RESEARCH ON UTILIZING THE POTENTIALS OF SOLAR ENERGY TO SUPPLEMENT NIGERIA'S ENERGY SUPPLIES

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A Project Report Submitted In Partial Fulfilment of the requirements for the Award of Bachelor of Engineering (B.Eng) in Electrical/Computer Engineering, Federal University of Technology, Minna, Nigeria

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DECLARATION

I declare that this thesis titled "Research on Utilizing the Potentials of Solar Energy to Supplement Nigeria's Energy Supplies" presented for the award of Bachelor of Engineering is an output of my own research endeavours. It has not been presented either wholly or partially for the award of any other degree elsewhere. In carrying out the work, I have made conscious efforts to acknowledge all sources of data and information used through references. I accept full responsibility for any shortcomings or errors of judgment, logic or fact in this study.

Sign: .... Date: 7th Dec. 2005

Iornem Hangem Daniel,

Project Student.

CERTIFICATION

This is to certify that this work titled " Research on Utilizing the Potentials of Solar Energy to Supplement Nigeria's Energy Supplies" was carried out by Iornem Hangem Daniel under the supervision of Mr. J. Ajiboye (M.Sc.) for the award of the Bachelor of Engineering (B.Eng) degree in Electrical/Computer Engineering of the Federal University of Technology, Minna, Nigeria

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External Examiner

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DEDICATION

This project is dedicated to my Lord Jesus Christ. You remind me that dreams can actually be realized, and I will never forget this single thing; I place my life in Your hands and I know my destiny is secured.

ABSTRACT

The potentials of solar energy in Nigeria cannot be denied. This source of energy can be used to adequately meet the increasing demand for more adequate supply of electrical energy. This study has attempted to prove that there is need to generate more electricity especially through solar energy technologies. Also, it makes a case for the protection of the environment through adopting this clean energy alternative. To this end, hypotheses were stated and proven. It was found that Nigeria`s potential for generating electricity through solar energy from the sun stands at above average. Also, environmental data is a serious need within Nigeria and has not been given the required attention in the past. From the findings, conclusions were arrived at and further recommendations made for the purpose of required action and future studies. Prominent among such recommendations are the provision of adequate funding and the development of a dedicated policy on energy which will emphasize renewable energy technologies, particularly solar energy as a highly prospective means of meeting the present and future energy needs of the country.

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CHAPTER ONE:

INTRODUCTION

1.1 BACKGROUND OF STUDY

It is common knowledge that whereas the energy consumption of most developed countries has reached a very high level, the developing countries, on the other hand, have to do more to increase their level of energy production, as this has a direct bearing on their level of development and the living standards of their populations [1], [2].

Conventional electrical energy sources –fossil fuels (coal, oil, natural gas) and hydro power are currently being used in Nigeria to supply the energy needed for domestic as well as industrial applications. Although the potentials of some of these conventional sources has not been fully developed, and need not be due to important ecological considerations, an early effort towards exploring the potentials of solar energy in providing a balance between efficiently managing our ecology and a foreseen/recommended need for more energy production is worthwhile.

The choice of solar energy as a back-up energy supply source (and possible replacement for fossil fuels and hydro sources, subsequent upon a breakthrough in research) is informed by certain factors including the fact that an enormous amount of solar energy per year (with an intensity of $600W/m^2$) is incident upon the earth's surface [3]. This energy has the advantage of being totally free of cost, non-exhaustible (or renewable) and pollution-free. These simple facts make room for the consideration of many desirable possibilities.

1.2 STATEMENT OF THE RESEARCH PROBLEM.

The various means of generating electrical energy are plagued with notable problems. Despite the huge benefits obtainable from electrical energy generation there are certain effects this activity has on the environment, which must not be ignored.

Also, varying estimates have been put forth for the earth`s non-replenishable fuel resources like oil, gas and coal. There is therefore a need to look elsewhere, particularly towards renewable energy resources, to avert the imminent energy crisis.

The level of awareness among Nigerians concerning the latest advances and the current status of the energy industry is generally unimpressive. This calls for concerted efforts towards aimed at popularizing the need for research and development of renewable energy alternatives like solar energy.

1.3 RESEARCH OBJECTIVES

The following are the main objectives of this research:

1. To expose the important facts about the amazing opportunities of solar energy.
2. To compare the ecological and economic features of solar thermal electric power plants with coal/gas-fired thermal electric power plants and hydro electric power plants
3. To determine the capital and time requirements for setting up commercial solar power plants
4. To analyse the progress of countries that have considered the use of solar energy to meet increasing energy demand.

5. To compare the major solar thermal technologies in use today and enumerate the prospects of hybrid operation.
6. To outline the climatic factors favouring the construction of large-scale solar electric power plants and the installation of smaller solar technologies, in Nigeria.

1.4 JUSTIFICATIN OF THE STUDY

Clean solar electric energy can be generated in reasonable quantities that would significantly improve the amount of electricity that is currently being produced by conventional means in Nigeria as well as worldwide. The relevance of this study is particularly critical to Nigeria, as it is aimed at generating awareness or rather making a case for the development of our solar potential. This will lead to the successful utilization of the opportunities that abound in the solar energy industry. Generally, the following points justify this study:

1. Apart from the additional returns expected, solar technology especially solar thermal power plants will create a multiplied number of skilled, high paying jobs as do conventional power plants.
2. Solar generated electricity is typically suitable and is currently being planned for Nigeria's rural communities, which have found it quite challenging to be connected to the national grid
3. Solar thermal electric power systems are becoming more popular as the years go by; they are equally becoming more affordable

1.5 RESEARCH METHODOLOGY

Data was collected by means of enquiries on the subject across regions of the world that have developed their local solar energy potential. The history, progress and experience of these regions in the exploration of the viability of solar electric power to meet their respective energy needs were noted.

Relevant tables and fact sheets were referred to and analysed accordingly. Local and global energy authorities and associations including organizations that generate, provide and market energy were also consulted in order to gain in-depth and up-to-date insight on the topic of this research project.

Appropriate tools and relevant statistical techniques were used in analysing and interpreting the data available.

1.6 STATEMENT OF HYPOTHESES

Each hypothesis is stated in two opposing terms such that the rejection of the null hypothesis (H0) leads to the acceptance of the desired statement or the alternative hypothesis (H1). See [4].

<u>HYPOTHESIS 1</u>

Null (H0): There is no great need for more electrical energy than is currently being produced in Nigeria.

Alternative (H1): The need for more electricity than is currently being produced in Nigeria is high.

Null (H0): The potential of solar energy for generating electricity to meet increasing enrgy demand has been well utilized in Nigeria

Alternative (H1). In Nigeria, the potential of using solar energy to generate electricity for increasing energy demand has been under-utilized

HYPOTHESIS 3

Null (H0): Embarking on the development of Nigeria's solar energy potential will not alter the level of commercial activity already existent in the country.

Alternative (H1): Embarking on the development of Nigeria's solar energy potential will increase the level of commercial activity going on in the country.

HYPOTHESIS 4

Null (H0): The use of our solar energy potential has a more damaging effect on environment and ecology than does the use of conventional energy –fossil fuels (coal, oil, natural gas) and hydro power .

Alternative (H1): The use of conventional energy –fossil fuels (coal, oil, natural gas) and hydro power has a severe damaging effect on the environment and ecology than does the use of solar energy.

