. In order to get standard projects executed, those involved must have the basic technical knowledge and expertise. This is very fundamental and necessary in every step of the project implementation right from design to final installation. Putting a round peg in a square hole will have attendant consequences hence the need to get round pegs put into round holes in this industry if we want to make progress.

10.2 Gathering Design Data

Data are very necessary in designing a PV system hence assumptions must be minimized and precise data utilized in order to obtain a working system that will perform as expected. Balance of energy must be done and weather data acquired with detailed load and demand data in order to design a good system and because of variation in irradiation within a region or country, figures for Abuja cannot be used for Enugu or Yenangoa.

10.3 Comprehensive System Design

After getting the necessary input data, the next thing is the ability to properly utilize the data to design the system comprehensively. This stage needs technical expertise and carefulness because a lot of things are put into consideration beside the acquired data. Furthermore, long term weather data and efficient loads must be considered amongst other things. It is important to get the correct sizing of components as this will determine the system performance so a system that will be of standard must have its design properly and correctly carried out.

10.4 Use of High Quality System Components

Anything that is worth doing is worth doing well. There are companies that are known for manufacturing high quality solar system components which are sold all over the world. We must refuse to accept components that cannot be sold or used in Europe. Nigerians must stop liaising with some manufacturers to manufacture less quality products. For us to get standard PV projects implemented, standard system components must be utilized.

10.5 High Quality Support Structure and Good Civil Work

Base foundations for all PV projects and their support structures must also be of high quality if we must get standard projects done. Any good work that does not have a strong structural support will not stand the test of time as rain storms and vehicular accidents will knock them off before their time. So we must imbibe the spirit of quality assurance in every aspect of the implementation of such projects in order to see that the projects survive their lives spans.

10.6 Following Standard Installation Procedure

There are procedures to follow while carrying out installation of PV projects. If they are properly followed, the chance of having a standard project is high. For example, for battery installation, the best position is to be housed underground to avoid high temperature. Also, for panel mounting, there is a specified angle of inclination towards the south (for places in northern hemisphere like Nigeria) for each location. All these are part of the procedures that must be followed in order to achieve standard.

10.7 Proper Maintenance

The place of proper maintenance in ensuring longevity of a project cannot be overemphasized. For a solar panel to work effectively for 20-25 years, it must be cleaned regularly in order to remove dusts and other particles that will prevent insolation. Same applies to the other system components. Once any of them runs out, or goes bad, they should be properly replaced. If we imbibe a good maintenance culture, the failure rate of PV projects in the country will reduce drastically.

11.0 Conclusion

Solar PV projects are worth their investments only if they are implemented in a standard way so that they will perform maximally. A lot of poor work has been implemented in the country in this aspect but we cannot fold our arms and let the trend continue. It is time to rise up and say no to sub-standard PV projects in the country and imbibe the right way of executing standard solar PV projects.

Nigeria is striving towards becoming one of the 20 strongest economies in the world come year 2020.This vision needs a lot of efforts in order to get to the target and one area the country must seriously look at is the scaling up of solar PV projects in the country and ensuring that such projects are implemented in accordance with international best practice in this sector. The challenges confronting PV industry in the country can be overcome and all hands must be on deck in order to achieve this. Implementation of standard solar PV projects in the country has a lot of advantages to the country's economic and industrial growth- the greatest advantage being increased energy access. Something must be done to correct the impression that PV projects are not worth the investments and the thing to be done is to shun sub-standard work and embrace the pathway of standard project implementation.

In line with the foregoing, we will like to recommend the following measures in order to help achieve standard in the implementation of solar PV projects in Nigeria:

- **Development of Standards Code**: Standards code for solar PV system components should be developed by the Standards Organization of Nigeria in conjunction with relevant agencies and bodies like the Energy Commission of Nigeria, NERC, and NSE. This will go a long way in regulating the kinds of products that come into this country.
- **Capacity Building**: There should be more training of manpower that will handle solar PV-related issues. The Federal Government should financially

empower the Energy Commission of Nigeria to set up Special Training Centres on solar PV technologies in the country in partnership with foreign counterparts.

- **Warranty on products**: The distributors of solar PV components in Nigeria should ensure that such products have warranty. If someone is buying a battery for example, he should be sure that the battery will work for a certain number of years failure of which the supplier will replace. Consumer Protection Council has a role to play here.
- **Holding Contractors Responsible**: All contractors who execute sub-standard projects should be held accountable by those who award such projects. Such contractors should be made to either go back and do a thorough job or have their contracts cancelled and make to refund money collected for such projects and should not be given such projects again by any agency.

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