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Adoption of Solar Energy Systems in Remote and Rural Communities of Nigeria (A Review)

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Abstract:
Continuation of the use of fossil fuels is set to face multiple challenges; depletion of fossil fuel reserves, global warming and environmental concerns. These problems indicate an unsustainable situation. A renewable energy resource such as solar energy that is free, abundant, inexhaustible and environmentally friendly is the solution to the growing energy challenges in our remote and rural communities, and the world at large. This article highlights the Nigeria's solar energy potentials, energy needs in rural areas and energy consumption pattern in rural areas. The paper also reviews the solar energy systems ready for local adoption and thereafter put forward essential ingredients that will promote the adoption of the readily available solar energy systems in the remote and rural communities of Nigeria.

Keywords: *Adoption, desert encroachment, depletion, energy, fossil fuels, renewable*

1. Introduction

Energy in its various forms is essential to life. The development of any society is heavily tied to adequate supply of energy, as it is essential to the means of other indices of developments, namely transportation and communication. In addition to sustaining of life, energy is of fundamental important in man's attempt to control nature. Perhaps, energy resources can be regarded as the most important of all resources (man, money, machines, material, etc.) in the socio – economic development and economic growth of any Country.

The objective of energy system is to provide energy services. Energy services are the desired and useful products, processes or services that result from the use of energy, such as for lighting, cooking, provision of air-conditioned indoor climate, refrigerated storage, transportation etc. The energy chain to deliver the above cited services begins with the collection or extraction of primary energy, which is then converted into energy carriers suitable for various end uses. These energy carriers are use in energy end-use technologies to provide the desired energy services (Sambo, 2005).

Energy is at present derived mostly from material occurring in or on the earth surface, although non-material (renewable) sources of energy such as sunlight source is yet to be fully tap on a large scale. Energy exists in different forms, viz: - mechanical, electrical, chemical, fission, biomass, geothermal, solar etc. This various forms of energy are further categories into three, namely fossil; fuels, nuclear and renewable that is employed worldwide to meet human energy requirements (Muye, 2003).

Currently, a high proportion of the world's total energy output is generated from fossil fuels such as coal and oil. The 2002 statistics of International Energy Agency shows that 80% of the world primary energy demands are met by the fossil fuels. Fossil fuel, in their various forms (coal, oil, natural gas, wood, natural waste, peat, etc.) have been the main source of energy supply and have served the human needs for thousands of years. Fossil fuels are also sources of chemical substances used, other than as fuels, in the manufacture of goods such as plastics or chemicals for agriculture and animal foodstuff. This employed energy system will be unable to cope with future energy requirements as their reserve are depleting and it is only a matter of time before their reserves become exhausted. Estimates of reserves of fossil fuels all reach the same conclusion. Extended use of these reserves worldwide, in the current manner will continue for no more than some decade to come. Fossil fuels production and consumption is closely linked to environmental degradation that threatens human health and quality of life, and affects ecological balance and biological diversity. These problems associated with the continued use of fossil fuels indicate an unsustainable situation (Asif and Muneer, 2005).

Solar energy is the energy obtained directly from the sun and is the most promising of the renewable energy sources in view of its apparent limitless potential. The sun radiates its energy at the rate of about 3.8E26W per second at about 6000 km from the earth surface. Most of this energy is transmitted radially as electromagnetic radiation which comes to about 1.7E17W permeter square at the boundary of the atmosphere (Sambo, 2005).

Solar energy is a very clean, non-polluting, safe to use, renewable source with endless supply that belongs to no one and have the potential to provide energy services with zero emissions of both air pollutants and greenhouse gases. It is distributed over the entire surface of the earth facing the sun, though works best in sunniest, often the poorest parts of the world and can be utilized without long term intermediate storage. It is flexible, dovetails with other clean systems and its modular- systems can be resized (Rai, 2004).

