Study of Nigeria Energy Resources and Its Consumption

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Abstract-This study focuses on Nigeria energy resources and its consumption. The present situation in Nigeria is that energy supply does not meet the energy demand. Energy is considered as the most important resources of any country. It is a well known fact that high rate of industrial growth of a country is a function of the amount of energy available in that country and the extent to which the energy is utilized. In our study, we classified energy resources on their basis of renewability which are; renewable and non-renewable energy resources. Under renewable, we looked at wind, solar, water, biomass, and under non-renewable, we looked at fossil fuels which includes; coal, oil and natural gas. Analysis of solar energy consumption to other forms of energy was carried out and the way in which PV cell can be applied in energy generation was also enumerated. We also conducted three separate studies that were used to determine the measurement of the average wind speed in Sokoto, Imo, and Borno State for period ranging from three to ten years. The factors that lead to the inability of Nigeria to explore her rich natural energy resources were examined. We analyzed the energy consumption by sector from 1999 to 2004 with household sector having the highest percentage of the nation's total domestic energy consumption. The strategies for optimum exploitation of the natural resources in Nigeria were also enumerated, which if they are properly followed or implemented, will solve the problem of energy imbalance facing this nation.

Index Terms—Renewable energy, Non renewable energy, Wind energy, Solar energy, Hydro energy, Biomass energy, Fossil fuel, Coal, Natural gas, Petroleum.

1 INTRODUCTION

THE concept of "resources" is a human centered concept. In other for something to be considered a resource, it must be perceived to have value by humans. Energy is fundamental to all human activities. Globally, more than 1.6 billion people live without access to electricity and 2.4 billion are without modern energy sources for cooking and heating. Nigeria is an energy resource, rich country blessed with a lot of resources such as solar, wind, biomass, crude oil, natural gas and coal, yet an estimated number of 60-70% of Nigerians population does not have access to electricity. This simply means that Nigeria as the most populous country in sub-Saharan Africa nearly one quarter of sub- Saharan African's population despite their huge National Energy resources had not been able to harness them for proper development of the country. Nigeria Energy supply is at present almost entirely dependent on fossil fuels and firewood (conventional energy sources) which are depleting fast. The 1995 distribution of energy consumption typified the current energy supply mix in the country which shows that the total energy consumption, the share of natural gas was 5.22%, hydroelectricity took 3.05%, fuel wood had a lion share of 50.45% and petroleum product had 41.23% share. This is an indication that the renewable energy used in the country is split essentially between hydroelectricity and traditional fuel wood [1].

The Nigerian economy can be disaggregated into industry, transport, commercial, household and agricultural sector with household sector presently dominating energy consumption in Nigeria [2]. This makes it the most important energy sector of the Nigerian economy.

2 CLASSIFICATION OF NATURAL ENERGY RESOURCES IN NIGERIA

Nigeria energy resources can be classified on the bases of their renewability as

(1) Renewable
(2) Non-renewable.

Renewable energy sources are sources that can be replenished or produced quickly through natural processes. The rate at which they are used does not affect their availability in future and as such cannot be exhausted. All the regions of the world have reasonable access to one or more forms of renewable energy supply because the resources are generally well distributed all over the world, even at wide spatial and temporal variations [3] . Many of the renewable resources can be depleted by human use, but may also be replenished thus maintaining a flow.

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The types of Renewable energy resources that occur are as follows:

(1) Wind Energy
(2) Solar Energy
(3) Hydro Energy
(4) Biomass Energy.

Non-Renewable energy resources are resources that cannot be produced, generated, grown or used on a scale that can sustain its consumption rate because they will not be available for future need once they are depleted. They are consumed much faster than nature can create them, thus their rate of formation is extremely slow [4]. The type of Non-renewable energy resources that occur are as follows.

(1) Coal.
(2) Natural gas.
(3) Petroleum.

2.1 Wind Energy

Differences in atmospheric pressure due to difference in temperature are the main cause of wind. Wind is powered by the sun. In fact all renewable energy and even energy in fossil fuels, ultimately comes from the sun. The sun heats our planet to different temperature variation in different places and at different times. This unequal distribution of heat is what creates wind as warm air rises and cooler air descends to fill the void thereby producing wind which is the ongoing movement of this air.

