Potential for Sustainable Renewable Energy Development in Nigeria.

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ABSTRACT

Nigeria is currently faced with an energy crisis. Crude oil has been the major source of energy and revenue for the country. Environmental degradation, unstable oil prices in the international market, global warming, and the crisis in the Niger Delta area where the bulk of crude oil is derived has further made the choice of renewable energy inevitable. This paper takes a look at solar energy, hydropower, and wind energy, which are the major renewable energy sources in Nigeria and concludes that for Nigeria to meet the energy needs of its citizens, both domestic and industrial, the abundant renewable energy potentials must be tapped. However, increased awareness amongst the citizenry, investment in research and development in renewable energy technologies, workable policies, and collaboration with relevant international agencies are needed to fully tap the gains of renewable energy.

(Keywords: solar power, wind power, hydropower, renewable energy, sustainable development)

INTRODUCTION

The importance of energy in our everyday life cannot be over-emphasized. For example, energy is used in the agricultural sector for irrigation, food processing and preservation; in the household sector for lighting, heating, refrigeration, and cooking; in the industrial sector for turning raw materials into finished goods; and in the transportation sector to power cars, trucks, trains, airplanes, etc. Energy contributes in multiple ways to the Gross National Product (GNP) of a country.

Non-Renewable energy source are energy sources that cannot be replenished in a short period of time once they are used up. Non-renewable energy sources can further be classified into fossil fuel and nuclear.

Non-renewable energy sources come out of the ground as liquids, gases and solids. Right now, crude oil (petroleum) is the only liquid commercial fossil fuel available. Natural gas and propane are gases, and coal is a solid. They are called fossil fuels because they were formed over millions and millions of years ago by the action of heat from the earth's core and pressure from rock and soil on the remains of dead plants and animals. Other non-renewable energy sources are isotopes of the elements uranium and plutonium, whose atoms we split (through a process called nuclear fission) to create heat and ultimately electricity (1).

In Nigeria today, the bulk of her energy source is from non-renewable sources, namely petroleum, coal, and gas. This has caused a lot of environmental problems leading to ecosystem degradation. Burning of fossil fuels produce carbon dioxide from our generating stations, cars, and trucks, pollutes the environment and contributes, in no small measure, to global warming. Sulfur dioxide is also produced from burning of these fossil fuels, and this causes acid rain which greatly affects the soil and vegetation (2).

Renewable energy sources are the energy sources that can be replenished or recreated when they are used. They are generally less-polluting and cannot be exhausted. They include solar energy, hydropower, biomass, biogas, wind, water waves, and geothermal. Nigeria is endowed with these energy sources but they are still not being exploited due partly to ignorance and partly to high cost of the conversion technologies involved. Nigeria still depends solely on the non-renewable energy source to meet her energy needs.

LITERATURE SURVEY

Solar Energy

Solar energy is the energy from the sun. It is the sun's rays (solar radiation) that reach the earth. Solar energy can be converted into other forms of energy, such as electricity (photovoltaic) and heat (photo-thermal).

Photovoltaic Conversion: Photovoltaic (PV devices) or "solar cells" change sunlight directly into electricity. Photovoltaic systems are often used in remote locations that are not connected to the electric grid. Photovoltaic energy is the conversion of sunlight into electricity. A photovoltaic cell, commonly called a solar cell or PV, is the technology used to convert solar energy directly into electrical power.

The photovoltaic cell was discovered in 1954 by Bell Telephone researchers examining the sensitivity of a properly prepared silicon wafer to sunlight. Beginning in the late 1950s, photovoltaic cells were used to power US space satellites. The success of PV in space generated commercial applications for this technology. A photovoltaic cell is a non-mechanical device usually made from silicon alloys (1).