Even though solar energy has been called a non-conventional source of energy, all fossil fuels, winds, clouds, hydroelectric generators and ocean waves have their energy directly or in directly from the solar radiation. Solar energy has developed to a point where it can replace most of the fossil fuels in many applications. It is already economical and it is a matter of time before it becomes economical for other applications.

Solar energy technologies are divided into two broad group's namely solar thermal and solar photovoltaic. In solar-thermal applications, solar energy electromagnetic waves is first converted into heat energy and then used either directly as heat or converted into cold or even electrical or mechanical energy forms. Solar-thermal applications are used in drying, cooking, heating, distillation, cooling and refrigeration as a well as electricity generation. in thermal power plants. In solar photovoltaic applications, the solar radiation is converted directly into electricity, commonly through the use of silicon solar cells.

The method of using solar radiation for modern application involves collection, conversion, storage, and control uses as neat or electricity. The available solar collector systems may be broadly classified as flat-plate and concentrating collectors. Concentrating collectors which are usually employed for high temperatures often requires serious attention for their operation. The straight toward arrangement is the flat plate collectors which is more appropriate tor rural areas. The basic components of flat plate solar collector are; a heat transfer medium (working fluid) like air or water; an absorber usually a dark thermal conducting surface to absorb as much as possible of solar radiation incident, re- emit as little as possible and allow efficient transfer of heat to the working fluid; a trap for thermal re-radiation such as glass for the purpose of reducing heat loss by convection and to transmit shorter wave length solar radiation and block the longer ones; and an insulator to minimize heat loss from the back and side of the collector. For applications requiring high working fluid, a fan or pump is used to blow or pump the working fluid through the collector

The Utilisation of solar heat collection systems for producing electrical or mechanical power using thermodynamic heat engines has been confirmed to be technically feasible and a large number of real life systems have been constructed in several countries. However, the costs of using solar energy for power production, and for the development of both small and large scale solar thermal power systems are high, and the systems cannot compete in heavily populated urban cities or areas serviced by a National grid electrical power distribution system. But, in most remote and rural communities where the costs associated with providing power may be five to fifty times of those in metropolitan areas, solar thermal power generation schemes are already cost effective (Sambo, 2005).

2. Nigeria's Solar Energy Potentials

Solar energy has considerable potential in Nigeria, and could bridge the major energy gaps in rural areas, particularly northern Nigeria (Newsom, 2012). Nigeria is endowed with daily sunshine that is averagely 6.25 hours, which is ranging between about 6.25 hours and 3.5 hours northern region and southern region of the nation respectively (Bala, et al, 2000).

Nigeria receives about 4909.212 kWh of energy from the sun which is equivalent to about 1.082 million tons of oil; this is about 4000 the current crude oil production per day, and also put at about 13 thousand times of daily natural gas production based on energy unit. Also, if solar energy appliances with just 5% efficiency are used to cover only 1% of the country's surface area, then 2.54 X 10^6 MWh of electricity can be obtained from solar energy. This amount of electrical energy is equal to 4.66 million barrels of oil per day (Usman, 2012).

Solarradiationis fairly distributed in Nigeria, almost everywhere is suitable for solar PV application with potential ranges between 3.5 – 7.5 kWh/m^2/day with peak radiation at north eastern part of the country. Northern Nigeria with the minimum direct normal irradiance in the range of 4.5 – 7.5 kWh/m^2/day as shown in Fig.1 has met the minimum DNI threshold of 4.1 – 5.8 kWh/m^2/day needed for economically viable CSP project.

