**SOLAR TECHNOLOGY: AN ALTERNATIVE SOURCE OF ENERGY FOR NATIONAL DEVELOPMENT**

**ABSTRACT**

This research was carried out to understand solar technology: An alternative source of energy for national development. The study was based on the pursuance of basic objectives to ascertain the present state of power generation and supply in Nigeria, to examine the possibility of reviving the energy sector of Nigeria, highlight the advantages of solar technology as it affects national development. In essence the study sets out to contribute to the advancement of knowledge on solar energy in Nigeria as an alternative power supply for national development. The qualitative research technique was utilized during the course of the study. The research explores the historical development of solar energy. It further highlighted solar energy and its applicability and the solar thermal technology. It is important to note that for Nigerian to have a stable power supply, solar energy should be use as an alternative source of power. It is imperative to know that if Nigerian hopes to develop her economy, government should develop solar energy power plant across the nation. Universities should also be encouraged to undergo researches into solar technology. The government should introduce solar in the science curriculum in Nigeria schools at all levels.

**CHAPTER ONE**

**INTRODUCTION**

**1.1 Background of the study**

The development of a nation brings an effective transformation of its socio-political, economic, cultural, technology and industrial bases. More so, within the particular conception of socio-economic processes which underscores every economic system, economic development, globally, resolves around the issues of the character, structure, pattern and evolution of desirable inter-personal relations of production, allocation and utilization of available resources in any country.

In order to achieve these and put national development on course, modern operational technologies with respect to production, allocation and utilization is designed and tied strictly to the use of energy in one form or the other. Based on the above, it is seen that the quest to rapidly and firmly put the Nigerian state on course of sustainable development is technically a function of adequate and sustained supply and distribution of energy. According to the present Governor of the Central Bank of Nigeria, Sanusi, the Nigeria economy will continue to take a wrong course until the power sector of the nation is put on the right track. This underlines the need of an adequate supply of energy to the nation in general and the industrial sector in particular.

The above synopsis indeed, explain the major reason why one of the frustrating and disturbing issue in Nigeria national development today is that of epileptic power supply particularly since the late 1980’s. The situation of the emerging electricity outrage from the supply inadequacy, especially in the late 1990’s was that of persistent electricity power shortage at alarming rates. This is in the face of abundant primary electricity resources- coal, natural gas, geothermal, tide, solar, biogas, and biomass to mention but the few. This period was a period that could by tagged the “Dark days” in Nigeria.

Apart from economic and political crisis that grounded socio-political and economic activities in the country, the period of the 1990s was defined as a period of serious electricity crisis. This period was also tagged to be a crucial or decisive moment; an undesirable turning point; a time of difficulty and distress. To cap it, the ugly situation of electricity shortages and inadequacy shows the emergence of a crisis situation in which electricity supply could not catch up with its high demand. The use and need of alternative power generators then become the order of the day. The use of generators has however cost the nation in ways of air pollution in the form of carbon monoxide which has resulted to death especially of member of households. Some other cost has been noise pollution, and the expensive cost of maintaining some of these generators which has at one time or the other stalled industrial production and high cost of production.

This has thus created the need for other safer and less expensive alternatives of power supply. The adoption of solar energy as an alternative power supply then becomes most necessary. This involves the use of lenses or mirrors and tracking system to focus a large area of sunlight into a small beam and then converts light into electric current using the photo electric effect, while PV is a device that converts light into electric current using the photo electric effect.

Solar power has great potential. In 2008, solar power supplied about 0.02% of the world total energy supply. The technology is now been popular following the energy crisis that engulfed that world system in the 1990’s. There are many competing technologies, including fourteen types of photo electric cells, such as thin film, mono crystalline silicon, polycrystalline silicon, and amorphous cells, as well as multiple types of concentrating solar power. This creates the bases for many alternatives and options even in the solar power energy technology.

The adoption of solar technology in Nigeria especially in recent times has been rather dramatic with its increasing role especially in household usage. The Nigerian Conservation Foundation (NCF) director, Dr. Onyebuci Onyegbule, in a fundraising expressed that the NCF considered the introduction of Photo Voltaic (PV) technology a necessity. The consensus was that GWU Solar should consider rural communities by fabricating small power machines for agriculture, the running of cottage industries, and the introduction of demonstration centres for raising awareness.

The tropical climate makes solar energy the most viable alternative source of renewable energy in Nigeria. Harnessing the sun’s energy to produce power is an imperative for rural areas where the hope of being connected to the national grid is very remote and extremely expensive. It is however unfortunate that in spite of the inherent high potentials for solar technology in Nigeria and the immense benefits of the use of solar technology Nigeria is yet to take full advantage it.

**1.2 Statement of problem**

It is a fact that the quest for national development in Nigeria relies heavily on the need for a sustainable power supply. Nigeria been a country with a lot of potentials and resources stands a chance to acquire such sustainable power supply. However the country still battles with the high rate of power outages which has not only crippled the business environment of the nation but has also discouraged foreign investment. The development of Nigeria however relies heavily on investment in the industrial sector which in turn is dependent upon a sustainable and adequate power supply in the nation.

The household sector has also suffered greatly from the power problem in Nigeria. Power supply in some areas in Nigeria remains a mirage as people continue to seek for alternative power supply for their homes and small businesses. One of such alternative power supply which however has not been fully tapped is the solar energy. Based on the foregoing, this study seeks to proffer answers to the following:

1. What is the present state of power generation and supply in the country?
2. Can the energy sector in Nigeria be revived?
3. Can solar energy be an alternative to the present source of energy in Nigeria?
4. What are the advantages of solar technology as it affects National development?

