# Application Potentials and Sustainability of Solar Energy in Nigeria.

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## ABSTRACT

Despite its relative abundance and pollution-free nature, the use of solar energy in Nigeria is at present very limited, although its application potentials are believed to be significant. So are its potentials for sustainable use, which have been found to exceed by far, its total consumption. This paper presents an overview of the availability, comparative inherent advantages, technologies, and economic implications for effective harnessing of solar energy in Nigeria. It also looks at what limitations exist in terms of extracting useable amounts as well as of the various application potentials. How to realize some of these potentials, the associated local barriers and the challenges they pose to the development and sustainability of this energy resource that carries enormous appeal and utility are also examined with some suggestions.

(Keywords: solar energy, potential, sustainable use, alternative energy, developing nations)

## INTRODUCTION

At present, a majority of the general energy resources in Nigeria are still from firewood and fossil fuels such as coal and oil which inevitably leads to continuing deforestation, depletion of other energy resources and emerging of adverse environmental impacts. On the other hand, energy demand is rising steadily and with deregulation almost in full swing, prices are also rising.

These growing energy needs and increasing environmental concern have prompted investigation into alternatives to the use of non-renewable and polluting fossil fuels. Of all the renewable energy sources available, solar presents itself as the most outstanding in that only in solar power do we find the potential for an energy source capable of supplying much more energy than is used [9]. By estimation, the amount of energy that falls to the Earth's surface in a single minute is enough to meet the world's energy demands for an entire year.

However, no adequate data is available to assess how much solar energy is now being utilized in Nigeria. It is only known that a relatively few, scattered projects and places have successfully employed the use of solar energy scheme on a large scale. However, smaller-scale application activities, like solar energy trapped by solar box cookers for example, have been extensively used for cooking and are still in very high demand. Several other solar technologies that can be readily applied are still being steadily integrated in both the rural and urban environments.

The subsequent gains derivable from the huge application potentials of solar energy suggest a clear need for sustainable development programs. It is found that the solar market would be stimulated the more and a desirable level of sustainability achieved with increased and efficient use of this renewable source of energy. This is achievable through mass education about the socio-economic benefits of solar energy, effective information exchange, strategic planning, and support by the government.

## AVAILABILITY

An immense amount of energy from the sun strikes the surface of the earth every day. The amount of solar energy reaching a specific site on the surface of the earth at a specific time, referred to as *insolation*, depends on several factors. These include the geographical location of the place, relative position of the sun, reflection or diffusion and absorption by the atmosphere besides other local conditions such as seasons, sunshine hours, and cloud covering among

others. Therefore, it can be said that intermittence is a fundamental characteristic of solar energy. It follows also that for these apparent uncontrollable factors, only a fraction of the total energy produced may actually reach the Earth's surface. Of the energy produced, roughly 19% is absorbed by the atmosphere while clouds on the average reflect a further 35% of the total energy and so on.

Nigeria, situated approximately between $4^0$N and $13^0$N and with landmass of $9.24 \times 10^5$ km$^2$ enjoys an average daily sunshine of 6.25 hrs, ranging between about 3.5 hrs at the coastal areas and 9.0 hrs at the far northern boundary [4]. This is equivalent to an annual average daily solar radiation of about 5.25 kW/m$^2$/day, varying between about 3.5 kW/m$^2$/day at the coastal area and 7.0 kW/m$^2$/day at the northern boundary. Consequently, Nigeria receives about $4.851 \times 10^{12}$ kWh of incident solar energy per day or an average of $1.804 \times 10^{15}$ kWh annually.

**Nigeria's Energy Consumption Pattern:** The Nigerian economy can be disaggregated into industry, transport, commercial, household, and agricultural sectors, with the household sector dominating energy consumption [2, 10]. The energy consuming activities in the household sector still remain mainly cooking, lighting, and operations of electrical appliances (i.e., non-substitutable electricity). The percentage distribution of the total final consumption in 1989 in this sector and in terms of the major energy carriers is Kero (13%), Electricity (4%), LPG (1%), and Wood/Others (82%) [10].