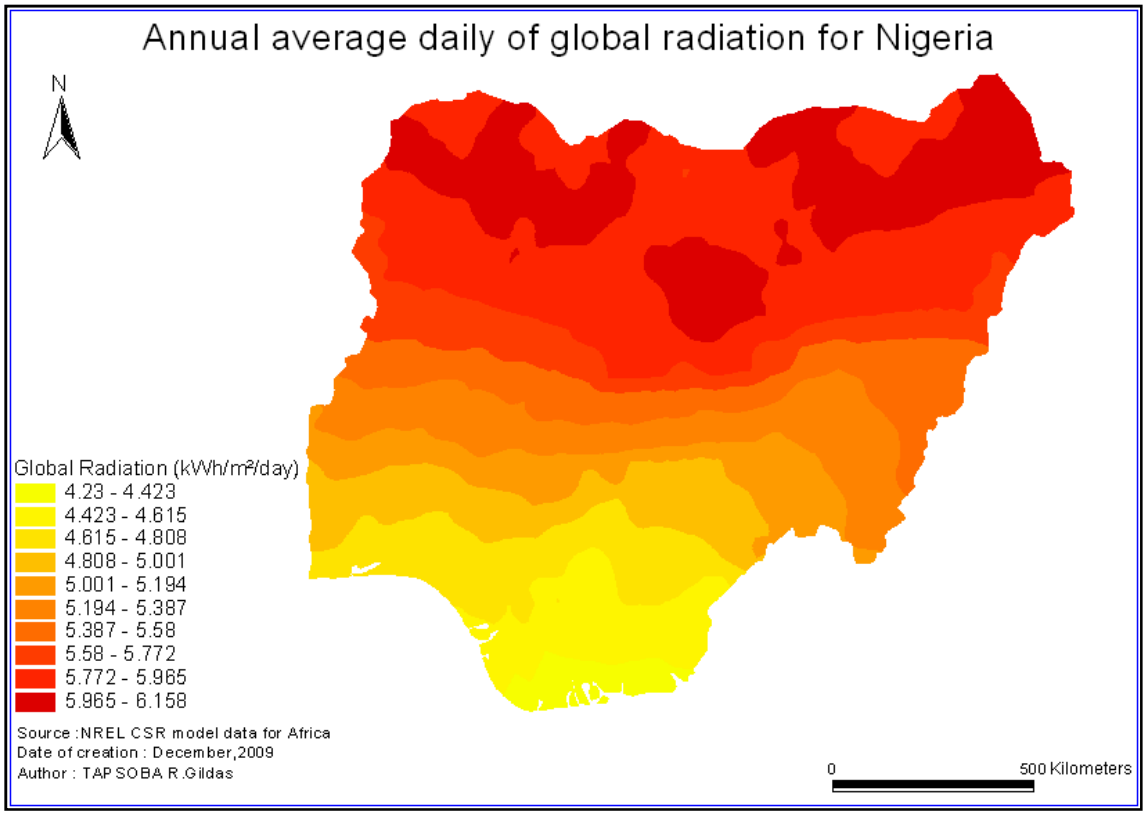

Figure 1: Map showing DNI of towns in Nigeria.

Many studies have been conducted to ascertain the potential of operating Solar PV and CSP plants in Nigeria. These studies have fully indicated large scale CSP plants and off – grid Solar PV systems can be deployed to the Northern part of the country for sustainable electric power generation (Habib, et al, 2012; Usman, 2012; Olumide and Andrew, 2013).

Habib, et al, 2012 examined the Nigeria's Solar PV and CSP potentials for sustainable electricity development. The study presented the potential CSP capacity of fourteen selected states in Northern Nigeria which indicates high potential. The potential electricity production and CSP capacity of the selected states was put at 26,841 TWh/year and 427,820 MW. The paper highlighted challenges affecting CSP development in Nigeria to include; high initial investment cost as compared to conventional plants of same output, lack of indigenous manufacturing companies, lack of trained personnel to install and maintain existing equipment, low system efficiency compared to conventional plants, and lack of adequate storage technology for the operating plants.

Usman, 2012 provides a comprehensive review on renewable energy potentials and distribution for rural development. The paper recommended that amongst others; establishment of renewable energy funding machinery agency that will fund and finance renewable energy projects in the country, and creation of enabling environment to attract investment in renewable energy sector.