**1.3 Objectives of the study**

The general objective of this study is to examine the possibility of using solar technology as an alternative source of energy for Nigeria national development. Specifically, the study will achieve the following objectives:

1. Examine the present state of power generation and supply in Nigeria.
2. Examine the possibility of reviving the energy sector of Nigeria.
3. Consider the use of solar energy as an alternative source of energy for National development in Nigeria.
4. Highlight the advantages of solar technology as it affects national development.

**1.4 Significance of the study**

The importance of this study is underscored by the fact that it would contribute to the advancement of knowledge on solar energy in Nigeria as an alternative power supply for National development. The investigations in this study will also assist Government agencies particularly the Ministry of Power and Energy to appreciate the significance of solar technology in enhancing National development. It will further help in stimulating further research on the solar energy as an alternative power supply. It is also hoped that the study will add to existing literature and body of knowledge on the interrelationship between the concepts of energy supply and National development. It will also provide material for future studies on this topic.

**1.5 Scope of the study**

The issue of the adoption of solar energy as an alternative power supply in Nigeria has been ongoing for a while now. This has led to projects and programmes which have been introduced in Nigeria Since the inception of democracy in Nigeria in 1999, different states in the federation have implemented several measures in developing the power.

In the course of this study, only relevant literature on this topic from the periods of 1999 to 2010 will be referred to. This is because of the need to make the study familiar to current leadership who has been key players in the formulation of existing policies.

**1.6 Limitations**

A major limitation is the dependence of this study on secondary data to analyse the problems in the study. Although the data used was from reputable agencies and bodies, the authenticity of their findings might not be insulated from bias. This however did affect the quality of research carried out as the researcher adopted proper and comparative analysis in arriving at a veritable research work.

**1.7 Methodology**

This is a literature based conceptual study. The researcher reviewed literature on solar energy potential and issues surrounding their successful deployment and proceeded to develop a detailed road map of how this potential can be harnessed for sustainable energy generation in Nigeria. Numerous advantages that should serve as a stimulant to policy makers to both adopt and implement the plan are also provided.

**CHAPTER TWO**

**CONCEPTUAL CLARIFICATION**

**2.1 Conventional energy generation in Nigeria**

The bulk of the supply for Electrical energy in the country has been the main task of power distribution companies and in terms of increased facilities they expands annually in order to meet the ever increasing demand electricity generation and consumption . At present, the installed and available electrical capacity in the Nigerian generating stations as cited by (Okoro and Madueme 2004) a total grid capacity of5924.7MW, only 4586 MW were available This implies that about 22% of the installed capacity was unavailable. This may be due to operational inadequacies and inability of units to operate at full capacities of the generating stations and their respective percentage contributions to the total energy products.

**2.2 Disadvantages of conventional power generation and usage**

The following are some of the demerits of the present source of power supply in Makurdi and Nigeria at large:

1. Hydro plants depend for sustained operation on in-flow of water into the storage and this in-flow can be affected up stream by drought and outside the borders of this nation, by political or other considerations.

2.The pollution arising in the case of thermal combustion of fuel is not environment-friendly due to the fact that sulphur oxides, heavy metals, radio-active elements, hydrocarbons and large quantities of carbon-dioxide are emitted which leads to acid rain.

3. Fossil and nuclear fuels are finite and non-renewable energy sources. The world oil and gas reserve are running out, nuclear power has turned out to be problematical, the use of coal is constrained by the adverse environmental impacts of its extraction and burning

4. Burned nuclear fuel is radioactive; it requires remote handling and special processing and disposal of toxic waste.

5. Special system designs are required to prevent radioactivity release during normal operation or due to accidents.

6. Major portions of nuclear plants are radioactive during and after operation, requiring special precautions and advanced technology for maintenance of much of the plant.

7. High charges in tariffs is another hindrance in the usage as most users are unable to pay the bills leading to disconnection.

8. Constant disruption of supply due to inadequate or substandard materials from the generating companies.

9. Low voltage supply from the present source of power.(Okoro and Madueme 2004)

**2.3 The concept of solar energy**

Solar energy is the energy of sunlight collected and used to provide electricity, to heat water, and to heat or cool homes, businesses or industry. Sunlight is a clean, renewable source of energy. It is a sustainable resource, meaning it doesn't run out, but can be maintained because the sun shines almost every day (Fagbenle 1990). Coal or gas is not sustainable or renewable: once they are gone, there is none left. .Photovoltaic (PV) solar cells directly convert sunlight into electricity. The simplest cells are used to operate wristwatches and calculators, and more complicated systems are used to light houses. PV cells are combined into modules called arrays, and the number of arrays used determines the amount of electricity produced. For example, a large number of arrays would be needed to generate electricity for a power plant. A power plant can also use a concentrating solar power system where sunlight is focused with mirrors to create a high-intensity heat source to produce steam or mechanical power to run a generator that creates electricity. Solar power is important because every beam of light that we can convert into electricity is another step in reducing our dependence on polluting fossil fuels.

**2.4 How electricity is generated through solar power.**

Solar panels turn energy from the sun’s rays directly into useful energy that can be used in homes and industries. There are two main types: solar thermal and photovoltaic,( PV). Solar thermal panels use the sun’s energy to heat water that can be used in washing and heating. Photovoltaic panels use the photovoltaic effect  to turn the sun’s energy directly into electricity, which can supplement or replace the conventional supply (Acher and Mark 2005).A photovoltaic panel is made up of a semiconducting material, usually silicon-based, sandwiched between two electrical contacts. To generate as much electricity as possible, PV panels need to spend as much time as possible in direct sunlight . A sloping, south-facing roof is the ideal place to mount a solar panel .A sheet of glass protects the semiconductor sandwich from hail, grit blown by the wind, and wildlife. The semiconductor is also coated in an antireflective substance which makes sure that it absorbs the sunlight it needs instead of scattering it uselessly away.When sunlight strikes the panel and is absorbed, it knocks loose electrons from some of the atoms that make up the semiconductor . The semiconductor is positively charged on one side and negatively charged on the other side, which encourages all these loose electrons to travel in the same direction, creating an electric current . The contacts capture this current in an electrical circuit.The electricity PV panels generate is direct current (DC). Before it can be used in homes and industries, it has to be changed into alternating current (AC) electricity using an inverter. The inverted current then travels from the inverter to the building’s fuse box, and from there to the appliances that need it.  
PV systems installed in homes and industries can include a dedicated metering box that measures how much electricity the panels are generating.