The number of modules connected together in an array depends on the amount of power output needed. The performance of a photovoltaic array is dependent upon sunlight. Climate conditions (e.g., clouds, fog) have a significant effect on the amount of solar energy received by a photovoltaic array and, in turn, its performance. Most current technology photovoltaic modules are about 10 percent efficient in converting sunlight (2). Further research is being conducted to raise this efficiency to 20 percent.

Photovoltaic systems provide a direct conversion of solar radiation to electric energy. Some advantages of photovoltaic systems include: Conversion from sunlight to electricity is direct, so that bulky mechanical generator systems are unnecessary; PV arrays can be installed quickly and in any size required or allowed; the environmental impact is minimal, requiring no water for system cooling and generating no by-products (3).

Photovoltaic system comprises of the following major parts;

(i) Silicon based solar panels: This receives the solar ray from the sun and coverts it to useful form.

(ii) Inverter: This is the part that converts the direct current (dc) to the alternating current (ac). This becomes necessary because most of our electronics like television sets, radio sets, etc make use of alternating currents.

(iii) Battery: This is to store the power during the day or when there is solar radiation and give the power out during the night or when there is no more solar radiation.

(iv) Charge controller: This is to protect the battery against overcharging.

Photovoltaic systems has been very effective in Nigeria to provide electrical power for varying applications ranging from small lighting units, water pumping, and offices/cybercafés. Special features of the photovoltaic system include quiet operation, low maintenance, flexibility for systems sizing, clean and reliable output, and environmentally friendly generation of electricity. Photovoltaic cells, like batteries, generate direct current (DC) which is generally used for small loads (electronic equipment). When DC from photovoltaic cells is used for commercial applications or sold to electric utilities using the electric grid, it must be converted to alternating current (AC) using inverters, solid state devices that convert DC power to AC.

Photo-thermal Conversion: Photo-thermal technology is used to generate electricity when the heat from solar thermal collectors is used to heat a fluid which produces steam that is used to power generator. It is often used for heating swimming pools, heating water used in homes, and space heating of buildings. Solar space heating systems can be classified as passive or active.

Generally, solar thermal power plants use the sun's rays to heat a fluid, from which heat transfer systems may be used to produce steam. The steam, in turn, is converted into mechanical energy in a turbine and into electricity from a conventional generator coupled to the turbine. Solar thermal power generation works essentially the same as generation from fossil fuels except that instead of using steam produced from the combustion of fossil fuels, the steam is produced by the heat collected from sunlight. Solar thermal technologies use concentrator systems due to the high temperatures needed to heat the fluid (4).

Hydropower

Hydropower systems make use of the water stored behind the dam that is allowed to fall through the head, and potential energy in the fall is converted to kinetic energy. The energy in the flowing water turns the water turbine, while the rotating shafts turns the rotor of the generator to yield electrical power. In hydro power systems the potential energy difference between water resources, dams or lake and discharge tail water levels downstream is of great significance for power generation. The energy supply is mechanical and the conversion efficiency is relatively high. In Nigeria, there are Waya Dam, Tunga Dam, Owu Falls, Ikpoba Dam, and Erin-Ijesa Waterfalls to mention just a few (5).

Hydropower accounts for about 40% of the total electric power supply in Nigeria (5,6). Some people regard hydropower as the ideal fuel for electricity generation because, unlike the non-renewable fuels used to generate electricity, it is almost free, there are no waste products, and hydropower does not pollute the water or the air. However, it is criticized because it does change the environment by affecting natural habitats. Different approaches to fixing this problem have been used, including the construction of "fish ladders" which help the salmon "step up" the dam to the spawning grounds upstream (1).

Wind Energy

Wind is air in motion. It is caused by the uneven heating of the Earth's surface by the sun. Since the Earth's surface is made of very different types of land and water, it absorbs the sun's heat at different rates. During the day, the air above the land heats up more quickly than the air over water. The warm air over the land expands and rises, and the heavier, cooler air rushes in to take its place, creating winds. At night, the winds are reversed because the air cools more rapidly over land than over water. In the same way, the large atmospheric winds that circle the earth are created because the land near the earth's equator is heated more by the sun than the land near the North and South Poles (2).