In the commercial sector, in which the household sector is subsumed, it can be said that Nigeria's energy supply is at present almost entirely dependent on fossil fuels (crude oil, natural gas, and the like) and firewood, even though it is blessed also with some other renewable energy resources like hydro, wind, solar, biogas and so on. All these are consumed in different proportions yearly. For example, a typical distribution of energy consumption for 1985 is natural gas (5.22%), hydroelectricity (3.05%), fuel wood (50.45%), and petroleum products (41.28%) [2].

A more recent report [7] put it that petroleum accounted for the lion's share of Nigeria total energy consumption in 2001, making up 61.4% of the total. Natural gas accounted for the bulk of the remainder with 31.7%, hydropower 6.8%, and coal, 0.2%. The report also reveals that in recent years, natural gas has made in-roads in Nigeria, up from 22% of the country's primary energy consumption in the mid- 1990's to nearly 32% at present. Owing to its continuing population boom and the further development of the country's economy, Nigeria's relatively low-energy consumption, when compared with some other smaller African nation's, rose from just 0.42 quadrillion BTU (quads) in 1980 to approximately 0.90 quads in 2001.

**A Case for Solar Energy Utilization:** At Nigeria's current non-sustainable consumption level of fossil fuels and fuel woods, depletion of the reserves of these energy resources is now highly predictable and of growing concern.

If the production still remains at the 1989 predicted levels and if there are no further efforts to increase the reserves, the reserve/production ratio or the depletion time of Nigeria's crude oil may be within the next 25 –30 years and of its natural gas, the next 180 years.

Coal is very abundant in Nigeria and it is of high grade. Its depletion time is estimated to be about 1,278 years from now [1]. The depletion period may be less because of the progressive or increasing demands for Nigeria's coal globally. It is therefore instructive to note that the country's coal reserves are not unlimited. Furthermore, attempts at promoting coal for domestic consumption and industrial uses as a means of combating over-reliance on oil have met with expressions of concern by environmentalists. They have successfully argued that a renewed emphasis on coal mining as a replacement for oil would not only lead to environmental degradation, but also to increased carbon emissions.

According to another well-informed source [6], the use of fuel wood as an alternative energy resource is much more of a problem. Daily consumption of firewood by the rural communities in Nigeria is estimated to be 27.5 million kg/day which translates to deforestation of hundred of hectares of woodland. This agrees with the report [7], which claims that during the 1990s, Nigeria lost nearly 500 square miles of forested land annually, in part due to fuel wood consumption. Some other salient ecological consequences of the indiscriminate consumption

of fuel wood include loss of biodiversity, soil degradation, greenhouse gas emission, and destructive erosion.

Yet another, but low level energy resource is hydroelectricity. Nigeria has very many locations that are sparsely populated and somewhat inaccessible. Often, the nearest power line is several kilometers away. It is usually too expensive to bring in electrical services. The cost of servicing such locations is high because services and supplies must be transported from distant population centers. The source [6] put it that share of households in Nigeria with access to electricity is only 34%. The source claims further that over 60% of the populations who live in the rural areas do not have access to electricity. Lack of electrification has affected the provision of clean water for drinking and good health care, water for irrigation and general agriculture which is the main occupation of these rural dwellers, communication, and education. This has created, and is still responsible for high level of underdevelopment and poverty in the rural areas.

Other identifiable energy resources which, though are promising and of interest but again which, are either neglected or not adequately explored in Nigeria are wind, geothermal, tidal wave energy, ocean thermal energy conversion (OTEC), and nuclear fission. Clearly, these would take many more years to develop in a developing economy such as Nigeria.

In view of the dwindling nature, potential hazards, relative inadequacies, and seeming cost ineffectiveness among other problems associated with or posed by the use of the energy resources discussed above, it would be plausible to explore a resource that eliminates or ensures drastic reduction of the undesirable impacts. Solar energy offers itself as an outstanding alternative.