**2.5 Advantages of solar power**

Solar energy is a resource that is not only sustainable for energy consumption; it is indefinitely renewable (at least until the sun runs out in billions of years). Solar power can be used to generate electricity; Solar panels also require little maintenance. After installation and optimization they are very reliable due to the fact that they actively create electricity in just a few millimetres and do not require any type of mechanical parts that can fail. Solar panels are also a silent producer of energy,

Other advantages as cited by ( Okoro and Madueme 2004) include;

1. The sun is constant – it will always be there and is therefore a reliable, utterly renewable source of energy.
2. Once the initial financial outlay has been made to purchase the solar panels, the sun’s energy is completely free.
3. As it does not rely on the burning of harmful fuels to generate electricity, solar power is non-polluting – it does not contribute to global warming or greenhouse gas emissions.
4. As there are no moving parts in a solar panel, they require very little maintenance.
5. Solar power allows those in remote locations to live off the grid without having to rely solely on noisy, smelly generators. It is part of the solution to becoming energy self-sufficient.
6. Without the need for wires, cords or power sources, solar panels are incredibly easy to install.
7. Solar energy is renowned for its versatility – it can be used to power anything from a tiny torch to a satellite in space.
8. Solar technology is improving and reducing in cost all the time, whereas fossil fuel prices are only steadily increasing.

**2.6 Solar energy research in Nigeria**

Solar energy research is not new in Nigeria and has continued to gain popular acceptance nationwide. Several solar energy research works have been carried out and all point to the fact that optimism on the conventional method of electrical power generation is at low ebb. (Davidson and Oni 1991) are of the opinion that since the fossil and nuclear fuels are delectable to a severe energy crisis as the world’s energy demands remain doubtful. The paper highlights the seemingly way out to avert the looming danger. Consequently, a call was made for measures and adequate policies in effective management, conservation, exploration, exploitation and utilization of Nigeria energy sources, and minimally reduces her dependence on oil by developing more fuel alternative in Africa. The prospects and problems of applying solar energy in transport technology in Nigeria have been reviewed by (Fagbenle.1991) the prospects of solar energy application in road, air, sea, rail and military transports were enumerated. The paper underscores the importance of producing solar photovoltaic cells, modules, and arrays locally if the large scale application of solar energy type transport systems is to be feasible. The paper concludes by bringing the attention of government to bear in the area of establishment of more solar energy technology centres and encouragement of research on the local production of solar cells. The work of (Ishaku.1990) gives a nod to an independent power generating system for use in rural areas that incorporates solar energy in the form of sunlight, wind and running water as primary energy sources. The paper however warns that such proposition may not be necessarily cheap, the primary energy sources (Solar) not withstanding because .albeit solar energy is free, its conversion devices and production remain cost intensive. He called on Engineers and Scientists to acquire skills that will enable them to fabricate energy conversion devices in order to meet the needs of millions of Nigerians in their yearning to enjoy the numerous benefits accruing from electrical power generation. (Fagbenle. 1990) using meteorological data estimates the total solar energy radiation in Nigeria. The paper observes that total solar radiation In Nigeria generally increases with latitude. The month of August, irrespective of the zone, was seen to witness the least total solar radiation throughout the country. The work is indeed important as it shows the possibility of the development of solar energy in Nigeria. Mika’ilu and Kamaluddeen (2007) configured the solar energy scenario for Nigeria from a purely economic perspective. The result of the study reveals that economics just like technology will play a vital role in the success or failure of a solar energy system. The paper advocates an alternative energy sources for the country and earnestly employ the policy makers of the need to channel resources along that direction. This becomes imperative, the paper noted, because of the increasing cost of fuels ,dwindling resources at Nigerian Journal of Technology, Vol. 23, No. 1, March 2004 Most recent work on the use of photovoltaic plants to supply modest amounts of power to efficient end use equipment in areas where a connection to the electricity distribution network is not possible or is prohibitively expensive was carried out by Jenkins (2010) which noted that photovoltaic equipment is very robust and costly but has low maintenance requirement. He is of the view that high capital cost can be minimized and the power supply made cost effective if the overall system is carefully designed. As research on this vital area of alternative energy resource continues to gather momentum, the nation's policy makers should be prodded into action to ensure that any research findings are converted into concrete terms through adequate funding. It is only by so doing that the efforts made in this area could be meaningful and thus combat the impending world energy crises attested to by the escalating fuel prices and high rate of depletion of oil and natural gas. Our environment will be best for it as emphasis is shifted from fossil fuels to renewable energy sources.

**CHAPTER THREE**

**GENERATION AND APPLICATION OF SOLAR ENERGY IN NIGERIA**

# 3.1 Electrical energy generation potential from solar energy in Nigeria

The energy generated in Nigeria is grossly inadequate, hence the need to improve structures on ground, and also introduce alternative energy technologies (i.e. renewables) to complement current government efforts to provide sustainable energy for the citizens (Federal Ministry of Environment, 2013). Nigeria’s present electricity supply is highly insufficient and epileptic; a situation which has led to individuals corporate and government organizations making alternative arrangements to provide electric power for their installations using various generators with a wide range of power capacity. No doubt, this has increased the cost of production and by direct consequence supports inflation and a lower standard of living of Nigerian Citizens. The additional cost these installed generators bring with their usage is that of environmental degradation which has become a major concern in our world today. Thinking “renewables” is therefore a general approach that has been identified to fill in this energy shortage without degrading our environment.