1.7 SCOPE AND LIMITATIONS OF THE STUDY

The overall focus of this study is biased towards Nigeria. Although relevant data available in other regions/countries have been repeatedly adopted, this is justifiable because no country can advance its technology in isolation. The energy industry is a global one; therefore important characteristics must be studied comprehensively and on a broad basis, to make substantial deductions.

Due to limited resources in time and money, the administration of a detailed questionnaire and conduction of in-depth interviews was hampered.

Also, the study is purely a research not accompanied with experiments or the design of a prototype of any sort.

CHAPTER TWO:

LITERATURE REVIEW

2.1 INTRODUCTION.

Amidst the untapped potentials of solar energy, there is widespread inefficiency in the adequate provision of electrical energy through conventional means for the Nigerian population. It is estimated that only 30 – 40 % of the population is connected to the national electricity grid. This is irrespective of Nigeria's position as the sixth largest petroleum oil exporter in the world, and a leading gas exporter. The nation suffers enormous energy crisis manifesting in various forms (according to [5]): about 60 -70 % of the nation's population (projected at about 130 million for 2002) are excluded from the national electricity grid; the grid is plagued by rather frequent power outages that last for as long as about 20 hours daily in places that are connected to the grid."

2.2 HISTORICAL DEVELOPMENT OF NIGERIA'S ELECTRICAL ENERGY.

Hydroelectric power furnished about 14 percent of the energy consumed by Nigerians in the 1980s. Total energy used in the form of electricity was considerably larger, however, because much of the energy provided by petroleum products and gas was converted into electricity. In 1990 most electricity was supplied by NEPA (now the Power Holding Company of Nigeria. PHCN). This agency had been established in 1972 as a semiautonomous government activity through the merger of the Electric Corporation of

Nigeria (ECN--created by the government in 1950 to generate and transmit power nationally) and the Niger Dam Authority (NDA--set up in 1962 to develop the economic potential of the Niger River). As part of its mandate, the NDA had constructed the Kainji Dam and an associated hydroelectric plant, which began operations in 1968. Until the late 1970s, the plant was the principal source of Nigeria's electrical power. [6]

The demand for power grew at an average annual rate estimated at 15 to 20 percent after the start of the 1973-74 oil boom. NEPA's total generating plant, having an installed capacity of 881 megawatts in FY 1976--almost half of which was located at the Kainji hydroelectric plant--was unable to meet the rapidly growing requirement. By FY 1978 an additional 250 megawatts had been installed, of which 200 megawatts were at Kainji, but a drought in 1977 and 1978 significantly lowered the level of Kainji Reservoir and thus reduced the plant's output. During the drought, blackouts were frequent, having catastrophic effects on major industrial establishments. Goods in the process of assembly had to be destroyed, and interruptions in machine operations substantially reduced productivity. The situation improved in the 1980s, with two 120-megawatt units added to the Kainji hydroelectric station, ten units of 120 megawatts each installed in Sapele, new hydroelectric stations built at Shiroro on the Kaduna River and Jebba downstream from Kainji Reservoir, and another 200 megawatts added at various smaller plants.

Power was distributed through a national grid that linked many of the large towns, some of which had been previously served by local diesel power stations. Yet the power sector, lacking spare parts, had neglected maintenance to the point that generating capacity was rapidly declining. [6]

Today, after repeated optimistic projections by successive government administrations, the situation is yet to improve although more settlements have now been connected to the national grid, and the privatization exercise which has began with NEPA now been transformed to PHCN before its full take-over by private sector investors slated for January to December 2006. See [7]. But it remains practically unrealistic to have the country's entire population connected to this grid, especially in the nearest future. Although, Nigeria's President Obasanjo and the Manager of the grid operator (PHCN) claim that 85% rural electrification and stable power supply will be achieved in 2010 and 2007 respectively, these are unrealistic promises when the current power generation paradigm or strategy based on Conventional Energy Technologies (CETs) are retained. Only Renewable Energy Technologies (RETs) prominent among which is solar, have the potentials to advance electricity supply in Nigeria and developing nations. [5]

2.3 GENERAL PROSPECTS OF SOLAR ENERGY

2.3.1 Solar Heating and Cooling

The use of solar energy for space heating and cooling evolved over time to the level at which it is being employed today in the US (one of the leading promoters of solar energy technologies). As at the late 70's active use of the sun's energy for space heating was relatively a new concept in the US but became increasingly attractive as the costs of fossil fuels rose. It was evident that solar energy would be a significant supplemental energy source in the future as is now obtainable. [8]

2.3.2 Rural Electrification.

Six hundred and sixty-five houses in the athletes' village for the Sydney Olympic Games in 2000 in Australia were supplied with photovoltaic (PV) systems. [9]

But despite the advantages PV cannot compete in places where there is easy access to an electric grid, because its capital costs are high. It is also suitable where relatively little power is needed.

The wide range of applications of PV systems are suited to in the rural areas include lighting TV, radio, computers, communications, water supply, health centres, schools, community centres, refrigeration, public lighting and others (see [9]).

2.3.3 Residential and Other Uses

With the use of solar panels, inverters and regulators, solar water-pumping systems can be set to generate a constant supply of water for residential use, irrigation projects and other commercial projects. Companies can also use solar panels to back up their communication systems even if hydro electric power is used. [10]

It will have become evident to the reader that the utilization of solar energy on a small scale is entirely possible using commercially available equipment. The area where development is required is in relation to extending the scale to meet the requirements of whole communities, be the commodity finally provided heat or electricity. [11]

2.4 SOLAR ENERGY RESEARCH IN NIGERIA

Solar energy research in Nigeria is relatively new in spite of the fact that the efforts are worthwhile. Most of the research projects and conferences on solar energy in Nigeria are funded or sponsored by the Energy Commission of Nigeria (ECN). In this literature review I have attempted to list a number of projects embarked upon, indicating various bodies that are promoting the development and use of solar energy in Nigeria.

2.5 SOLAR ENERGY PROJECTS IN NIGERIA.

2.5.1 Solar PV Installations

According to [12] following a survey of activities in solar PV in the country up to 1999 a total of 316 installations amounting to 238.8kWp. were identified nationwide. Based on installed capacity, the percentage distribution of the installations over various applications were as follows:

Table 2.1 Percentage distribution of solar PV installations over various applications.

S/N	Solar-PV Applications	% by Capacity
1	Residential (mostly lighting)	6.9
2	Village Electrification & TV	3.9
3	Office/Commercial lighting & Equipment	3.1
4	Street, Billboard, etc, lighting	1.2
All Lighting		**15.1**
5	Industrial	0.4
6	Health centre/clinic	8.7
7	Telecom & Radio	23.6
8	Water pumping	52.2
Total		**100**

Of the 316 installations, there was at least one 26 out of the 37 states and the FCT. Lagos (23.6%), Yobe (16.3%), Kano (8.6%) and Akwa Ibom (8.6%) States had the highest number of installations. Financing of the installation came principally from the Federal Governments, (ECN, NITEL, FMWR, DFRRI, PTF, ADP), State and Local Governments, European Union and Mobil. Some installations especially in the Lagos area were funded by private persons.

More recently, Delta and Lagos States had embarked on projects to use Solar-PV for street light. No other modern RE technology has anywhere near the usage or number and capacity of installations in the country as solar-PV [12].