Today, wind energy is mainly used to generate electricity. A typical wind machine consists of blades, generator, cable, and a simple computer system. The blades catch the wind and spin, the generator converts mechanical energy into electricity, the cable carries electricity to transmission line while the computer system controls the direction of the blades. The wind flows over the airfoil shaped blades causing lift, like the effect on airplane wings, causing them to turn. The blades are connected to a drive shaft that turns an electric generator to produce electricity (9).

PROSPECTS FOR LOCAL UTILIZATION OF SOLAR ENERGY IN NIGERIA

Solar energy is the most promising of the renewable energy sources in view of its apparent limitless potential. A large percentage of Nigerian communities are rural dwellers, and exhibit what could be described as subsistence living. Any energy method adopted must be such that can be adapted for the vast majority of the Nigerian populace. Solar energy has been described as the most promising energy source of the future.

Nigeria lies within the tropical region between latitude 4^o N and 14^oN, where there is abundance of sunshine energy all year round (3). Solar radiation data for various cities in Nigeria are available from the Department of Metrological services, Lagos. For example, Ado-Ekiti, south-west Nigeria, which lies on latitude 7.5^oN has a mean irradiance of 22.4MJ/m^2 per day for the month of April (2, 3).

The sun radiates its energy at the rate of about 3.8×10^{23} KW per second. Most of this energy is transmitted radially as electromagnetic radiation which comes to about 1.5kW/m^2 at the boundary of the atmosphere. After traversing the atmosphere, a square meter of the earth's surface can receive as much as 1Kw of solar power, averaging to about 0.5 over all hours of daylight.

Nigeria receives about 4.851×10^{12} Kwh of energy per day from the sun. This is equivalent to about 1.082 million Tones of oil equivalent (mtoe) per day, and is about 4 thousand times the current daily crude oil production, and about 13 thousand times that of natural gas daily production based on energy unit (5). This huge energy resource from the sun is available for about 26% only of the day. The country is also characterized with some cold and dusty atmospheric conditions during the Harmattan season, in its northern part, for a period of about four months (November-February) annually.

Based on the land area of 924 x 10^3 km^2 for the country and an average of 5.535kWh/m^2/day, Nigeria has an average of 1.804 x 10^{15} kWh of incident solar energy annually. This annual solar energy insolation value is about 27 times the nation total conventional energy resources in energy units and is over 117,000 times the amount of electric power generated in the county in 1998 (3). In other words, about 3.7% of the national land area is needed to be utilized in order to collect an amount of solar energy equal to the nation's conventional energy reserve.

Present Level of Solar Utilization in Nigeria

Solar energy has been utilized in Nigeria in various forms: namely, solar PV for rural electrification, solar cooker, solar crop dryer, solar manure dryer, solar water pump, solar water heaters, solar chick brooders etc. A national survey by the Energy Commission reveals a total of 33 companies that were active in Solar PV by 1999. Most of them were established within the last ten years. There are over 200 solar PV installations, in the country as at 1998, with capacities ranging from 3.5 to 7.2 kWp. In 2001, Solar Electric Light Fund (SELF), an NGO based in USA. Jigawa State Government initiated a proposal to bring solar-generated electricity (PV) to power essential services in 3 villages of Jigawa State (4).

Notable solar projects in Nigeria include:

1. Street lighting in Ado Ekiti, Ekiti State.

2. 7.2kWp Kwalkwalawa Village Electrification, Sokoto State.

3. 1.87kWp Iheakpu-Awka Village Electrification/TV Viewing, Enugu State

4. 1.5kWp Nangere Water Pumping Scheme , Sokoto State

5. 2-tonne Solar Rice Dryer, Adani, Enugu State

6. 1.5-tonne Solar Forage Dryer, Yauri, Kebbi State.