According to Nnaji and Unachukwe, (2010), Nigeria (lying in the tropics) receives abundant sunshine, where about 1500PJ (about 258 million barrels of oil equivalent) could be available annually from solar energy, if solar appliances with 5% conversion efficiency were used over only one per cent of the total land area of the country for about six months of a year. A giant feat recorded by some scientists at the United States energy department, National Renewable Energy Laboratory (NERL) in August 2008 set a world record in solar cell efficiency with a photovoltaic device that converts 40.8% of light that hits it into electricity (National Renewable Energy Laboratory, 2008; Tyagi et al., 2013). Higher PV cell efficiencies are still being pursued; hence the total land mass requirement will continue to be on the decrease. With this improvement in technology, Nigeria will therefore need a land mass smaller than 1% of its total landmass to get the required energy needed.

Oseni (2012) gave a detailed analysis of energy trends in Nigeria between the year 2007 and 2008. The author extensively presented ways of improving household access to electricity and energy consumption pattern in Nigeria with a focus on using renewable energy alternatives. According to the author, the country receives an average solar radiation at the levels of about 19.8MJm-2 per day and average sunshine hours per day estimated at 6hday-1. With an average solar radiation level of about 5.5kWh per day and the recent improvements in PV panel efficiencies, it is possible to generate 190550GWh of solar electricity per year with solar panels covering only 1% of the entire land mass of Nigeria (Oseni, 2012).

The energy demand in Nigeria will continue to increase as the Nigerian population continues to increase and as the energy demand per person increases due to fast urbanization. This means that the pressure on existing energy sources will continue to increase. Although Nigeria is known as a major producer of fossil fuel (which is a primary energy), a greater percentage of her secondary energy needs are supplied by expensive imports. According to Oseni (2012), Nigeria consumed 8.41 million tonnes of oil equivalent of petroleum products in 2007 with more than 93% of it imported where fossil fuel provided about 61.4% of the total indigenous primary energy production, with crude oil (49.9%) and natural gas (11.5%).

Although fossil fuels contributed immensely to indigenous production, they contributed only 17.8% to the total primary energy consumption in the country (Oseni, 2012). This is the case because most of the crude oil produced as primary energy resource is exported in their crude state. This situation has given Nigeria less value than what would have been available if the capacity to refine the abundant raw crude oil for consumption in the country was installed.

Presently in Nigerian refineries, the flaring of natural gas resulting in serious environmental issues is still the norm rather than the exception. A greater capacity to refine crude oil without addressing these issues will lead to further pollution of the environment, a situation that has dire impacts on citizens. It is therefore necessary that other alternatives be considered as supplements to crude oil so as to create an energy utilization balance for the Nigerian economy.

# 3.2 Issues of solar energy utilization for generating electricity

Solar energy utilization for generating electricity no doubt has several advantages which include: low operational and maintenance cost, a very high meantime between failures of about 20-30 years, noiseless and no moving parts during operation, availability of PV panels in different sizes or modules over a wide range of power rating, perceived environmental friendly nature with respect to release of greenhouse gases, global warming, ozone layer depletion, etc. However several issues arise in generating electricity from solar energy. These issues include:

# Long Energy Pay-Back Time

Sherwani et al. (2010) carried out a review of the life cycle assessment of solar PV based electricity generation systems. According to their findings, the variation in the energy pay-back time (EPBT) and green house gas (GHG) emissions have been dependent upon many factors, such as the type of solar cell, solar panel orientation and angle, irradiation of the location, difference installation (integrated or non-integrated systems as well as facade, flat roof and solar roof tiles), efficiency of the Balance of system (BOS) components, size (capacity) of the system, lifetime of the system and the electricity mix of that particular country and year of study. The main issue that arises from this is that EPBT influences the decision of investors to invest in electrical energy generation using PV panels. If investors perceive the EPBT in solar PV based electricity generation systems to be too long, they may decide to seek for alternative investments which will hinder the growth of the Solar PV electricity generation Industry. It is therefore necessary that the energy pay-back time of solar PV based electricity generation systems be reduced considerable through continuous improvements in designs to facilitate production of PV cells that are cheaper and yet have higher efficiencies.

# High Up Frontal Capital Cost

Another major down side of solar energy utilization in generating electricity is the high up frontal capital cost compared to its conventional energy alternatives (Chigbo, 2010). The general perception is that this technology is not yet mature hence it is only suited for particular markets and even then will require heavy subsidy to make it viable. This is quite erroneous to some degree as many countries such as Germany, the United States and China have succeeded with their solar energy utilization plans and are already enjoying the numerous dividends (Tyagi et al., 2013). Solar voltages have been powering space modules since the beginning of space programmes and talking about the cost, the high up frontal capital cost can be handled by letting Giant companies and Governments play a part in the programme by bringing in the much needed up front capital and recouping their investment over time.

**Ignorance of the Benefits of the Technology**

Another serious setback to the solar energy program is ignorance of the benefits of this technology. Awareness of the opportunities offered by solar energy and its technology is low among members of the public and private sector stakeholders. This lack of information and awareness creates a market distortion that results in higher risk perception for potential renewable energy projects. According to Kok et al. (2011), energy conservation interventions have frequently failed because they often did not take the full range of significant influences on human behaviour, into account. There is therefore a need for dissemination of information on solar energy resource availability, benefits and opportunities to the general public in order to raise public awareness and generate activities in the sector. Kenya has taken giant steps in the number of solar power systems installed per capital (but not the number of watts added). More than 30,000 very small solar panels are sold in Kenya annually, as more Kenyans adopt solar power every year than they make connections to local grid.