2.5.2 Solar Thermal Applications

A number of locally adapted solar thermal applications have been listed in [13]. They include the following:

- **Solar Rice Dryer**

Year of Operation: 1991

Location: Adani,Uzo-Uwani LGA, EnuguState

Sponsor: Energy Commission of Nigeria

Installation by: CERD/UNN

Floor Area: 173.5 m2

Application: Rice drying

- **A Family size Solar Chick Brooder** of 100 chick capacity built by the National Centre for Energy Research ad Development (NCERD), Nsukka
- **2000 Bird Capacity Large-scale Solar Energy Poultry Brooding System.**

Year of Operation: 2002

Location: Adani,Uzo-Uwani LGA, Enugu State

Sponsor: Energy Commission of Nigeria

Installation by: NCERD/UNN

Floor Area: 96 m2

Glazing Material: 3 mm thick PVC Sheets

Application: Chick Brooding

- **Solar Cookers**

Box-type Cooker

Under sunny weather, (850 W/m2or more) it can cook rice and beans in 45 minutes.

Concentrator Cooker

Higher Temperatures (400 °C) and faster cooking rates are possible.

- **Solar water heater** developed by the NCERD, Nsukka.

CHAPTER THREE:

MAJOR SOLAR TECHNOLOGIES

3.1 SOLAR THERMAL POWER SYSTEMS

Solar thermal power systems are otherwise called 'concentrating solar power (CSP)'. The thermal power plants today (either coal- or gas-fired) use fossil fuels as a heat source to boil water. The steam generated from the boiling water rotates a large turbine coupled to a generator that generates electricity. Concentrating solar power systems mark the coming of a new generation of power plants which use the sun as a heat source while maintaining the principle of a large turbine coupled to a generator that produces electricity upon rotation of the turbine blades. There are three main types of concentrating solar power systems: *parabolic-trough*, *dish/engine*, and *power tower*. Each of these types is discussed below.

3.1.1 Parabolic-trough

Parabolic-trough systems concentrate the sun's energy through long rectangular, curved (U-shaped) mirrors. The mirrors are tilted toward the sun, focusing sunlight on a pipe that runs down the center of the trough. This heats the oil flowing through the pipe. The hot oil then is used to boil water in a conventional steam generator to produce electricity. Figure 3.1 shows a picture of an array of the U-shaped mirrors mentioned above.

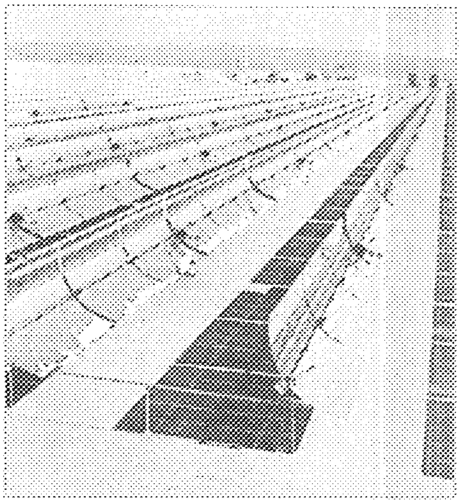

Figure 3.1 Pictorial illustration of a parabolic trough.

3.1.2 Dish/engine

A dish/engine system involves the use of a mirrored dish (similar to a very large satellite dish). The dish-shaped surface collects and concentrates the sun's heat onto a receiver. The receiver then absorbs the heat and transfers it to fluid within the engine. Mechanical power is then produced by the heat which causes the fluid to expand against a piston or turbine. The mechanical power is then used to activate a generator or alternator to produce electricity. See Figure 3.2 below.

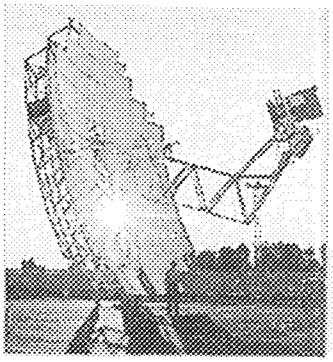

Figure 3.2 Pictorial illustration of a dish/engine system.

A Solar Dish-Engine System is an electric generator that "burns" sunlight instead of gas or coal to produce electricity. The major parts of a system are the solar concentrator and the power conversion unit. Descriptions of these subsystems and how they operate are presented below.

3.1.2.1 The Dish

The dish, which is more specifically referred to as a concentrator, is the primary solar component of the system. It collects the solar energy coming directly from the sun and concentrates or focuses it on a small area. The resultant solar beam has all of the power of the sunlight hitting the dish but is concentrated in a small area so that it can be more efficiently used. Glass mirrors reflect about 92% of the sunlight that hits them, are relatively inexpensive, can be cleaned, and last a long time in the outdoor environment, making them an excellent choice for the reflective surface of a solar concentrator. The dish structure must track the sun continuously to reflect the beam into the thermal receiver.

3.1.2.2 The Power Conversion Unit

This includes the thermal receiver and the engine/generator. The thermal receiver is the interface between the dish and the engine/generator. It absorbs the concentrated beam of solar energy, converts it to heat, and transfers the heat to the engine/generator. A thermal receiver can be a bank of tubes with a cooling fluid, usually hydrogen or helium, which is the heat transfer medium and also the working fluid for an engine. Alternate thermal receivers are heat pipes wherein the boiling and condensing of an intermediate fluid is used to transfer the heat to the engine.

The engine/generator system is the subsystem that takes the heat from the thermal receiver and uses it to produce electricity. The most common type of heat engine used in dish-engine systems is the Stirling engine [14]. A Stirling engine uses heat provided from an external source (like the sun) to move pistons and make mechanical power, similar to the internal combustion engine in an automobile car. The mechanical work, in the form of the rotation of the engine`s crankshaft, is used to drive a generator and produce electrical power.

3.1.3 Power Tower

A power tower system uses a large field of mirrors (otherwise called heliostats) to concentrate sunlight onto the top of a tower, where a receiver is situated. This heats up molten salt flowing through the receiver. The salt's heat is then used to generate electricity through a conventional steam generator. The notable reason for the use of molten salt is that it retains heat efficiently, so the heat can be stored for days before being converted into electricity. That means electricity can be produced even on cloudy days or even several hours after sunset.

A power tower converts sunshine into clean electricity for the world's electricity grids. Early power towers such as the Solar One plant (see [15]) utilized steam as the heat transfer fluid; current designs like Solar Two (see also [15]and [16]) utilize molten nitrate salt because of its superior heat transfer and energy storage capabilities. Individual commercial plants could be sized to produce anywhere from 50 to 200 MW of electricity.

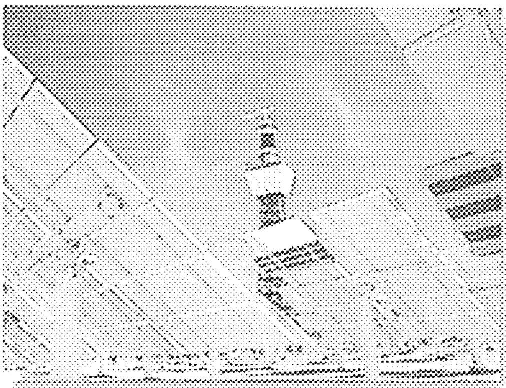

Figure 3.3 Pictorial Illustration of a Power Tower Installation.