Generally about 26 states and the Federal Capital Territory, Abuja has solar projects either sponsored by the government (Federal or State), Energy Commission of Nigeria (ECN), or private companies or individuals. States like Ekiti, Rivers, Jigawa, Lagos, Delta, Yobe, Akwa-Ibom, Kano, Rivers, Sokoto, Ondo, Enugu, and Kebbi are in the forefront of solar energy utilization in Nigeria (2).

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 government in the nearest future. The major constraints to the expansion of solar utilization in Nigeria are (4):

1. Cost: Solar energy technologies and its deployment are very expensive. The cost of importation of the various parts is also very high.

2. Some of the parts are not locally available as they cannot be manufactured locally.

3. Government policy on the deployment of Renewable energy is not comprehensive and investors friendly.

PROSPECTS FOR LOCAL UTILIZATION OF HYDROPOWER IN NIGERIA

Nigeria is blessed with rivers and dams that have great potentials for power generation. The two major rivers in Nigeria are River Niger and River Benue, there are however other rivers that can be dammed 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 as shown by Table 1. Also about 12 states are also endowed with great hydropower potentials as shown in Table 2.

Table 1: Overall Distribution of Small-Scaled Hydropower Potential among Seven River Basins (5).

S/N	*River Basin*	*Status*	*Type Capacity*					
			Micro		Mini		Small	
			No	Cap.(MW)	No	Cap.(MW)	No	Cap.(MW)
1	Sokoto-	D	-	-	-	-	1	3.0
	Rima	U	10	3.2	11	8.4	10	29.6
2	Hadejia-	D	-	-	-	-	1	6.0
	Jama'are	U	8	2.8	20	11.4	7	31.6
3	Chad	D	-	-	-	-	-	-
		U	10	2.8	8	6.8	2	5.6
4	Niger	D	-	-	-	-	-	-
		U	16	6.4	23	18.2	22	191
5	Upper	D	-	-	-	-	-	-
	Benue	U	8	3.2	36	27	25	185.1
6	Lower	D	-	-	-	-	5	19.0
	Benue	U	11	4.4	23	19.2	17	138
7	Cross	D	-	-	-	-	-	-
	River	U	1.7	7	6	4.6	5	21.8
	Total	D	-	-	-	-	7	28.0
		U	70	24.5	126	95.6	86	704.1

D= Developed. U= Undeveloped.

Table 2: Summary of Small Hydropower Potential Distribution According to States (5).

States	River Basin	Hydropower Potential			
		Total Sites	Developed (MW)	Underdeveloped (MW)	Total Capacity (MW)
Sokoto	Sokoto-Rima	22	8.0	22.6	30.6
Kastina	Sokoto-Rima	11	-	8.0	8.0
Niger	Niger	30	-	117.6	117.6
Kaduna	Niger	19	-	9.2	59.2
Kwara	Niger	12	-	38.8	38.8
Kano	Hadejia- Jama'are	28	6.0	40.2	46.2
Bornu	Chad	28	-	20.8	20.8
Bauchi	Upper Benue	20	-	42.6	42.6
Gongola	Upper Benue	32	-	12.7	162.7
Plateau	Lower Benue	38	18.0	92.4	110.4
Benue	Lower Benue	19	-	9.2	69.2
Cross River	Cross River	18	-	28.1	28.1
Total		277	32	702.2	734.2

Present Level of Hydropower Utilization in Nigeria

Currently, most of the country's electricity is generated through hydropower. There are three functional hydro power stations in Nigeria as shown in Table 3.

Table 3: Hydropower Stations in Nigeria and their Capacity (5).