**Requirement of Large Expanse of Land**

Another major issue in the use of solar PV panels is the large expanse of land required for their installation. Clearly, moving to solar energy as a major energy producer would mean an enormous reallocation of land and resource use. However with the continuous improvement in PV efficiencies, the required space per Kwh of electricity generated will continue to be on the decrease.

**Low efficiencies of PV panels.**

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| Table 1: PV panel materials and their efficiencies   |  |  |  | | --- | --- | --- | | **PV panel material** | **Present Average**  **Efficiency (%)** | **Remark** | | Monocrystalline Silicon Solar Cell | 28 | Available Commercially | | Polycrystalline Solar Cell | 19.8 | Commercial efficiencies are about between 12 and  15% | | GaAs Cells (often mixed with other metals as alloys) | 40.7 | Highest efficiency so far | | Dye-sensitized and organic base cells | 5.4 | Lowest efficiency | | Thin film technology | 19.9 | Available Commercially | | Hot carrier solar cell | 66 | Has never been commercialised but remains an experimental technology due to lack of suitable material that can decrease carrier cooling rates |   ***Source: Tyagi et al, (2013).*** |

Low efficiency of PV panels is another draw draw-back presently limiting the widespread diffusion and usage of PV cells in generating electricity. PV panel efficiencies must be increased to establish their acceptance in the energy market. Table 1 shows some materials used for making PV panels and their efficiencies. It can be seen from the table that GaAs cells which uses multi-junction cells have the highest efficiencies so far. It is believed that exploiting the multi junction technology will provide the future PV panels with higher efficiencies. PV panel efficiencies and output power decreases due to increase in temperatures hence the need to provide cooling at high illumination conditions. Dust and humidity also reduce the efficiencies of solar PV cells to lower values.

# Solar Irradiation

Solar irradiation which varies throughout the entire day and affects the efficiency and output of PV cells is another issue being considered in using solar cells. Increase in solar irradiance increases the PV module efficiency because the high number of photons hitting the module increases and many electron-hole pairs are formed which will produce more current. During the night, solar irradiation is zero hence PV cells will have zero output at night. A simple way to solve this problem is to incorporate another renewable energy source such as wind energy with the solar PV modules so that they will deliver the required power at night. Electricity storage in batteries is also useful to make electrical energy available during these periods when solar irradiation is low or not available.

**Environmental Pollution**

Although solar PV cells are generally acclaimed to be environment friendly, their by-products during the manufacturing process and waste after their useful life can also constitute environmental hazards. Raw materials for making solar PV cells are obtained through mining operations which may cause danger to miners. In addition, mining machines involve usage of fossil fuels such as petrol and diesel which also cause environmental pollution through emission of hazardous gases and heavy metal from the mines. As more PV cells are manufactured and installed, the environmental pollution which results through their manufacturing process and disposal after their useful life will also be on the increase.

**Long life storage and long distance transportation (Goffman, 2008).**

The problem of storing large amount of solar energy after it has been converted to electrical energy is a huge challenge yet to be overcome before solar energy becomes a major contributor to the world energy grid. A major infrastructure investment will be necessary for such a storage system to be possible. Also, transporting the energy from where it is produced to where it is needed is another huge challenge to be overcome. A new highvoltage, direct-current (HVDC) power transmission backbone would have to be built using Direct Current for this to be possible.

# 3.3 Applications of solar energy

The basic applications of solar energy are in the following areas: Agriculture, engineering. Medical Sciences, Power generation and Recreation.

## **Agriculture**

Tremendous efforts have been made in area of application of solar cells in agricultural sector. This can be seen in the areas of solar water heating for dairy farms and micro irrigation Solar crop dryers have since been in use. In order to facilitate harvesting, storage, feeding, germination and milling, crops need to dried. In Ghana the solar dryers were used for drying of mainly Okro and Pepper and in some few occasions. maize. Drying was averagely three days with the solar dryers as compared to one week with sun-drying. The products of the solar dryers were more beautiful, cleaner and fast -selling than sun-dried ones. Solar cells are being widely used in agriculture as a primary source of energy to drive water pumps. These PV-powered portable pumps can be used by those engaged in dry season cultivation of high value market crops for micro irrigation. In a research conducted by Peter (2019) design criteria of solar water pumping systems for Agricultural production was presented. The author enumerated the merits of solar water pumps to include:

(a) Their no-fuel requirement, no-noise pollution free and little or no maintenance requirement.

(b) They are compact and light in weight, etc.

# Engineering

The contribution of wind energy, photovoltaic energy .geo thermal energy, waste heat and biomass amounts to only a few tenths of one percent on the world list of power sources. Phorovoltuic solar cells, however, are becoming more and more popular. They were first used in electronic calculators, which thus no longer needed a battery- and became environmentally more, friendly. But since then photovoltuic cells have gradually replaced other power sources also in battery re-chargers, portable radios, emergency roadside telephones, buoys and even homes. Solar **PV** generator can be used to power long distance relay telecommunication stations that arc linked by one part of the country to the other. This has the potential for not only reducing road transport trips and consequently fuel consumption by the transport sector but also efficiently improving the internal communication system considerably.

Another important application of the solar energy in engineering is in the area of heat pumps and solar furnaces. A heat pump is used for heating purposes rather than cooling, and it can operate in such a way that in the cold season of the year it will take the colder air from outside the building and give up the energy as warm air inside the building. By using large radius convex lenses or large-curvature paraholic reflectors, the solar radiation can be concentrated upon a very small area to generate veryhigh temperatures. Solar furnaces can therefore be built by employing radiation concentrators. A solar furnace built in Puran in Yugoslavia used a 1.5m diameter searchlight reflector with a 65cm focal length to produce temperatures exceeding 2000°C for the purposes of studies on the growth of crystals and the production of pure minerals.