3.1.3.1 Benefits of Power Towers [15]

Solar power towers offer large-scale, distributed solutions to our nation's energy needs, particularly for peaking power. Like all solar technologies, they are fueled by sunshine and do not release greenhouse gases. They are unique among solar electric technologies in their ability to efficiently store solar energy and dispatch electricity to the grid when needed — even at night or during cloudy weather. A single 100-megawatt power tower with 12 hours of storage needs only 1000 acres of otherwise non-productive land to supply enough electricity for 50,000 homes. Throughout the sunny Southwest, millions of acres are available with solar resources that could easily produce solar power at the scale of hydropower in the Northwest U. S.

3.1.3.2 The Status of Power Tower Technology [15]

Power towers enjoy the benefits of two successful, large-scale demonstration plants in the U.S. The 10-MW Solar One plant near Barstow, CA, demonstrated the viability of power towers, producing over 38 million kilowatt-hours of electricity during its operation from 1982 to 1988. The Solar Two plant was a retrofit of Solar One to demonstrate the advantages of molten salt for heat transfer and thermal storage. Utilizing its highly efficient molten-salt energy storage system, Solar Two successfully demonstrated efficient collection of solar energy and dispatch of electricity, including the ability to routinely produce electricity during cloudy weather and at night. In one demonstration, it delivered power to the grid 24 hours per day for nearly 7 straight days before cloudy weather interrupted operation.

The successful conclusion of Solar Two sparked worldwide interest in power towers. As Solar Two completed operations, an international consortium, led by U. S. industry including Bechtel and Boeing (with technical support from Sandia National Laboratories), formed to pursue power tower plants worldwide, especially in Spain (where special solar premiums make the technology cost-effective), but also in Egypt, Morocco, and Italy. Their first commercial power tower plant is planned to be four times the size of Solar Two (about 40 MW equivalent, utilizing storage to power a 15MW turbine up to 24 hours per day).

This industry is also actively pursuing opportunities to build a similar plant in the desert Southwest of the U.S., where a 30 to 50 MW plant would take advantage of the Spanish design and production capacity to reduce costs, while providing much needed peaking capacity for the Western grid. The first such plant would cost in the range of $100M and produce power for about 15¢/kWh. While still somewhat higher in cost than conventional technologies in the peaking market, the cost differential could be made up with modest green power subsidies and political support, jump-starting this technology on a path to 7¢/kWh power with the economies of scale and engineering improvements of the first few plants It would, at that point, provide clean power as economically as more conventional technologies.

3.2 PHOTOVOLTAIC (PV) SYSTEMS

Solar cells, also called photovoltaic (PV) systems by solar cell scientists, convert sunlight directly into electricity. Solar cells are commonly used to power calculators and watches. They are made of semiconductor materials similar to those used in computer chips. When sunlight is absorbed by these materials, the solar energy renders electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the *photovoltaic (PV) effect*.

Solar cells are typically combined into modules that hold about 40 cells; about 10 of these modules are mounted in PV *arrays* that can measure up to several meters on a side. These *flat-plate* PV arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture the most sunlight over the course of a day. About 10 to 20 PV arrays can provide enough power for a household; for large electric utility or industrial applications, hundreds of arrays can be interconnected to form a single, large PV system.

Thin film solar cells use layers of semiconductor materials only a few micrometers thick. Thin film technology has made it possible for solar cells to now double as rooftop shingles, roof tiles, building facades, or the glazing for skylights or atria. The solar cell version of items such as shingles offer the same protection and durability as ordinary asphalt shingles.

Some solar cells are designed to operate with concentrated sunlight. These cells are built into *concentrating collectors* that use a lens to focus the sunlight onto the cells. This approach has both advantages and disadvantages compared with flat-plate PV arrays. The main idea is to use very little of the expensive semiconductor PV material while collecting as much sunlight as possible. But because the lenses must be pointed at the sun, the use of concentrating collectors is limited to the sunniest parts of the country. Some concentrating collectors are designed to be mounted on simple tracking devices, but most require sophisticated tracking devices, which further limit their use to electric utilities, industries, and large buildings.

The performance of a solar cell is measured in terms of its efficiency at turning sunlight into electricity. Only sunlight of certain energies will work efficiently to create electricity, and much of it is reflected or absorbed by the materials that make up the cell. Because of this, a typical commercial solar cell has an efficiency of 15%—about one-sixth of the sunlight striking the cell generates electricity. Low efficiencies mean that larger arrays are needed, and that means higher cost. Improving solar cell efficiencies while holding down the cost per cell is an important goal of the PV industry.

3.3 PASSIVE SOLAR HEATING AND DAYLIGHTING

During hot and sunny days the power of solar heat and light is felt. Today, many buildings in more advanced countries like the U.S. are designed to take advantage of this natural resource through the use of passive solar heating and *daylighting*.

The buildings designed for passive solar heating usually have large windows facing the side of the building that receives the most sunlight. Materials that absorb and store the sun's heat can be built into the sunlit floors and walls. The floors and walls will then heat up during the day and slowly release heat at night, when the heat is needed most (particularly for the temperate regions which are usually very cold at night). This passive solar design feature is called *direct gain*.

Other passive solar heating design features include *sunspaces* and *trombe walls*. A sunspace (which is much like a greenhouse) is built on the side of the building, which receives the most sunlight. As sunlight passes through glass or other glazing, it warms the sunspace. Proper ventilation allows the heat to circulate into the building. On the other hand, a trombe wall is a very thick, sunlight-facing wall, which is painted black and made of a material that absorbs a lot of heat. A pane of glass or plastic glazing, installed a few inches in front of the wall, helps hold in the heat. The wall heats up slowly during the day. Then as it cools gradually during the night, it gives off its heat inside the building.

Many of the passive solar heating design features also provide daylighting. Daylighting is simply the use of natural sunlight to brighten up a building's interior. To lighten up rooms not facing the sunlight source and upper levels, a *clerestory*—a row of windows near the peak of the roof—is often used along with an open floor plan inside that allows the light to bounce throughout the building.

Of course, too much solar heating and daylighting can be a problem during the hot summer months and especially in the tropical region. Fortunately, there are many design features that help keep passive solar buildings cool in the summer or in hot weather. For instance, overhangs can be designed to shade windows when the sun is high in the summer. Sunspaces can be closed off from the rest of the building. And a building can be designed to use fresh-air ventilation in the summer or on sunny days.

3.4 HYBRID OPERATION

Solar energy technologies fall under a suite of quite a number of renewable energy technologies (RETs). As a matter of fact, one must certainly come across these other renewable energy systems when studying solar energy systems The other renewable energy sources include hydro power, wind power, biomass, etc

There exist wholesome approaches towards the combined utilization of these technologies. This leads us to the question of the prospects of hybrid operation. A number of possible combinations are enumerated in [17]. Solar technologies are also combined with non-renewable energy technologies to realize specific desired results. For example, solar/fossil operation minimizes pollution while at the same time providing high profile power supply that can be switched between the two sources depending on which one is more appropriate for a given period

The following table (Table 3.1) shows a comparison of the major solar thermal technologies. It also reveals the suitability of each for hybrid operation, specifically solar/fossil operation.