S/N	*Hydro-Power station*	*Capacity (MW)*
1	Kainji	760
2	Jebba	540
3	Shiroro	600

The United Nations Industrial Development Organization (UNIDO) under her Regional Centre for Small Hydro Power in Africa (RC-SHP) with office in Abuja is working on Hydro Power projects to generate electricity in some states of the Federation (6). For example, UNIDO is collaborating with Ekiti State government to generate about 1.5MW of electricity from Itapaji Ekiti river. Table 4 shows other ongoing hydro power projects sponsored by UNIDO.

Table 4: On-going UNIDO Projects (5).

S/N	*Dam/River*	*Location*	*Capacity*
1	Waya Dam	Bauchi State	150KW
2	Ezioha-Mgbowo Dam	Enugu State	30KW
3	Obudu Cattle resort Dam	Cross River State	30KW
4	Ikpoba Dam	Edo State	3.12MW
5	Tunga Dam	Plateau State	1600KW
6	Ta Hoss Community	Plateau State	100KW
7	Omi Community	Oyo State	625KW
8	Oyan Dam	Ogun State	9MW
9	Ikere Gorge	Ogun State	5MW
10	Erin-Ijesha	Osun State	3MW

There is a great prospect for expansion of hydropower potentials in Nigeria. Most hydropower resources in Nigeria are still largely undeveloped as shown by Tables 1, 2 ,and 4. With partnership between various levels of governments and an international organization like UNIDO, hydropower will definitely receive a boost in Nigeria and solve the problem of power in Nigeria (5).

DEVELOPING A WIND POWER SCHEME

In order to have a well efficient system of wind turbine arrayed in a wind farm to form a mini-grid system for rural electrification, one of the main factors which will determine the economic viability of such a wind power project is the annual mean wind speed at a site. These wind speed data are provided by the Nigerian Meteorological Agency (NIMET) and several researchers have ventured into the field for provide updated wind parameters for a particular site.

The power produced by a wind turbine depends on several parameters including the wind speed (the main factor), the area swept by the blades and the efficiency of the rotor and generator (7). The power output can be doubled by increasing the rotor blade length by 40%, or by an increase in wind speed, for example from 6 m/s to 7.5 m/s (8).

Wind speeds vary enormously from region to region and from valley floor to hill-top, so wind speed measurements will usually be needed for virtually all proposed developments, other than those for only a few kilowatts. For schemes larger than about 10 kW, on-site, wind measurements will usually be required, with results being correlated to longer term, local meteorological data of average wind speed in the region. For smaller schemes, meteorological data may be all that is required, even though there will be some discrepancy between the data and the actual wind speed at a given site. A full wind speed assessment will normally involve:

(a) Erecting a mast, preferably of similar height to the proposed turbine, with a recording anemometer,

(b) Monitoring the wind speeds and direction over an extended period, and

(c) Correlating the data with long term records from local meteorological stations.

A data collection period of six months is generally thought to be minimum time to obtain reasonably reliable results, but a 12 month collection period will reduce the uncertainty in the estimates as all seasonal weather patterns will have been recorded (9).

The following factors are essential to be duly considered before embarking-on or building a wind farm for a wind power scheme (9, 10).

[i] Understand the sites Wind Resource: The most important factor to consider in the construction of a wind energy facility is the site's wind resource. Local weather data available from airports and meteorological stations may provide some insight as to averages.

[ii] Determine Proximity to Existing Transmission Lines: A critical issue in keeping costs down in building a wind farm is minimizing the amount of transmission infrastructure that has to be installed. Whenever possible, availability and access to existing lines should be considered in selecting a site.

[iii] Secure Access to Land: Landowners, both private and public, will expect to be compensated for any wind energy development that occurs on their land. Royalty or lease agreements will need to be discussed with all parties involved. Roads, transmission equipment, maintenance infrastructure, turbines, and the likes need to be considered. Moreover, the construction of a wind farm necessitates the use of heavy industrial equipment. Developers will need to invest in roads capable of accommodating significant weight. To do so will require the cooperation of landowners and, in some cases, the local community.