As the sun warms the earth, it in turn, warms the air above it, making it less dense or lighter. As the light air rises, it creates a low pressure zone near the ground. Air from surrounding cooler areas rushes into balance the pressure [5]. These are called local winds. Temperature difference between the polar caps and equator, as well as the rotation of the earth, produce similar result on a global scale called prevailing winds.

Wind power system takes advantage of the power of wind. Lunge blades or "rotor", catch the wind and spin. In hydroelectric system, the spinning movement is transformed into electrical energy by the generator. The placement or "sitting" of the wind system is extremely important. In other for a wind powered system to be effective, a relatively consistent wind flow is required. Obstruction such as trees or hills can interfere with the rotors. Because of this, the rotors are usually placed on top towers to take advantage of the stronger winds available higher up. Furthermore, because wind speed varies with temperature season, and time of day. All these must be considered when choosing a site for a wind powered generator. Another important part of the wind powered system is the battery. Since wind does not always blow consistently, it is important to have a backup system that will provide energy. This can be done with generator that can store extra energy in a battery when the wind is very strong. The minimum speeds that the wind can blow for a small turbine is 36x10-7m/s and large plant require speed of 58x10-7m/s.

2.1.1 Design Consideration

In regions with an adequate wind pressure, the amount of potential power is dictated by the size of the windmill. Windmills vary in sizes. Small windmills can be used to pump water or provide power for cooking and refrigeration. Medium windmills provide electricity for one or more homes. Large windmills or utility scale windmill are capable of providing power for entire communities. Often these large windmills are connected to a mini-grid as to reduce the overall dependence on fossil fuels.

TABLE 1
AVERAGE WIND SPEED DETERMINATION IN VARIOUS PARTS OF NIGERIA

Location	Avg. wind speed (m/s)	Height (m)	Feasibility
Sokoto [6]	3.75	10	Yes
Borno [7]	2.93	10	No
Borno [7]	3.98	25	Yes
Imo [8]	2.8	10	No

The table above shows three separate studies that were used to determine the measurement of the average wind speed in the various parts of the country for period ranging from three to ten years. The table shows average wind speed in three states of three regions. Sokoto in the northwest, Borno state in the northeast, and Imo in the southeast. At wind speed of 3.5m/s or greater, wind powered system can provide energy at cost cheaper than photovoltaic, diesel and grid extension, therefore making sokoto and Borno state ideal location for wind power system [6,7,8].

2.2 Solar Energy

Nigeria is endowed with an annual average daily sunshine of 6.25 hours, ranging between about 3.5 hours at the coastal areas and 9.0 hours at the far northern boundary and an annual average daily solar radiation of about 5.25kw/m2/day at the coastal area and 7.0kw/m2/day at the northern boundary. Nigeria receives about 4.85×1012kwh of energy per day from the sun. These huge energy resources from the sun are available for about 26% only of the day. Based on the land area of 924×103 km2 for the country and an average of 5.535kwh/m2/day. Nigeria has an average of 1.804×1015kwh 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 it is over 117,000 times the amount of electric power generated in the country in 1998 as contained in the table below. In other words, about 37% only of the national land area is needed to be utilized in other to annually collect from the sun an amount of energy equal to the nation's conventional energy reserve [9].

TABLE 2
COMPARISION OF SOLAR ENERGY TO ITHERS IN NIGERIA

Energy (kwh)	Annual solar energy insolation	Conventional energy reserve (1999)	Electrici Generat (1988)
	1.804×1015	6.663×1013	15.11×1(
Ratio	27.1:1	1:1	0.00023:
	117826:1	4347.8:1	1:1

Electrical energy uses the power of the sun to produce electricity through solar cells, otherwise known as photovoltaic (pv) and it can be applied in three ways, as follows:

(1) Stand-alone
(2) Grid-connected
(3) Back-up

A photovoltaic cell is a device used for the conversion of the sun's ray into electricity. Photovoltaic system consists of solar panels, a battery, a charger controller, and an inverter. The lifetime of the panels is typically 20 to 25 years, which is considered the lifetime of the total system. The battery allows power to be supplied at night or during cloudy weather. Two types of battery can be used, deep-cycle and starter batteries. Deep –cycle batteries are more efficient and most commonly used, but starter batteries are already available in Nigeria due to their use in cars. A deep cycle battery last between three and eight years. The charge controller regulates the current added to and drawn from the battery in other to maximize the battery lifetime and for user safety [10]. Because photovoltaic system produce a direct current, the inverter is necessary only if the end uses of electricity require an alternating current.