Table 3.1 Comparison of Major Solar Thermal Technologies (tower, dish, trough)

	Power Tower	Parabolic Dish	Parabolic Trough
Applications	Grid-connected electric plants; process heat for industrial use.	Stand-alone small power systems; grid support.	Grid-connected electric plants; process heat for industrial use.
Advantages	Dispatchable base load electricity; high conversion efficiencies; energy storage; hybrid (solar/fossil) operation	Dispatchable electricity, high conversion efficiencies; modularity; hybrid (solar/fossil) operation.	Dispatchable peaking electricity; commercially available with 4,500 GWh operating experience; hybrid (solar/fossil) operation.

[Source: [18]]

CHAPTER FOUR:

FINDINGS ON ENVIRONMENTAL AND ECONOMIC ISSUES

4.1 STATUS OF ENVIRONMENTAL STATISTICS IN NIGERIA

According to [19], Environmental Statistics cut across the activities of many development Agencies in Nigeria, including:

- Federal and State Ministries of Environment;
- Federal Office of Statistics;
- Federal Ministries of Mines and Power, Petroleum Resources, Solid Minerals;
- Federal Ministry of Works;
- Federal Ministry of Agriculture and Rural Development;
- Federal Ministry of Water Resources;
- Nigeria National Petroleum Company (NNPC), National Planning Commission;
- National Electricity Power Authority (NEPA) - Energy Statistics;
- Research Institutes;
- Federal Ministry of Environment (FMENV)/University Linkage Centres;
- Environmental NGOs, etc.

Hitherto, most data collected by the various agencies were contained in technical reports and files, with limited chances for comprehensive collation and analysis; However, in recent time, there has been a growing institutional awareness and concern for environmental statistics in Nigeria. This has led to efforts evidenced in the following:

- The establishment of Environment Statistics in the Federal Office of Statistics

(FOS) in 1992 under the National Accounts Division to facilitate the long term integration of environment Statistics into National Accounting, with the aim of preparing environment accounts as a satellite Accounts in accordance with 1993 UN System of National Accounts (SNA);

- The establishment of the Federal Environmental Protection Agency in 1988 (FEPA) and the expansion of the Agency's mandate in 1992 to include the conservation of biodiversity and natural resources which later led to the establishment of a Data and Information Management Unit in the Agency (FEPA) as part a World Bank-assisted Environmental Management Project in 1993/96. The data derived from the Forestry, the Soil, the Water resources and the then FEPA nodes were to be networked through a central data base at FEPA. Unfortunately the idea could not be realized because only Forestry node could produce any substantial data out of all the nodes.

- The establishment of a National Data Bank Unit on Environmental Statistics in the National Planning Commission in 1996, the Unit which has now been transferred to the FOS;

- Creation of a full-fledged Federal Ministry of Environment by the present Administration in June 1999 and subsequent establishment of a full-fledged Department of Planning, Research and Statistics in the new Ministry in compliance with Government's directive for all Ministries;

- Nigeria's active participation in the UNEP-INFOTERRA network, with substantive input to the National Portal on the **INFOTERRA Website (http://www.unep.net).**

Despite the above efforts, it is still challenging to get data on the environment and ecology of Nigeria from the bodies responsible for such data, particularly the Federal Environmental Protection Agency (FEPA) which is an agency under the Federal Ministry of Environment. Checks at the Ministry's website (www.fmenv.com.ng) show that environment-related data is still pending.

However, some pieces of data have been gathered based on research theses and related studies carried out by individuals and/or organisations that have interest in the subject of concern.

4.2 THE SOLAR RESOURCE

4.2.1 Solar Energy Resources in Nigeria

According to [20] 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. Similarly, it has an annual average daily solar radiation of about 5.25 $kW/m^2/day$, varying between about 3.5 $kW/m^2/day$ at the coastal areas and 7.0 $kW/m^2/day$ at the northern boundary. See Figures 4.1(a) & (b). 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 reduction, and about 13 thousand times that of natural gas daily production based on energy unit. 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 atmosphere during the harmattan, in its northern part, for a period of about four months (November-February) annually. The dust has an attenuating effect on the solar radiation intensity.

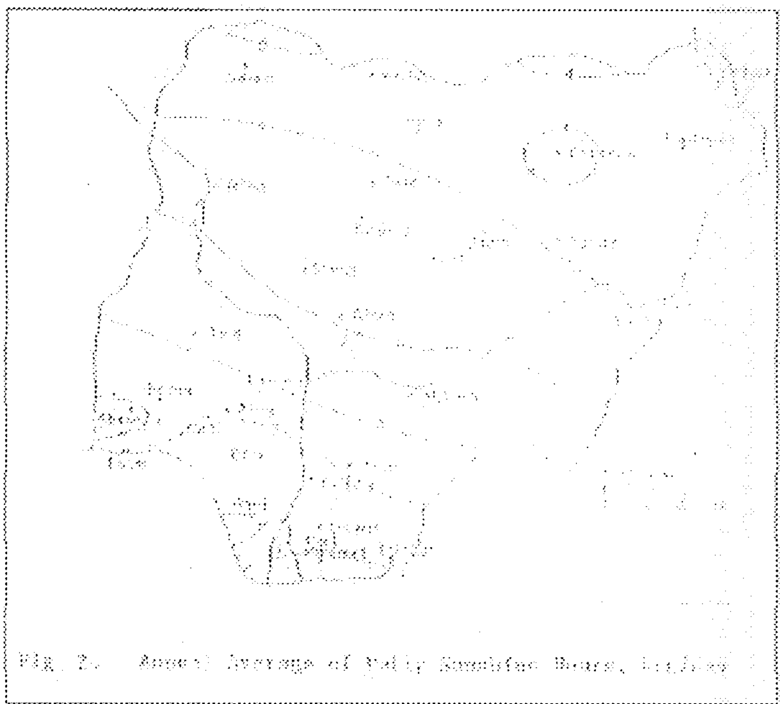

Figure 4.1 (a) Annual Average of Daily Sunshine Hours
Source: [13]

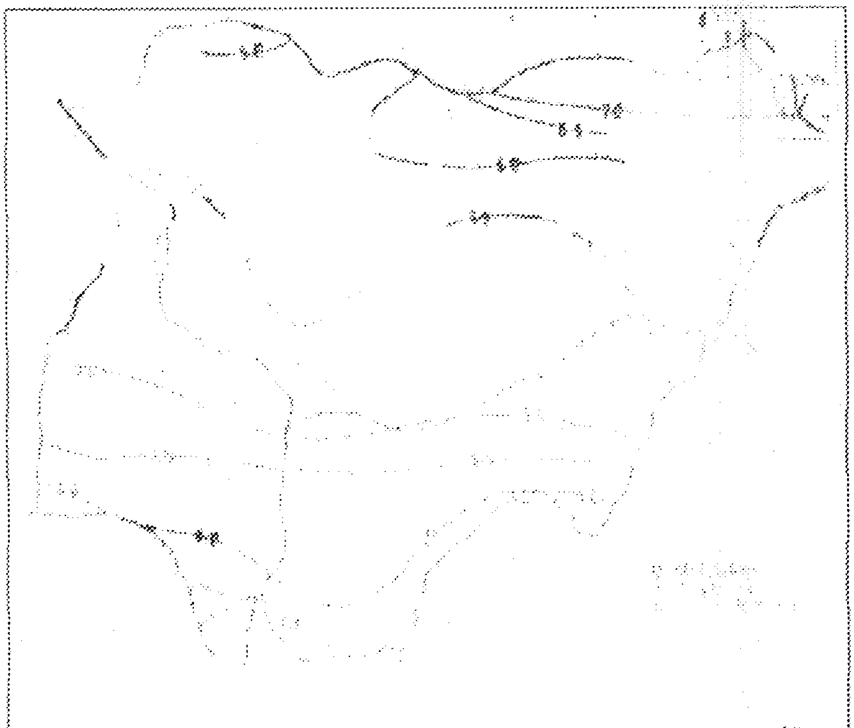

Fig 1. Annual Average of Daily Global Solar Radiation, kWh/m /day

Figure 4.1(b) Annual Average of Daily Global Solar Radiation (kWh/m^2/day x 10^{-1})
Source: [13]

Based on the land area of 924 x 10^3 km^2 for the country and an average of 5.535 kWh/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 as depicted in Table below [21].