Olumide and Andrew, 2013 analysed the CSP technology and its potential contribution to electricity supply in Northern Nigeria. The results discuss in the study shows that subsidy and low domestic price of gas in the country will continue to distort the enabling market and also create a barrier to renewable energy. In order to encourage renewable energy technology such as CSP, the paper recommends putting up of strategies to phase out blanketed subsidy and review the domestic prize of gas in place.

A study on simulation of molten salt solar tower CSP plant behaviour in three cities in Northern Nigeria carried out by Muye et al, 2015 indicates that the CSP plant can favourably operate in the region of study with annual electrical energy generation of 89 GWh, 106 GWh and 112 GWh in Minna, Kano and Sokoto respectively. Also, the LCOE values for the CSP plant at Minna, Kano and Sokoto sites are 0.272 US $/kWh, 0.221 US $/kWh, and 0.220 US $/kWh respectively. These LCOE values are lower than the Feed – in Tariffs (FIT) for solar energy generation in Nigeria for 2013 (0.425 US $/kWh). This implies that over the life time of the projects, the project will break even.

There are evidences of development of large numbers of solar energy systems in Nigeria as a result of research and development activities that have been undertaking in the universities and Energy research Centres; thus, many are ready for adoption into the economy. Even though Solar photovoltaic technologies are gaining increasing acceptance in Nigeria as it's showing increasing promise in terms of efficiency improvements and costs,and despite improvements in local R&D effort, the body of knowledge on these technologies and their market potentials is considerably inadequate.

Solar PV systems can be extensively used for a wide range of electrical energy requirements, including solar home systems, water pumping, refrigeration and telecommunications that will reduce the load curve of electricity demand. These applications have positive social and economic impact on the lives of individual users, businesses and local communities that are not connected with the national power grid.

3. Energy Needs in Rural Areas

In general, the energy needs according to Sambo (2005) in remote and rural communities of Nigeria can be categorized as follows;

3.1. Household Needs

Energy is needed in the household for;

i. Cooking,
ii. House lighting,
iii. Water pumping and distribution,
iv. Television and radio powering, and
v. Water heating and refrigeration.

3.2. Agricultural Production

Energy is needed in agricultural production for;

i. Water pumping and distribution for irrigation,
ii. Operation of various agricultural equipment/implements,
iii. Processing and storage of agricultural products, and
iv. Drying of products.

3.3. Community Needs

Energy is needed for community use in the:

i. Hospital,
ii. Clinics,
iii. Schools,
iv. Barracks, and
v. Prison houses

3.4. Industrial/Commercial Needs

Energy is needed for industrial/commercial in;

i. Small and medium industries, and
ii. Business establishments (shops, banks, restaurants, bakeries etc.)

4. Energy Consumption Patterns in Rural Areas

The survey report on energy consumption pattern in rural areas in Nigeria carried out by the Sokoto Energy Research Centre in 1991, at the instance of Energy Commission of Nigeria of 55 Local Government Areas in Niger, Kano, Katsina and Sokoto State as well as in Federal Capital Territory, Abujashows that all sectors of the rural areas namely household, agricultural, industrial, transport and service depend on fossil fuels ranging from fuel wood to petroleum products such as petrol and diesel for cooking, heating, lighting, agricultural production, bakery, steel work, ceramic/pottery work, and as fuel for saloon cars, buses, trucks and lorries. From the report there is no evidence of the use electricity from Power Holding Company of Nigeria in the remote villages. Evidence of the use of Electricity in some few villages provided by the State Electricity Boards (REB) is recorded in the household sector for lighting and heating and in the services sector for lighting, sterilizing of appliances and storage of drugs as well as vaccines. The absence of Mains electricity from Power Holding Company of Nigeria in the rural areas may not be unconnected to the high costs associated the extensions, as well as the maintenance of the power grid system to the rural areas. According to ***Charters (1985)*** "the costs of grid extensions will vary from country to country and will be heavily dependent on the system used, the length of connection required, the type of topography, the usage pattern and the load factor of the supply point"