A preponderant reason that makes solar a choice energy resource in Nigeria is that it is very abundant and that it is renewed indefinitely as a course of nature. With appropriate technology therefore, it can be harnessed, converted and used sustainably. Nigeria's present largest source of processed energy (the Kainji dam) for example, generates about 3.2 x 108W (1998) and when fully developed, would generate 9.6 x 108W [3]. By comparison, this amount represents a millionth of what the Sun is capable of supplying freely. More precisely, the annual solar energy insolation value (1998) is about 27 times the nation's total conventional energy resources in energy units and is over 117,000 times the amount of electric power generated in the country then [5]. Interestingly, this huge energy resource from the Sun is available for about only 26% of the day.

Another equally important reason that favors solar energy utilization is that it is relatively pollution–free. Unlike the other energy resources mentioned earlier on, the use of solar energy would not lead to many of the serious negative environmental impact(s) seen with conventional energy sources.

Other comparative advantages possessed by solar power over other energy sources include the following:

(a) The simple and low-cost technology involved in harnessing solar radiation.

(b) Solar energy is found at the places where it is needed for use. This is a convenience that saves transportation costs,

(c) Solar energy utilization would help inhibit or arrest the process of desertification brought about by mass use of fuel wood and

(d) The advantages embodied in the practical use of solar energy tend to promote widespread implementation at the household level as well as personal interest and acceptance.

## APPLICATION POTENTIALS

Solar energy resources can be effectively exploited to meet a substantial part of Nigeria's ever-increasing energy requirements. It can be used in diverse ways and are divided into two principal technologies for utilization viz: solar thermal and solar photovoltaic. In other words, most solar energy is harnessed as heat or electricity, which may then be utilized directly or indirectly using appropriate technology or combination of technologies. It is also found that solar power systems can be tailored to a wide variety of applications, tasks, or situations; some large and some small. The technologies have been developed, domesticated and their viability

proven. So far, no other modern renewable energy technology has anywhere near the usage or number and capacity of installations in Nigeria as Solar – PV [8].

Table 1 presents some of the existing and potential applications of solar energy in Nigeria. It is important to note that the outlines presented are far from exhaustive. There exist many other potential applications that have not been fully explored or have not been explored at all. These include solar thermal tech used to generate electricity using the steam from boiling water to drive turbine and which in turn generates electrical power, solar desalination, solar absorption refrigerators, transportation signaling (e.g. in offshore boats which are very common in Nigeria, light houses, aircraft warning lights on pylons or structures and general road traffic signals), among other applications. All these point to the fact that potential applications of solar energy in Nigeria are numerous.