## **Medical sciences**

One of the most important amenities to be provided in rural areas is small health care facilities. The most basic equipment to such a centre, located in remote rural areas, is the ability to meet its cold-chain requirement necessary for vaccines storage. Advancements In solar technology have made available in the markets efficient and portable solar refrigerators that can be used for storage of medication, vaccines, etc. Solar powered refrigerators can also provide chilled and frozen storage for bulk meat, vegetable, and dairy products.

**Power generation**

Majority of the country's population dwells in the rural areas. Most of these people do not have access to electrical energy from the national grid.

Consequently, Kerosene-powered lamps becomes a predominantly power source for most rural dwellers. The alternative solution to this, calls for extension or the nations central power grid system to the vast majority of the rural areas or to establish a diesel generating set system (DGSS) to supply the teeming rural community. The alternative solution may not be realised due to its affordability and for the fact that the energy demand accruing from such exercise may outweigh power generation capacity (PGC)- which presently is saddled with load demand crisis (LCD). This inherent problem of the above methods could be solved by the provision of electrical power to remote locations through solar powered plants.

Photovoltaic (PV) equipment is now available to provide a very reliable power supply at locations remote from the electricity network and where conventional fuel supplies are unavailable. In order to use this technology in a cost -effective manner it is essential to understand the resources, the component and system aspects of the photovoltaic plant and also to have a load served by efficient end- use equipment with a high-value service. Solar energy can also be applied in vehicular road transportation system. As noted by Fagbenle (2014), three options are open in applying solar energy to vehicular road transport namely:

1. Solar energy to provide 100% motive power of the vehicle.
2. Solar energy to provide only electric power requirement of the accessories (i.e. a solar energy generator)
3. Solar energy to drive a key sub-system such as air conditioning, air compressors (trucks), radiator and AC condenser cooling fans, etc.

# Recreation

Solar powered systems provide essential recreational facilities for remote dwellers. Solar energy can be used particularly for heating swimming pools in which large -area unglazed collectors are mostly commonly employed. Solar powered systems can also be used to provide reliable power to very high frequency (VHF) transceivers for communicating with the flying doctors and other important service. Power for a communal Television/Video set can also be supplied using solar energy.

**CHAPTER FOUR**

**SOLAR TECHNOLOGY AS AN ALTERNATIVE SOURCE OF ENERGY FOR NATIONAL DEVELOPMENT**

**4.1 Need for an alternative source of power. (Solar energy)**

For a substantial industrial development of an economy like the one of Makurdi and Nigeria at large, there is a need for an alternative source of power supply (solar energy). This is because of the present challenges faced from the present conventional source of power supply ranging from constant failure in power supply, high tariff charges, low voltage supply and considering the fact that 'there is an impending energy crisis in Nigeria due to over-dependence in fossil fuels. The situation becomes more critical as the so-called fossil fuels are finite and fast depleting (Okoro and Madueme.2004). This underscores the need to look at the sunshine hours in Makurdi and Nigeria at large since sunlight is primary energy source. Earlier work done by ( Fagbenle. 1990), reveals that the mean annual temperature for most localities in Nigeria is about 27°C with the mean annual solar radiation about equal to that of several cities in the temperate climate. This assertion was confirmed by Sambo and Doyle (1986) who calculated the average yearly incidence of solar energy on the ground to be 2300KWh/m2 giving total incident energy of about 2.100 x l0el2 KWh per year for Nigeria. Therefore there is greater accessibility and availability of solar energy to boost the industrial activities in Makurdi and Nigeria at large as the source of power supply knowing that solar equipment has a very low maintenance requirement compared to the conventional methods of Electricity generation. This is even more glaring as solar energy source is free and renewable as compared to the 'Conventional fuels that are not only costly but finite.

# 4.2 Efforts to harness solar energy for sustainable energy generation in nigeria.

A major draw-back which most developing countries in Africa (including Nigeria) have is the lack of will and commitment to invest in developing and sustaining our indigenous technologies. We often opt for the short run solutions of purchasing finished goods and services while neglecting the seemingly hard way of developing the necessary technologies so as to use our abundant locally available raw materials to produce these goods and services ourselves. This has continued to put us behind as third world nations, a situation that will become worse if we do not begin to do things differently.

It has been recognized by all stakeholders that the major barrier to renewable energy and energy efficiency development in Nigeria is Lack of Policy and Legislation (Federal Ministry of Environment, 2013). This lack of policy and legislation on renewable energy technologies and also the need to address the inefficient use of energy has been identified as key barriers to the development of the sector.

The Researcher present a four stage pragmatic plan that will help Nigeria to harness her abundant solar energy as a means of providing sustainable energy generation in Nigeria. This plan can serve as a vital document to build on in the development of the renewable energy policy for Nigeria. The four stages described in the plan are

1. Solar PV Panel Technology Development Stage
2. Solar/Wind Power Plant Development Stage
3. Commercialization Stage
4. Evaluation , Adjustment and Expansion Stage

These stages which are overlapping in some cases are described in details in the following sub sections.

**Solar PV Panel Technology Development Stage**

This stage involves the acquisition of the necessary infrastructure, equipment and facilities, engaging skilled personnel, training and re-training and development of Nigerian Photo Voltaic (PV) Panels which will be used in the Solar / Wind Plants to be developed.