Table 4.1 Solar energy resources in comparison to others in Nigeria

	Annual solar Energy Insolation	Conventional Energy Reserve (1999)	Electricity Generated (1988)
Energy (kWh)	1.804×10^{15}	6.663×10^{13}	15.11×10^{9}
Ratio	27.1:1 117826:1	1:1 4347.8:1	0.00023:1 1:1

Source: [21]:

4.3 SOLAR ENERGY AS A CLEAN ENERGY SOURCE COMPARED TO FOSSIL FUELS

4.3.1 Photovoltaic Cells

In the United States of America, photovoltaic systems are considered likely to provide the nation with a significant portion of its electrical energy suitable for use in homes, industries, and utilities [22]. Before widespread use, however, improvements are needed in the photovoltaic cells to make them economically competitive. Test photovoltaic cells that consist of silicon solar cells are currently up to 21% efficient in converting sunlight into electricity [23]. The durability of photovoltaic cells, which is now approximately 20 years, needs to be lengthened and current production costs reduced about fivefold to make them economically feasible. With a major research investment, all of these goals appear possible to achieve [22].

With the above prospects in mind, it is interesting to know that photovoltaic technology offers several environmental advantages in producing electricity compared with fossil fuel technologies. For instance, carbon dioxide emissions and other pollutants from present photovoltaic technology are minimal.

The major environmental problem associated with photovoltaic systems is the use of toxic chemicals such as cadmium sulphide and gallium arsenide, in their manufacture [24]. Because these chemicals are highly toxic and persist in the environment for centuries, disposal of inoperative cells could pose a major environmental challenge. However, the most promising cells in terms of low cost, mass production, and relatively high efficiency are those being manufactured using silicon. This material makes the cells less expensive and environmentally safer than the heavy metal cells.

4.3.2 Solar Thermal Conversion

Solar thermal energy systems collect the sun's radiant energy and convert it into heat. This heat can be used for household and industrial purposes and also to drive a turbine and produce electricity. System complexity ranges from solar ponds to the electric-generating central receivers.

Solar ponds are used to capture solar radiation and store it at temperatures of nearly 100°C. Natural or man-made ponds can be made into solar ponds by creating a saltconcentration gradient made up of layers of increasing concentrations of salt. These layers prevent natural convection from occurring in the pond and enable heat collected from solar radiation to be trapped in the bottom brine. The hot brine from the bottom of the pond is piped out for generating electricity. The steam from the hot brine turns freon into a pressurized vapor, which drives a Rankine engine. This engine was designed specifically for converting low-grade heat into electricity. At present, solar ponds are being used in Israel to generate electricity [25]. In several locations in the United States solar ponds are now being used successfully to generate heat directly. The heat energy from the pond can be used to produce processed steam for heating at a cost of only 2¢ to 3.5¢ per kWh [26].

The only hazards associated with solar ponds have negligible effect on the environment, but most can be prevented with careful management. For example, it is essential to use plastic liners to make the ponds leak proof and thereby prevent contamination of the adjacent soil and groundwater with salt. Burrowing animals must be kept away from the ponds by buried screening [27].In addition, the ponds should be fenced to prevent people and other animals from coming in contact with them. Because some toxic chemicals are used to prevent algae growth on water surface and freon is used in a component engine called the Rankine engine, methods will have to be devised for safely handling these chemicals [27].

Central receiver plants use computer-controlled, sun-tracking mirrors, or heliostats, to collect and concentrate the sunlight and redirect it toward a receiver located atop a centrally placed tower. In the receiver, the solar energy is captured as heat energy by circulating fluids, such as water or molten salt heated under pressure. These fluids either directly or indirectly generate steam, which is then driven through a conventional turbo generator to yield electricity. The receiver system may also be designed to generate heat for industry.

The land requirements for the central receiver technology are approximately 1100 hectares (ha) to produce 1 billion kWh/yr, assuming peak efficiency, and favorable sunlight conditions like those in the western United States [28] which are similar to what we have in Nigeria, earlier shown in Fig 4.1 by [13].

The potential environmental impacts of solar thermal receivers include: the accidental or emergency release of toxic chemicals used in the heat transfer system [29]; bird collisions with a heliostat and incineration of both birds and insects if they fly into the high temperature portion of the beams; and—if one of the heliostats did not track properly but focused its high temperature beam on humans, other animals, or flammable materials—burns, retinal damage, and fires [30]. Flashes of light coming from the heliostats may pose hazards to air and ground traffic [30].

Other potential environmental impacts include microclimate alteration, for example reduced temperature and changes in wind speed and evapotranspiration beneath the heliostats or collecting troughs. This alteration may cause shifts in various plant and animal populations. The albedo (the fraction of electromagnetic radiation that is reflected by a surface or body) in solar collecting fields may be increased from 30% to 56% in desert regions [30]. An area of 1100 ha is affected by a plant producing 1 billion kWh.
The environmental benefits of receiver systems are significant when compared to fossil fuel electrical generation. Receiver systems cause no problems of acid rain, air pollution, or global warming [31] which are environmental concerns associated with fossil fuels.

4.3.3 Passive Solar Heating

Although none of the passive heating and cooling technologies requires land, they can cause environmental problems. For example, some indirect land-use problems may occur, such as the removal of trees, shading, and rights to the sun [32]. Glare from collectors and glazing could create hazards to automobile drivers, pedestrians, cyclists, and airline pilots. Also, when houses are designed to be extremely energy efficient and airtight, indoor air quality becomes a concern because air pollutants may accumulate inside. However, installation of well designed ventilation systems promotes a healthful exchange of air while reducing heat loss during the winter and heat gain during the summer. If radon is a pollutant present at unsafe levels in the home, various technologies can alleviate the problem [33].

4.3.4 Fossil Fuels

In general, many environmental problems are associated with fossil-fuel power generation [34]. The problems include air pollution, acid rain, global warming, as well as the safe disposal of large quantities of ash [35]. Fossil-fuel electric utilities account for two-thirds of the sulphur dioxide, one-third of the nitrogen dioxide, and one-third of the carbon dioxide emissions in the United States [31]. In Nigeria, the main environmental challenges result from oil spills, natural gas flaring and deforestation. Oil extraction in the Niger Delta region has caused severe environmental degradation, owing to the legacy of oil spills, lax environmental regulations for the oil industry. Air pollution from natural gas flaring, exhaust emissions from the explosion in car ownership, and electricity generators continue to leave the commercial city of Lagos shrouded in smoke. See [36]. It is clear how much of this problem will be solved supposing those generators were replaced with equally portable but environment-friendly photovoltaic installations.