**Table 1:** Some of the Existing and Potential Applications of Solar Energy in Nigeria.

| Applications | Technology & Types | Suitability and/or Advantages | Stage(s) of Development | Remarks |
|---|---|---|---|---|
| 1.Lighting | Solar PV<br>(a) standalone PV cells<br>(b) Centralized (Shared) PV | Suitable for isolated communities not connected to the National Power grid. Equally useful in cities for office/commercial lighting equipments, billboards, traffic signals and so on. The systems have been found to be more cost-effective on the long run than diesel generators and grid electricity. | PV Installations available as at 1998 were with capacities ranging from 3.5–7.2kWp while the percentage of lighting activities by 1999 was about 15.1% of the Solar energy technology applications in Nigeria. The activities have remained on the upward trend. | • The most popular of the SE technologies in Nigeria.<br>• Have been successfully used in rural electrification projects in quite a number of villages for streetlights, schools' and centers' Lighting, Household lighting and TV viewing.<br>• They possess great prospects for investors. |
| 2.Heating<br>(a)Water Heating<br>(b) Space Heating | Solar Water and Space Heaters<br>• Horizontal &Vertical tanks<br>• Passive Solar Technology (PSBT) | • Suitable for heating water for use at homes in cities or at other places like clinics located at off-grid areas.<br>• A house, building or swimming pools may be heated directly with these types of technology.<br>• More desirable than the normal fossil fuel heaters. | • Fast developing. Some family size models like 70L capacity tanks that can generate water at 500 –700C on an averagely sunny day have been introduced.<br>• A 800L capacity model is already in use at a teaching hospital (UDTH, Sokoto, Nigeria) | • Heating is the business for which solar energy is best suited.<br>• Solar heating requires almost no energy transformation so it has a very high efficiency.<br>• Very great potentials for getting hot water for industries such as Laundry and food processing factories. |
| 3.Heating Agricultural Applications<br><br>(a) Crop and Grain Drying | (a)Solar Crop Dryer | (a) Used to dry rice and Forage in particular. It can be further developed for drying vegetables and fruits for home use. More sophisticated solar dryers protect grains and fruits, reduce losses, dry faster and more uniformly, and produce a better quality product than open-air methods. | (a)- Ranges available are from experimental through demonstration to large scale natural circulation dryers. Existing models include 2 – tonne capacity each of rice and forage dryers. | Agricultural Applications of Solar energy is relatively new in Nigeria. The area is not being actively explored as yet. These technologies therefore hold great promise to be competitive with conventional ones for all the farm activities. When properly sized and installed, the technologies are very reliable and require little maintenance. The Market potential for these technologies is huge. |
| (b) Space and Water Heating | (b) Passive Building cooling Tech. & Solar Water Heating Systems | (b) Suitable for air and water heating requirements in livestock and dairy operations at comparatively lower cost. Modern pig and Poultry farms raise animals in enclosed building where it is necessary to carefully control temperature and air quality to maximize the health and growth of the animals. | (b) & (c) - These technologies are not poplar in Nigeria and no significant breakthroughs have been recorded. The potentials use in the nearest future is quite predictable however. | |
| (c) Water Pumping for Irrigation & Livestock use. | (c) Water Pumping Solar PV Systems | (c) Very useful and cost effective for remote livestock water supply, pond aeration and small irrigation systems depending on the local solar source and water demand. The overall cost and size of the system depend, in addition, to the pumping depth as well as system purchase and installation costs. | | |

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| (d) Chick Brooding | (d)Solar Chick Brooders | (d) Developed specifically for conditioning brooder space temperature over the first four weeks of life instead of using kerosene, gas or electricity heated brooders. Improved weight gain and less mortality rates have been reported. | (d) 100 – 2000 bird capacity models are now available in quantities and with satisfactory performance. Many more are being developed. | |
| (e) Manure Drying | (e) Manure Dryer | (e) Suitable for drying poultry waste and similar materials. Suitable for cooking rice and beans, yams e.t.c<br>Potential health problems associated with charcoal and fuel practically eliminated. | (e) The overall performance of existing model, which has a capacity of over 71kg of wet manure, is quite satisfactory. Research activities are being stepped up for improved performance. | |
| (4) Cooking | Solar Cookers<br>(a) Concentrating type<br>(b) Flat Plate type | | Impressive. For example, The flat plate types available could cook rice and beans in 4.5 minutes at solar intensities of bout 850 W/m$^2$ | The use of these devices shows strong promise. Both types have been successfully constructed and tested at some Energy Research Centers in Nigeria. The need for indoor cooking is the only major shortcoming. |
| (5) Telecommunication | Solar PV<br>• Stand Alone PV<br>• Centralized (shared) PV Systems | Very Suitable for Telecommunication at repeater / radio diffusion stations in remote and isolated area where power is not available. These devices offer high reliability and low operating cost when compared with the fossil fuel–powered generators or non-rechargeable batteries. | • Fast growing technology. It constitutes over 10% of all the Solar PV installations in the country as far back as 1998.<br>• The installed capacity distribution is about 23.6% by 1999. | It constitutes a growing market for photovoltaic technology especially with the establishment of more TV stations across the country and with the very fast expansion of area coverage by the Global System of Mobile Communication (GSM) operators in the country. There is still very huge market for these technologies. |
| (6) Computer Networking | Solar PV and Solar Backup systems<br>• Non Battery based Systems<br>• Small or large Battery based Systems (PV Utility Hybrids) | Available in variable sizes and ranges – from small battery backup (one unit inverter/charger) for single unit computers to the sophisticated solar/utility system of the VSAT. Small battery based systems are relatively inexpensive and can offer long hours of uninterruptible power for crucial work. | The uses of the various types are on the upward trend. The most recently installed system has nearly 10000watts of inverting capacity and over 4000ah battery power (can be found at some department s in UNIJOS, Nigeria). | Highly promising for Geologists, Biologists and other workers who set up field camps in remote areas. Users can benefit from photovoltaic energy to operate laptops and other electronic devices for effective research locally. |