The Researcher propose that the Nigerian Government should establish a Solar PV Panel Development Centre (SPVPDC) in one of the Northern or middle belt States of the federation. Developing this technology without any collaboration will be a hard way to start hence, the Government will have to sign contractual agreements (at least 10 years) with at least two proven Solar panels, cells and wafers manufacturers (such as Sungen Solar, Trina Solar, Yingli Green Energy and Suntech Power Holdings in China, Sharp in Japan, Hanwha SolarOne in South Korea) and their respective governments to facilitate collaborations with their experts who will at the beginning form the bulk of the skilled personnel in the Centre. They will be saddled with the responsibility of helping the Nigerian Government acquire the necessary infrastructure and equipment, training Nigerians and subsequently assisting in developing this Nigerian made PV panels. China is presently leading in solar PV production while European countries are leading in PV installation (Tyagi et al., 2013). China has taken the lead due to their government policies which provides subsidies to PV panel producers in China so as to give them comparative advantages over those produced in other countries in Europe, America, etc. This initiative has threatened the survival of PV producers in Europe and America (Bilby and Zhu, 2013; Young, 2013).

However, if talks with these giant solar companies fail to yield positive results, the government can collaborate with smaller companies in these same countries who have not yet made a strong impression on the world solar PV market. These Companies will be more willing to enter the agreement if they are presented with the numerous benefits they stand to gain through the collaboration (large market in Nigeria and other African countries for their product, protection from stifling bureaucracies that makes doing business difficult and rebates in taxes charged on their products before Nigerian PV panels are developed and continuity in using a percentage of their product even after Nigerian PV panels have been developed).

The necessary facilities and equipment for the centre will be acquired with the support and collaboration of these professionals, Companies and Governments. The cost will definitely be high but it is one of the prices we have to pay now if we must break away from the circle of purchasing finished goods and services. The Innoson Vehicle Manufacturing Company (IVM) in collaboration with foreign skilled personnel from China, Japan and Germany has made indigenous cars (IVM, 2013). If they have succeeded with using this model, the researcher believe that the Nigerian government can do the same if not better. The centre is not to work in isolation but will collaborate with Tertiary Institutions all over Nigeria. Those to be trained in the Centre will be harnessed from different Tertiary Institutions in the country after a rigorous test and screening exercise to determine those who have the basic practical and theoretical knowledge needed to proceed with the training. However anyone irrespective of educational background who shows a high degree of technical know-how which is related and relevant to this area of research should also is considered for further training at the centre.

Training modules for long and short term theoretical and practical hands on based courses will be developed for use in the centre. Selected outstanding training participants will be retained in the centre after they complete their courses for further training and participation in developing Nigerian made PV panels. Funds especially grants will be available for those in the Centre to proceed with research ideas to achieve this feat. The Skilled personnel engaged will be saddled with most of the training responsibilities as contained in the contractual agreements which they would have already signed. Having acquired the necessary equipment and infrastructure, proceeding with developing Nigerian PV panels will be a possibility.

Researchers in Tertiary Institutions will also be given the privilege to report their research findings related to PV technologies to the Centre and grant awards and other forms of rewards will be made available to such researchers so that they can further develop their findings in collaboration with the Centre. Original proposals will also be dully considered from researchers to ascertain if they have the potential to result in ground breaking inventions before they are funded in collaboration with the centre.

The government will also need to pursue policies to attract Companies that already manufacture PV panels into the country. This is necessary to enable ease of transfer of research findings into finished products by appropriate collaborations of the Centre and Tertiary Institutions with these companies. These Collaborations will also provide a platform where these companies are willing and committed to funding research in this centre. At the beginning, the centre can work in collaboration with these companies in their countries before they finally set up their branch in the country. One of the incentives to encourage them to establish their branch in the country will be the second and third stage of this pragmatic plan where their PV modules will be used to develop Solar and Wind Power Plants and the subsequent commercialization involving small Power companies using Solar technologies which will place their products in high demand.

**Solar/Wind Power Plant (SWPP) Development Stage**

Solar energy is available for less than twelve hours in a day hence the need to store it for use when it is not available. However several researches have shown that combining solar energy and wind for electrical energy generation will result in harnessing two useful renewable energy resources in a complimentary way (Dihrab and Sopian, 2010). Solar energy will be readily available during the day while wind energy will be very useful at night.

The Centre (in collaboration with the Nigerian Society of Engineers, Council for the Regulation of Engineering in Nigeria (COREN), Tertiary Institutions and Indigenous Companies which may or may not have collaborations with Foreign Companies) will set up a research team saddled with the responsibility to develop Nigerian Solar/ Wind Power plants of various units and specifications. This technology is already available here in several Tertiary Institutions here in Nigeria. There is however the need to upgrade it to international standards so that the Power plants developed will meet certain minimum criteria and be accepted in other markets outside Nigeria. Through appropriate government policies, Companies which produce high capacity batteries and inverters will also be encouraged to set up branches in the country in preparation for the mass deployment of these SWPP in a commercial scale. Indigenous companies will be given some advantages in terms of tax rebates, protection from stifling bureaucracies, etc. over those who chose to manufacture their products outside the country. Appropriate agreements should also be signed with these companies assuring them of the large scale use of their products made in the country along with the SWPP developed. Their products must however meet laid down criteria.

This stage can begin side by side with the development of Nigerian PV panels with already available panels but as a matter of laid down policies, a greater percentage of these panels will be replaced by Nigerian made panels as the centre makes progress in their development.

# Commercialization Stage

In this stage, Indigenous Power Companies which provide power, using the developed indigenous Solar/wind power plants are to be licenced having met minimum requirements and signed the necessary contractual agreements with the Government. These Companies are to be independent from Power Holding Company of Nigeria (PHCN) and given the right to install small, medium and large scale SWPP units directly in homes, offices, cottage companies, etc. They will determine their charge rates and Nigerians will have the right to choose between them and PHCN. The competition provided by PHCN will force their prices down to moderate values. The German government developed a feed-in tariff (FiT) support offered by the Renewable Energy Sources Act (EEG) which has enabled dramatic expansion of renewable power coupled with significant cost reductions (Bayar, 2013). The government of Nigeria should develop a similar initiative to encourage energy users to opt for solar alternatives. To offset the high initial investment cost of Solar PV panels, the Federal government will sign agreements with these companies to provide part of the initial investment funds which these companies will pay back through an agreed period of time. Since the maintenance cost is low, these companies will be able to pay-off their government support fund and will continue to sustain themselves in business.