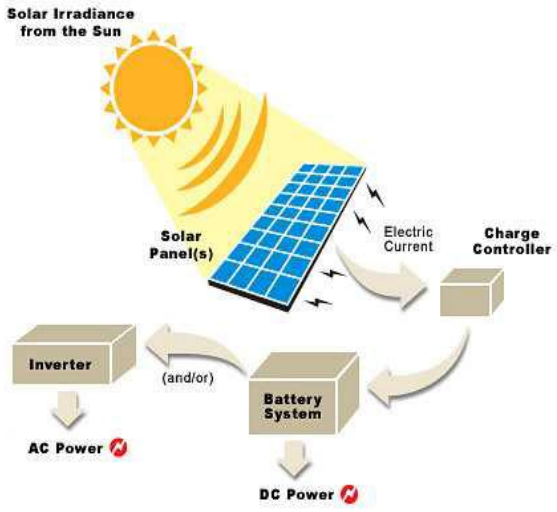

Fig. 1.Components of solar energy system

The design of a photovoltaic system must balance the rate of solar energy deposition on a given area with the power required by the load. The measure of total solar irradiance commonly used to assess the input for photovoltaic panels is dally "peak sun hours" and the number of daily peak sun hours is equal to the value in kwh of the total amount of direct and diffuse solar radiation incident on a square meter in a day [11].

2.3 HYDRO ENERGY

Hydro energy is the largest sources of renewable energy. This renewable source of energy provides 10% of the nation's electricity. As of now, there are 77,000 Megawatts of hydropower, enough to provide 35million homes with energy. Converting the flowing water into usable energy produces hydropower. Most of this water comes from river and is released through turbine to produce energy. The steam pressure from the boiling water turns "properties" called turbines spins coils of wire between magnets to produce electricity [12]. Hydro powered system also make use of turbines to generate electrical power, however, they do so by using the energy in moving water to spin the turbines. Water has kinetic energy when it flows from higher elevation to lower elevation. This energy in turn spins turbine.

In larger scale hydroelectric plants, large volume of water are contained by dams near the generator and turbines. The "forebay" is a storage area for water that must be deep enough that the penstock is completely submerged. The water is allowed to flow into the electricity generating system through a passage called "penstock". The controlled high-pressure water spins the turbines, allowing the generator to produce an electric current. The "powerhouse" contains and protects the equipment for the generating electricity. The high-pressure water exits the system through a "draft tube". The "fish ladder" attempts to minimize the environmental impact of hydroelectric system by providing a path for migrating fish to take.

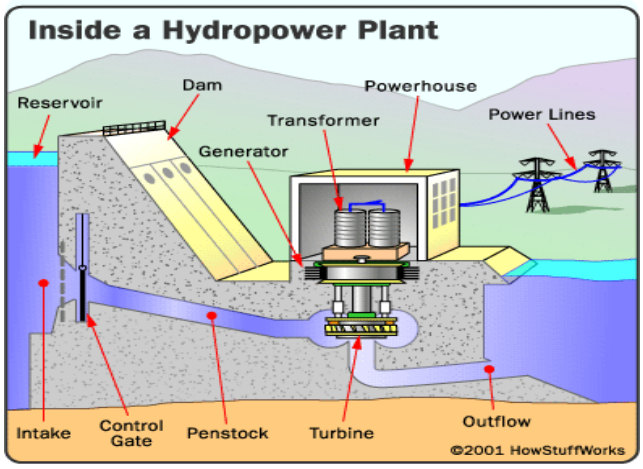

Fig. 1. Picture of a hydropower plant

The three major sources of hydro-energy are as in table below [13]:

TABLE 3
THE THREE MAJOR SOURCES OF HYDRO ENERGY

S/N	Name of Hydropower plant	Year established	Installed Capacity (MW)	Availability as of June 2010 (MW)
1	Kainji	1968	760	465
2	Jebba	1986	578	482
3	Shiroro	1990	600	450
		Total	1,938 MW	1,397 MW

The total technically exploitable hydropower potential based on the country's river system is conservatively estimated to be about 10,000MW of which only 19% is currently being tapped or developed.