5. Solar Energy Technologies Ready for Rural Adoption

There are large numbers of solar energy devices that were developed by Nigerian researchers in different part of the country and these devices are ready for adoption into the economy especially in rural remote areas (Usman, 2012).Evidence have shown that solar photovoltaic applications have wider current installation in the country and these include solar photovoltaic water pumping systems, solar powered vaccine refrigerators, solar photovoltaic power plants generating electricity to entire villages as well as telecommunication repeater stations that are powered by solar photovoltaic. Solar thermal systems that are ready for incorporation into the economy especially for rural areas includes solar water heater, solar dryer, solar stills, solar water pump, solar vaccines and drugs storage, and solar street light and traffic controllers (Sambo, 2005).According to Arobieke, et al, 2012 only one CSP plant is in operation in Nigeria. The CSP is a 2.5 kW BigParabolic dish.

Over the past 13 years, the Energy Commission of Nigeria, World Bank, Former Education Tax Fund, State Governments of Bauchi, Benue, Bayelsa, Ikwa-Ibom, Delta, Taraba, Ogun, Zamfara, Rivers, Nassarawa, and some few other organizations like United States Department of Energy and Jigawa Alternative Energy Trust Fund have sponsored the installation of many pilot solar energy systems for use to various communities across the country (Usman, 2012). In summary some of these pilot solar energy systems includes; 11 solar Electrification Projects executed by Sokoto Energy Research Centreat different location across Northern Nigeria, solar electrification of 22 communities in Zamfara State by Zamfara State MDGs, solar electrification of 20 communities in Yewa North

Local Government of Ogun State under World Bank Assisted Rural Electrification Project, constructed of a solar based electric and water pumping projects in 3 villages of Jigawa State by Jigawa Alternative Energy Trust Fund with the assistant of United States Department of Energy, and several thousands of solar security and street lighting systems in the major cities of the country.

6. Practical Measures for Adoption of Solar Energy Systems

Since solar energy is available in all parts of the country and with the present level of research/development, and adoption of solar energy systems in the country, there is the urgent need for the government through National Energy Commission, all Energy research Centres, higher Institutions of learning and individual researchers to take practical measures that will gradually and systematically introduce solar energy technologies/systems into all the remote and rural communities of the country for lighting, cooking, agriculture production, storing of drugs and vaccines and street lights. This is with the view of continuing use of conventional energy resources in the transport sector. To achieve this target, the following specific strategies are necessary;

i. Demonstration and pilot projects site of solar energy systems should be extended to all the rural communities and to be given adequate support to ensure that the general public becomes aware of the potentials of solar energy technologies that will as well assist in creation of markets for the solar systems,
ii. Provision of financial incentives to encourage the use of solar energy systems in rural areas where the greatest potential exist,
iii. Introduction of regulatory measures to encourage and protect local capabilities,
iv. The need for capacity building both at institutional and personnel level for acquiring technical, organizational, and managerial skills required for increased development of solar energy in the rural communities should be identified,
v. Activities such as entrepreneurship and managerial skills development training programmes and technical courses in solar energy technologies with a view of developing Energy Service Companies for providing services to rural areas need to be introduced,
vi. The existing Research and Development centers and technology development institutions should be adequately strengthened to support the shift towards increased solar energy utilization.
vii. Providing adequate incentives to local manufacturers for the production of solar energy systems
viii. Providing adequate incentives to suppliers of solar energy products and services
ix. Providing fiscal incentives for the installation of solar energy systems
x. Setting up and maintaining a comprehensive information system on available solar energy resources and technologies

7. Conclusion

In view of the consequences of continue use of fossil based energy resources like fuel wood and petroleum products for cooking, heating, lighting, agricultural production, bakery, steel work and ceramic/pottery work, and the high costs and difficulties associated with transmission and distribution of National grid to remote and rural communities, producing renewable energy locally through solar energy systems and adopting them in the Nigeria rural and remote areas without endangering the life of current and future generations can offer a viable alternative with the view of continue use of conventional energy resources in the transport sector.

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