4.4 SOLAR ENERGY AND RURAL DEVELOPMENT

Consider the success stories documented below.

4.4.1 Introducing Cost-Effective Rural Electrification in Brazil [37]

The United States and Brazil are collaborating to bring electricity to some 5 million households in rural Brazil. Over the next decade, there is a potential to install approximately 500 megawatts (MW) of solar home systems and 1000 MW of community systems, bringing light to households, schools, and health clinics throughout rural Brazil. Added to the potential for grid-connected systems—about 3 gigawatts (GW) from wind farms, biomass power, and photovoltaics (PV) in the next decade—the total potential for renewable energy systems in Brazil could reach 4 to 5 GW by 2010.

The U.S. Department of Energy (DOE), its laboratories, and U.S. industry are collaborating to help Brazil electrify many rural communities. This joint program is also helping create a new export market for U.S. renewable energy technologies.

Through this collaboration, DOE and the National Renewable Energy Laboratory (NREL) have increased Brazilian confidence in renewable energy technologies, thereby benefiting both Brazil and the United States.

U.S. manufacturers of PV, wind, and hybrid energy systems are poised to gain market footholds in Brazil. If the renewable energy potential of 4 to 5 GW is realized, it will translate into an $8 to $10 billion market for renewable energy technologies. Capturing a significant portion of this market will mean enormous growth for the U.S. renewable energy industry.

Figure 4.2 These 50-watt photovoltaic electric lighting systems provide four to six hours of light each night for residents of this village in Ceara, Brazil. (Source: [37])

4.4.2 Village Electrification in Jigawa State

An even more local example is the electrification of villages in Jigawa State of Nigeria. This should make up one of the most notable solar energy projects in Nigeria. The project was a product of joint funding by the United States government (through USAID) and the Jigawa State government of Nigeria. An overview of the briefs of this project initiative is provided by [21] as shown below.

In 2001, Solar Electric Light Fund (SELF), an NGO based in USA, and Jigawa State Government initiated a proposal to bring solar-generated electricity (PV) to power essential services in 3 villages of Jigawa State.

Funding Support: United States Government through USAID and Department of Energy (60%), Jigawa State Government (40%)

Project Goal: to demonstrate the comprehensive use of solar-generated electricity in a village setting to improve education, water supply, health, agriculture, commerce, security, and women's opportunities

Many projects scattered around the globe feature single or more limited use of PV technology such as in providing home lighting or vaccine refrigerators or water pumping. This project, while including the aforementioned applications, goes further by addressing virtually all of the things that a community needs electrical energy for nine types of PV systems were developed for this project and are described below. Unless noted, one of each type of system was installed in each village.

1. Community Water Pumping. The powerful solar-powered pumps supplied with this project are designed to run maintenance free for eight to ten years or more and are currently supplying the villages with clean, fresh water

2. Village Health Clinics. Solar lights enable health workers to see patients at night for the first time; vaccine refrigerators allow more effective vaccination programs and fans increase patient comfort.

3. Village Schools. Illuminated classrooms are allowing adult education classes for the first time and a place for children to work on their lessons. The headmasters have received computers and computer training.

4. Streetlights. In a hot climate where people enjoy the cool of the evening, lights provide safe gathering places for socializing and commerce. Ten to twelve lights were installed in each village.

5. Mosque Lighting. Lighting makes night time activities possible and a public address system facilitates the call to prayer.

6. Micro-enterprise Centres. The centres have been constructed to provide electricity to 6 very small businesses in each village. The shared PV systems, much less expensive than individual systems for each shop, increase productivity and income for tailors, barbers, electronic repairmen and other businesses. A micro-credit scheme helped some of the businesses buy electric appliances.

7. Home Lighting Systems. Approximately 20 home lighting systems were installed in each village to demonstrate lighting that is better, safer and no more costly than the kerosene lamps they replace. Better lighting in the homes supports home businesses and education.

8. Mobile Solar Irrigation Pumps. In the one project village that has a year-round source of surface water; efficient solar-powered pumps help the poorest farmers grow crops during the dry season to provide a critical inflow of food and cash into the village.

9. Groundnut Oil Expeller. The making and selling of groundnut oil is one of the few sources of income for village women. A solar-powered expeller installed in one project village saves time and labour while earning more income for women.

SELF was the lead implementing organization and partnered with the Jigawa Alternative Energy Fund (JAEF), a non-governmental organization formed to promote the use of renewable energy in Northern Nigeria. Installation began in June of 2003 and was completed in April of 2004. This project is now fully operational and is demonstrating the transformative effect that a sustainable source of electricity has on village life in the areas of health, education, water supply, security and economic development.

4.4.2.1 Costs and Benefits

The cost of PV electrification is much less than the cost of bringing in the national power grid or the cost of a local diesel power plant. The above project (the provision of solar electricity and water supply) was worth 40 million naira as observed by [38], and covered over 300 households in three local government councils

More importantly, PV plants require less maintenance and operational expense and with sustainability measures in place, can be expected to be a much more reliable source of power.

Even though the project was only recently completed, we are already hearing of the benefits. A school principal reports that his solar-illuminated classrooms are being used every night for new adult education classes, regular primary classes and as study centres. A village health officer reports that with the better light, he is able to safely perform procedures such as inserting intra-venous (IV) lines and injecting medications. Home businesses are reporting increases in efficiency with better lighting. Several young people have been able to utilize micro-credit to start new businesses that require electricity. New small businesses have cropped up under the streetlights at night.

In addition to the benefits to health, education, security and economic development as outlined above, PV electrification of offers the social value of making these three villages more desirable places to live. PV technology is encouraging village residents to stay and develop their own villages instead of migrating to larger cities and towns that are already short of employment and housing. Residents of one project village are proud that they have lights at night when the power is out in a larger grid-connected town located nearby.

4.4.2.2 Replication Potential

This project is highly replicable in that it works as designed, is well accepted by its users and meets the needs found in many Nigerian and West African villages.

The project has attracted a great deal of attention and has been visited by the Governors of several neighbouring states, President Obasanjo of Nigeria, Rick Roberts, the acting U.S. ambassador, and by international media such as Cable News Network (CNN) which broadcast a story on the project.

It has also piqued the interest of many people and businesses from outside the villages, who are connected to the national power grid but are looking to make their power supply more reliable. Because of the numerous inquiries, it is likely that JAEF will launch a for-profit enterprise to sell PV systems to people outside the project area. It is hoped that a privatized spin-off of this project will help create jobs and supporting micro-industries as the demand for these systems grow.

Replication is likely to be a reality as Governor Turaki reports that he is working on funding for the next phase of at least 30 more villages. In addition, SELF has been approached by another Government that provides aid to Nigeria about replication of the project in other Nigerian states.

4.5 THE SOLAR ENERGY MARKET IN NIGERIA

Commercial activities in relation to solar energy products are quite limited in Nigeria. While photo-voltaic systems are quite visible on the Nigerian scene, solar thermal energy systems utilization to supplement electricity supply is practically zero since there are no solar thermal power plants anywhere in the country. This is in spite of the observations of [13]; the solar thermal systems mentioned here are mere demonstration efforts of a very small scale in terms of industry and commerce, and they are not particularly used to generate electricity. Also, [21] provides a sample list of renewable energy (RE) actors in the country. This list includes about twelve (12) companies whose activities range from importation, wholesale and retail sales, installation, maintenance and repair, consulting, design, to project development, of mainly solar systems limited to photovoltaics. Some like Jon Paca Investments Limited, located in Garki Model Market, Garki, Abuja, and Honey – Fiks Investment (Suite 23, Gwarimpa Plaza, Abuja Nigeria), even stake a claim to exportation.