TABLE 4
CLASSIFICATION OF HYDRO SCHEMES IN NIGERIA

Scale of hydro scheme	Capacity Range (MW)
Large	>100
Medium	50-100
Intermediate	10-50
Small	1-10
Mini	0.5-1
Micro	<0.5

2.4 BIOMASS ENERGY

Biomass is simply the conversion of stored energy in the plant into energy that can be used. This burning wood is a method of producing biomass energy. Biomass is the most commonly used resources of rural energy in Nigeria because fuel wood is the cheapest and most accessible source of fuel even in the urban household. Fuel-wood is the traditional fuel source, which in spite of the availability of conventional domestic fuels, remains in high demand at the expense of Nigeria forest.

The biomass resources of the nation have been estimated to be about 8×102MJ. Plant biomass can be utilized as fuel for small-scale industries.

Methods of Converting Biomass to Energy

(1) Burning
(2) Alcohol fermentation
(3) Anaerobic Digestion
(4) Pyrolysis

2.4.1 BURNING

Wood is the largest biomass energy resources in Nigeria. Direct burning of biomass is the most straight forward method of energy production. Mankind has burned wood and other forms of biomass for thousands of years, to keep warm, to cook food and to eventually to forge weapons and other tools. The energy released by direct combustion takes the form of heat and can be used to directly influence the temperature of a small environment or to power steam driven turbines to produce electricity [12]. Wood energy is derived from both direct use of harvested wood as a fuel and from wood waste system. The largest source of energy from wood is pulping liquor 'black liquor,'' [15] which is a waste product from processes of the pulp, paper and paperboard industry.

2.4.2 ALCOHOL FERMENTATION

This is carried out by a group of living organism like yeast or bacteria. Ethyl alcohol, commonly known as alcohol is one of the most important and popular industrial fermented product of this process [16]. Ethyl is a cleaner-burning, renewable fuel that can be produce from a number of domestic feed stocks, mostly crops that are high in starches and sugars. Some conventional food crops that are high in starches and sugars, like sugarcane, corn, and sorghum can be fermented to produce ethanol which is relatively a clean process with a high fuel energy output. The overall chemistry in this process is to convert glucose sugar ($C_6H_{12}O_6$) to alcohol (CH_3CH_2OH) and carbon dioxide gas (CO_2) [17]. The overall reaction takes the process below:

$C_6H_{12}O_6 \rightarrow 2(CH_3CH_2OH) + 2(CO_2)$

Sugar → Alcohol + Carbon dioxide gas

(Glucose) (Ethyl alcohol)

2.4.3 ANAEROBIC DIGESTION

Refers to the process whereby microorganism converts chemical energy in solid biomass material into an energy carrier, usually with high efficiency relative to thermo-chemical conversion. These microorganisms have the flexibility to process waste stream as well as biomass feedstock from residues and energy crop [18].Anaerobic processes could occur either natural or in a controlled environment such as a biogas plant. Organic waste such as livestock manure and various types of bacteria are put in an airtight container called a digester where the processes can occur [19]. Biogas is typically 55 to 75 percent pure methane depending on the waste feedstock and the system design.

2.4.4 PYROLYSIS

Is a thermo-chemical decomposition of organic material at elevated temperature in the absence of oxygen and it occur under pressure and at operating temperature above 430°C[20]. Biomass such as wood or agricultural waste is heated to around 538°C and allowed to decompose into gas and charcoal (carbon)[12].This process is carbon free which is the main setback to most biomass energy conversion process.