## SUSTAINABILITY

Sustainability is a systemic concept, relating to the continuity of economic, social, environmental, and institutional aspects of human society. A definition of sustainability in the terms of the 1987 Brundtland Report, is "*meeting the needs of the present generation without compromising the ability of the future generations to meet their needs*". Put in simpler terms, sustainability is providing the best for the people and the environment now with due considerations of the effects on future generations. The term is always confused with "sustainable development" which relates to development activities and which, implies continued development.

The gross disparity between the potential applications and the current consumption level of solar energy in Nigeria suggests that it would be more appropriate to look into how the development drive of solar energy technology might be sustained rather than focusing mainly on creating a sustainable structure in solar energy supply and use by a way of translating the sustainability concept into action.

There is a small but growing solar energy market in Nigeria. The rate of growth is found to be relatively slow however. The reasons for this are not unconnected with the fact that the basic solar cell is not yet produced within Nigeria [9]. Modules and panels as well as other components like regulators and inverters are also imported. The only components that are locally produced are such common standard electrical components as cables, switch gear, overload protectors and consumers units. Again, this

situation buttresses the fact that there is huge potential in Nigeria for investors in solar technologies market.

Some limitations or constraints have been identified as being responsible for the slow pace of growth. It is clear that the goals of development sustainability could not he realized without dealing with these seeming barriers. Some of the identified key barriers [4], and suggestions that may assist in attaining the desired level of sustainable development include:

(a) **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. This can be solved for example if there exists a subsidy program that allows start-up investors to have long payback times. Fortunately the on-going energy reform in Nigeria emphasizes deregulation and may easily create this kind of framework. Private sector may also be actively involved in the development and the dissemination of the technologies.

(b) **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. Governments should encourage research into this area locally

(c) **General absence of comprehensive National Energy Policy**: There was virtually no comprehensive energy policy in Nigeria until very recently. Only sub-sectorial policies relating to energy exist. Concerned agencies and parastatals should be encouraged to hold roundtable discussions with all stakeholders and with a view to formulating realistic master plans (i.e., policies, strategies, implementation, and legislation) for the development and integration of solar energy applications in the country. Successful policies implemented elsewhere may be studied and appropriately adapted.

(d) **Low level of Public Awareness**: The level of awareness about the immense socio-economic and environmental benefits derivable from solar energy is very low in Nigeria. The current flow of information about the development, various applications, dissemination and diffusion of solar energy resource and technologies is inadequate. Government and researchers should create public awareness and enlightenment programs aiming principally, the end users and financiers.

(e) **Capacity Building**: There is definite need for capacity building and training both at institutional and personnel levels. This would enable stakeholders acquire the technical, organizational, and managerial skills required for increased development of solar energy technologies and market in Nigeria.

## CONCLUSION

Given the fact that fossil fuels, from which Nigeria's energy usage are primarily derived, have a limited lifespan and production period and that they carry significant environmental hazards, there is a clear need to invest in an alternative energy resources. Solar energy has been identified as a desirable alternative resource. It has a very important role to play in meeting Nigeria's future energy needs most especially in the sparsely distributed and poor non-urban communities. Its applications potential is huge in the urban cites also. However, there exist some barriers to its sustainable development and utilization. The barriers could be effectively removed through free information exchange, public awareness, education, and well articulated legal, administrative, and financing procedures.

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