[iv] Establish Access to Capital: Building a wind farm is not cheap and as being earlier noted, it is a scheme that can be facilitated by the government or can be facilitated by private organizations. To take advantage of economies of scale, wind power facilities should be in excess of 20 MW.

[v] Identify Reliable Power Purchaser or Market To date, wind energy is the most cost competitive renewable energy option on the market. In fact, wind energy's cost has declined so much that it rivals many traditional power generation technologies. However, utilities will tend to purchase power from what they consider to be the cheapest and most reliable technology. In most cases today, that is natural gas. That does not mean there is not a market for wind, though. Demand for “green power” (electricity from clean sources like wind that is sold to customers at a premium price) and environmental requirements are creating buyers for wind energy and competitive rates.

[vi] Address sitting and Project Feasibility Considerations: The fact that a site is windy does not mean it is suitable for wind power development. A developer needs to consider many factors in sitting a project. Is there high raptor activity in the area? Are there endangered or protected species that could be jeopardized by the presence of the facility? Is the site's geology suitable and appropriate for industrial development? Will noise and aesthetics be issues for the local community? Will the turbines obstruct the flight path of local air traffic?. There are quite a few environmental and social issues that will need to be addressed in the sitting of a wind power facility.

[vii] Understand Wind Energy's Economics: There are many factors contributing to the cost and productivity of a wind plant. For instance, the power a wind turbine can generate is a function of the cube of the average wind speed at its site, which means that small differences in wind speed mean large differences in productivity and electricity cost. Additionally, the swept area of a turbine rotor is a function of the square of the blade length (the radius of the rotor’s swept area). A modest increase in blade length boosts energy capture and cost-effectiveness. Financing methods can make a major difference in project economics as well. Securing significant investment capital or joint ownership of a project can cut costs significantly. Furthermore, there are federal and state incentives for which a project may qualify and which could reduce costs and encourage more favorable investment.

[viii] Establish Dialogue with Turbine Manufacturers and Project Developers: Every wind turbine is different despite seemingly similar power ratings. Some machines are designed to operate more efficiently at lower wind speeds while others are intended for more robust wind regimes. A prospective wind power developer would be wise to investigate all the various considerations and compare the performance to existing machines. Moreover, anecdotal information and even the professional services of wind power developers may prove helpful.

[ix] Secure Agreement to meet Operation and Maintenance (O&M) Needs: Turbine availability (reliability) is a major factor in project success, and the services of professional familiar with the operation and maintenance of wind turbines can prove to be invaluable.

RECOMMENDATIONS

In order to fully harness renewable energy in Nigeria, the following recommendations will be useful:

[1] Government at various levels should pay more attention to renewable energy resources by allocating more resources to it in their budget.

[2] Private sector should be given the right environment and encouragement by the Government to engage in the development of renewable energy and energy efficiency.

[3] Universities and other research institutions should provided with adequate fund to carry out more researches on a suitable conversion technologies for our country. More personnel should also be trained to provide workforce for renewable energy projects.

[4] The Federal Government through the relevant ministries and the Nigerian University Commission (NUC) should put in place mechanisms to ensure effective collaboration between research institutions, universities and relevant government agencies to develop renewable energy and energy efficiency.

[5] Workable policy should be formulated for the Renewable Energy Technologies.

[6] Government should partner with international organizations like UNIDO, World Bank to help finance some of the Renewable Energy Projects.

[7] Government, NGOs and development agencies should sensitize and encourage stakeholders to adopt the use of renewable energy and energy efficiency technology and practices.

[8] Government should develop a school curriculum that will teach stakeholders to shun the degradation of the environment and use energy more efficiently.

CONCLUSIONS

Nigeria is blessed with many renewable energy potentials. Renewable energy is the right way to go for Nigeria in order to meet the energy needs of her citizens. If the available renewable energy potentials in Nigeria are fully utilized, she will be able to meet her energy needs and power failure will soon be a thing of the past.

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