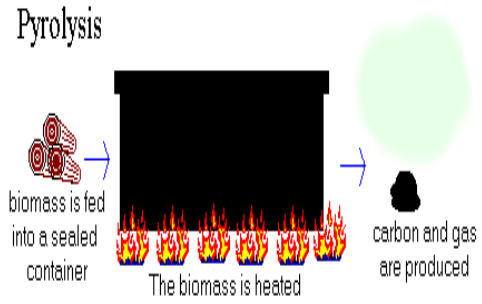

Fig. 2. Picture of pyrolysis

Non-renewable energy resources are composed of mainly fossil fuel. Fossil fuels are fuel formed by natural processes such as anaerobic decomposition of buried dead organisms. The age of the organism and their resulting fuels is typically millions of years and sometimes exceeds 650million years [21]. Fossil fuels consist principally of carbon and hydrogen bonds. There are three types of fossil fuels which can be used for energy provision and they are as follows:

(1) Coal
(2) Oil (Petroleum)
(3) Natural gas.

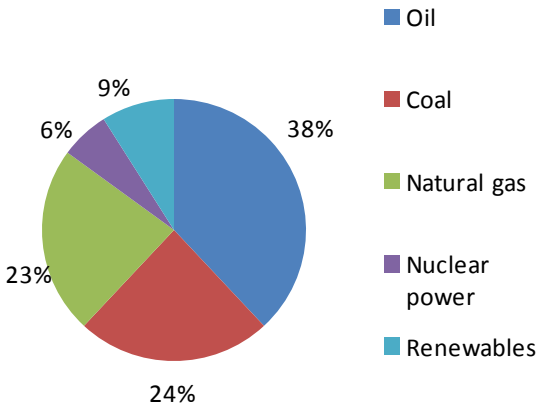

Fig. 3. Global energy consumption by fuel type (2001)

2.5 COAL

Coal is the oldest commercial fuel, dating in Nigeria from 1916 when 24000tons were produced. Production peaked at near one million tons in 1959, before declining to the present insignificant level. This is due to the reduction in the demand for coal and switching from coal to gas for thermal power generation. Nigeria's coal reserves are large, over two metric tonnes of which 650 million tonnes are proven. Coal productions are from the cretaceous Anambra Basin and extend to Dekina in the northern part of the basin of Benue state and to okigwe in the south. The coal in the basin is sub-bituminous and occurs principally at two levels, the lower coal measures (Mamu formation) and the upper coal measures (Nsukka formation). Mine production capacity after full rehabilitation and privatization at major minning sites in Nigeria could attain the following level: Onyeama and Okpara (150,000-400,000 tonnes/year), Owukpa (2500 tonnes/year) and Okaba (15,000-300,000 tonnes/year) [22].

The four types of coal are as follows;

(1) Lignite
(2) Sub bituminous
(3) Bituminous
(4) Anthracite

Lignite- This is the soft, brownish-black coal that forms of the lowest of the coal family. The sub bituminous is a dull black coal which gives off a little more energy than lignite when it burns. Bituminous is sometimes called "Soft coal" and it has more energy packed in it. Nigeria sub bituminous coal has a high calorific value (5,000-6,000 cal/g or 5500-6500 airdried), low ash and low sulphur content, with good storage characteristics. Anthracite is the hardest coal and it gives off a great amount of heat when it burns [23].

2.6 OIL

This is a liquid that is formed from the remains of marine micro organism deposited on the sea floor. After millions of years, the deposit ends up in rock and sediment where oil is trapped in small spaces. Oil is the most widely used fossil fuel. Crude oil consists of many different organic compounds which are transferred to products in a refining process.

2.7 NATURAL GAS

Is a gaseous fossil fuel that is versatile, abundant and relatively clean compared to coal and oil. Like oil, it is formed from the remains of marine micro-organisms. This is a relatively new type of energy source. Until 1999, more coal was used than natural gas. Natural gas consists of mainly methane (CH4)[24]. It is highly compressed in small volume at large depth in the earth.

Nigeria is a country richly endowed with both renewable energy resources such as wind, solar, water, biomass, and non-renewable energy resource like crude oil, natural gas, coal etc. that could be used for both domestic and foreign electricity power generation. However, the country is lacking in the policies and technologies that will enable her fully explore these rich God given natural resources. Nigeria holds the largest natural gas reserve in Africa but has limited infrastructure in place to develop the sector which leads to the flaring of the gas [2]. The household sector has consistently accounted for over half of the Nigeria total domestic energy consumption. 1989, its share was about 65%. This alone is enough to highlight the importance of the sector in the Nigerian energy system.