Appropriate Government policies must be put in place for these Power companies to install their PV panels which require large space and their protection from vandalism. Nigerian Electricity Regulatory Commission (NERC) will provide visible government support to these companies so as to avoid resistance and other challenges which will hinder speedy development. China has proven that this protection is necessary, hence Nigeria can learn from their experience.

All established institutions (both public and private) should be given a platform to participate in educating Nigerians of the numerous and potential benefits of solar energy as an alternative to the conventional sources. The media (both electronic and print) should be used as a tool to educate Nigerians of the numerous benefits accepting solar energy alternative has not just for them as individuals but for the world in general. This is necessary to avoid the unwillingness of the general public to accept the new trend or make the necessary changes to their power installations. The incentives introduced by the government should be projected so that Nigerians can see their potential benefits and opt to enjoy them.

# Evaluation, Adjustment and Expansion Stage

This stage involves evaluation of the progress made and making decisions of the necessary adjustments to correct the weaknesses identified in the plan and to strengthen procedures and processes already yielding positive results. It also includes expansion of the plan to develop other technologies that produce raw materials for making PV cells.

A feedback mechanism or structure must be put in place to allow proper evaluation of progress. A unit in the SPVPDC that is completely autonomous and free from the stifling bureaucracy of the other operations in the centre will coordinate this process. They will monitor the plans and ascertain their implementation in line with the stated objectives. They will, in collaboration with other stake holders involved in the plan, identify deviations from the proposed plan and the obvious reasons for such deviations. They will also be saddled with the responsibility of developing pragmatic solutions to overcome such challenges.

This stage will also pursue the development of other basic technologies that serve as raw material producers for the centre. This will include establishment of companies that develop silicon wafers for making, transistors, diodes, Integrated circuits (ICs) and PV cells. Development of Microelectronics and embedded systems technologies and other base technologies involved in production of PV panels will also be pursued during this stage. This will provide the necessary raw materials needed at the centre indigenously so as to further reduce the production cost while increasing the overall benefits associated with the establishment of these base industries that use these technologies.

# 4.3 Case for financial investments in solar energy

Solar energy investments in a developing economy become highly imperative when one discerns the fact that there is an impending energy crisis in Nigeria due to over-dependence in fossil fuels. The situation becomes more critical as the so-called fossil fuels are finite and fast depleting. The suggestion for financial investments in solar energy becomes understandable if the basis for such proposition is critically analysed. This underscores the need to look at the sunshine hours in Nigeria since sunlight is primary energy source. Earlier work done by Fagbenle (2014), reveals that the mean annual temperature for most localities in Nigeria is about 27°C with the mean annual solar radiation about equal to that of several cities in the temperate climate. This assertion was confirmed by Sambo and Doyle (2016) sufficient amount of sunshine. Its average solar insolation is greater than the world's averages. Therefore, there is greater accessibility and availability of solar energy for Nigeria to develop her solar energy technology. It has been noted previously that the cost of Electricity generated from a solar system is high. This is due to high cost of Phoiovoltaic modules. But solar equipment has a very low maintenance requirement compared to the conventional methods of Electricity generation. Also, with continuing research and development efforts, this high investment cost of PV modules is likely to fall and become more competitive. Even though the high investment cost of solar energy may deter willing investors, its long-term merit is quite encouraging. This is even more glaring as solar energy source is free and renewable as compared to the 'Conventional fuels that are not only costly but finite. The conventional energy sources arc not friendly to the environment. Apart from the fact that there is a day-to-day depletion of coal, gas and oil, the increasing problem of environmental pollution associated with the utilisation of conventional sources of energy is unprecedented. The ugly effects of conventional systems such as the wanton pollution of terrestrial arboreal and aquatic qualities through wastes and spillage add to make the expected call for solar energy investment in a developing economy apropos.

**CHAPTER FIVE**

**CONCLUSION AND RECOMMENDATIONS**

**5.1 Conclusion**

This study was carried out on Solar technology: an alternative source of energy for national development. The study looked at the present state of conventional energy generation and solar energy research and development in a developing economy like Nigeria. Emphasis are made on the suitability of the Nigerian environment for solar power generation. On the whole, solar energy remains the most attractive and efficient way of Electrical energy generation in such an economy where over-dependence on fossil fuels is alarming. A case therefore made for solar energy as an alternative source of power supply to complement the generation from conventional sources (Hydro-source). Nigeria has sufficient amount of sunshine and good solar isolation that favours solar energy usage with merits.

Investment in solar energy technology in a developing economy like Nigeria should be encouraged as the merits which include: Pollution free environment, free renewable energy source, high reliability and low maintenance cost are to her future technological advancement and sustainable industrial development in Nigeria.

**5.2 Recommendations.**

Solar energy should be adapted as the main source of power supply as to replace the conventional source and its numerous demerits which have in a big measure marred the industrial development in Makurdi and Nigeria at large considering several advantages of solar energy over the conventional form like ,environment friendly, low maintenance and renewability etc. The paper therefore offers the following recommendations;

1 .Government at all levels should endeavour to make concerted efforts towards the procurement of solar energy system.

2. Research and development institute for the study of alternative power source be established by Government in higher institutions of learning.

3. Government should institute special funds for the training of manpower in the design, construction, installation and maintenance of solar energy system

4. Government, private sector and all relevant stakeholders should partner together on the way forward for the adaptability of solar energy as an alternative source of power

5. Small and medium scale industries should be provided with an enabling environment for the adaptability of solar power

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