Energy consuming activities in this sector is cooking, lighting and operation of electrical appliances (non-substitutable electricity)[12]. In 1989, the shares of the activities in the final energy consumption were 91%, 6% and 3% respectively.

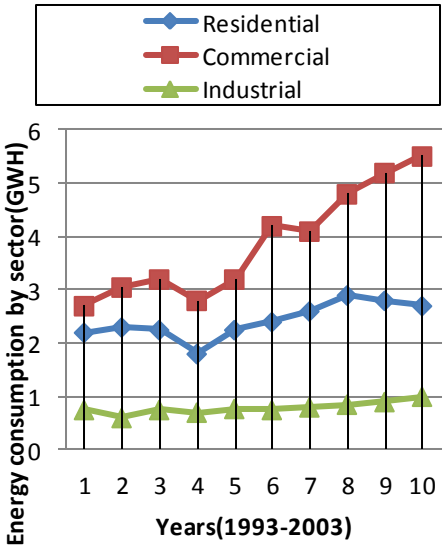

Fig. 4. Energy consumption pattern by sector

Figure 4, above shows the graph of energy consumption by sector from 1999 to 2004.From there we observe that the residential sector has the greatest consumption value of energy which account for about 65% of Nigeria's total

domestic energy consumption. This alone is enough to highlight the important of residential or household sector in Nigeria energy system. It was closely followed by the industrial sector which is slightly lower than residential or household sector. The commercial sector is the least, maintaining a trend that is approximately linear and almost parallel to the number of years.

3 STRATEGIES FOR OPTIMUM EXPLOITATION TO NATURAL RESOURCES IN NIGERIA

The strategies that should be employed for optimally exploit these energy resources for national development of Nigeria is as follows:

3.1 WIND ENERGY

1. Developing skilled manpower for provision for basic engineering infrastructure for the local production of components and spare parts of wind power system.
2. Developing extension programmers' to facilitate the general use of wind energy technology.
3. Providing appropriate incentive to producers, developers and consumers of wind power system.
4. Training skilled local craftsmen to ensure the operation and maintenance of wind energy system.

3.2 SOLAR ENERGY

1. Setting up and maintaining a comprehensive information system on available solar energy resources and technologies.
2. Providing adequate resources to Energy Commission of Nigeria to domesticate solar and other renewable energy technologies in Nigeria.
3. Providing adequate incentive to local manufacturers for solar energy system.

3.3 HYDRO-POWER

1. Ensuring increased indigenous participation in the planning, design and construction of hydropower stations.
2. Providing basic engineering infrastructure for the production of hydropower plants, equipment and accessories.
3. Encouraging the private sector, both indigenous and foreign, in the establishment and operation of hydropower plants.

3.4 BIOMASS ENERGY

1. Biomass and in petroleum fuel wood, account for over 90% of the domestic energy needs of over 70% of the nation's population, who dwells in rural areas and peri-urban centers and such aforestation should be encouraged.
2. Development of domestic capacity in Biomass production and usage so as to reduce the health implication associated with it.

3.5 COAL ENERGY

1. Re-introducing the use of coal for power generation especially with clean coal technologies.
2. Providing adequate incentive to indigenous and foreign entrepreneurs for the establishment of coal based industries.

3.6 OIL ENERGY

1. Maximizing and expanding the refining capacity in the country to cater fully for local consumption and export of petroleum products.
2. Reviewing existing laws and regulations to create the enabling environment for increased private sector participating in the oil industry, especially the downstream.

3.7 NATURAL GAS

1. Encouraging the establishment of the necessary infrastructure for the effective gathering, transmission and distribution of gas nationwide.
2. Formulating suitable urban and regional planning regulations needed for the effective distribution of natural gas and its utilization by domestic and industrial consumers.

4 CONCLUSION

Nigeria is endowed with many energy resources, such as the renewable energy which when properly utilized or

harnessed can enhance the socio-economic development of the nation. The strategies as enumerated above should be employed to optimally exploit these energy resources in full for national development creation of opportunities for investments and businesses in the energy sector.

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