A summary of this list of companies and their description in terms of activities, location, etc. is shown below.

Solarmate Engineering Limited

Business type: Service, Installations, wholesale, supplier, retail sales.

Product types: Packaged/custom built power systems. Xantrex/Trace Engineering Authorized Service Center.

Service types: system installation

Address: 435/437 Herbert Macaulay Street, P. O Box 1654, Yaba, Lagos Nigeria

Telephone: 234 1 7740887 OR 2880165

FAX: 234 1 4974607

Renewable Energy Solutions

Business type: importer

Product types: energy efficient appliances, refrigerators and freezers, DC to AC power inverters, solar water pumping systems, solar panels, charge controllers, battery chargers, power supply systems(0.1-45Kva modules)Semi-Traction and Deep Cycle Batteries Brands represented by the company include Sunfrost, ASP, Airtherm, Victron-Energy,

WAECO, Germanos and Moll.

Service types: consulting, installation, engineering, retail and wholesales

Address: 10, Oregun Road, Ikeja, Lagos, Nigeria

Telephone: +2341-4701020, +2341-4723831, 08033467821, 08033236026

FAX: +2341-3205553

Sabadel Solar System (Nig) Ltd

Business type: wholesale supplier, importer

Product types: photovoltaic systems, solar water pumping systems, energy efficient lighting, and renewable energy system batteries

Address: 16, Adegbola Street, Ikeja, Lagos Nigeria P.O.B 4733K

Telephone: 01 4930483

Comfort Zone (Nig.) Limited

Business type: retail sales, importer

Product types: solar electric power systems, packaged power systems, energy efficient lighting, energy efficient appliances, photovoltaic systems, renewable energy system batteries, Solar Powered gift items.

Service types: consulting, design, education and training services

Address: E052 Alade Shopping Complex Allen Avenue, Ikeja-Lagos, Nigeria

Telephone: 2341-497-1744

FAX: 2341-497-1744

Naija Solar Products

Business type: retail sales, importer

Product types: emergency backup batteries, energy efficient lighting, natural daylighting, photovoltaic systems, nickel metal hydride batteries, water filtering and purification systems, Educational & Gift items

Service types: design, installation, education and training services, maintenance and repair services

Address: 56, Adebayo Mokuolu Street, Anthony Village, Lagos Nigeria

Telephone: (01) 2341 493-6671

FAX: (01) 2341 493-6671

New World Energy Limited

Business type: retail sales, wholesale supplier

Product types: publications, photovoltaic cells, renewable energy system batteries, solar electric power systems, fluorescent light bulbs, photovoltaic module mounting systems, Solar Panels.

Address: #12 University Market Road Nsukka P.O. BOX 974, Nsukka, Enugu State Nigeria

Telephone: 08037240119

Solarec Engineering Limited

Product types: solar electric power systems, solar charge controllers, solar water pumping systems, DC lighting, backup power systems, photovoltaic modules, Inverters.

Service types: consulting, design, installation, project development services, maintenance and repair services

Address: 2nd Floor, 6A Ahmadu Bello Way, Kaduna, Kaduna State Nigeria P. O. Box 9062

Telephone: 234 62 241437

FAX: 234 62 241079

Dahiru Solar Technical Services

Business type: retail sales, importer

Product types: deep cycle batteries, air cooling systems, biomass energy systems, DC to AC power inverters, photovoltaic systems.

Address: 8/9 Kundila Market/Zaria Road, Kano, Kano Nigeria Box 10867

Telephone: 234 64 661408

Honey - Fiks Solar

Business type: wholesale supplier, exporter, importer

Product types: photovoltaic systems, solar outdoor lighting systems, solar water pumping systems, solar garden lights

Address: Suite 23, Gwarimpa Plaza, Federal Capital Territory, Abuja Nigeria

Telephone: 234-9-6712478

Jon Paca Investments Limited

Business type: wholesale supplier, exporter, importer

Product types: solar water pumping systems, investment and financial services, photovoltaic module components, air cooling systems, alternative home and building construction materials, packaged power systems, solar streetlighting, solar garden light.

Address: Suite 38, Kogi Street, Garki Model Market, Garki, Garki, Abuja Nigeria PMB 5066

Telephone: 234-8044115323, 234-8037034906, 234-8033031885, 234-9-6700832 Ext: 108

Eurel Energy Corp

Nae Ismail, President

(613) 748-1809

nismail0423@rogers.com

Details: Have an agent based in Lagos Nigeria who is currently working on a Nigerian Gov't sponsored project in the Abuja area to electrify schools using PV powered system. Their R&D department has developed a 1Kwatt wind generator that is for sale/distribution.

Philips Projects Center.

The center represents **Shell Solar of Holland**.

Services: Engineering services, PV consulting, retailing, equipment supplies, installation services.

#8 Kofo Abayomi St., V/I Lagos. Tel: 01-2620811; 01-2620632. Fax: 01-2620631; 01-2615143

It is important to note how [13] goes further to summarize the renewable energy (RE) market in Nigeria in general as follows:

RE MARKET IN NIGERIA:

•Mostly PV (Photovoltaic systems)

•Over 40 companies are engaged in RE business

•Activities of PV companies include consultancy, installation.

•Manufacturing

–A company in Ogun state manufactures saw dust briquettes

–No manufacture of modules, inverter, batteries

–A company in Jos, Plateau state has capacity to assemble Solar Refrigerator

CHAPTER FIVE:

CONCLUSION AND RECOMMENDATIONS

At the end of the research, the following conclusions were drawn and appropriate recommendations made where necessary.

Summary of Findings

1. Nigeria has a need for more reliable electricity supply. Answers to this need can be seen to lie in the exploration of the country's solar energy potential. With the remarkable Annual Average of Daily Global Solar Radiation of 5.535 $KWh/m^2/day$, Nigeria has an Average of 1.804×10^{15} kWh of incident solar energy annually. This energy amount translates to multiplication by thousands of the amount of electricity generated by conventional means in the whole of the year 1998.

2. The environmental concerns caused by solar energy systems (either photovoltaic cells or solar thermal converters) are negligible compared to the hazards caused to the environment by the fossil-fuel electricity generation systems.

3. The cost of electrifying an area covering over 300 rural households together with supporting amenities as Health Care centres, irrigation for potable water, street lighting, schools, micro-enterprise centres, etc. is estimated at a project cost of about 40 million naira with most systems being maintenance free for eight to ten years.

4. Solar thermal generated electricity, unlike photovoltaic (PV) systems, is yet to be visible or developed in Nigeria even though the use of PV systems within the country is also relatively little.

Conclusion

1. Solar energy electricity is found to be more environment-friendly compared to conventional fossil-fuel generated electricity.
2. System of data collection and documentation on the environment and related areas is not well established in Nigeria.
3. The development of Nigeria`s solar energy potential will lead to generation of more electricity and speeding up of rural development.

Recommendations

1. More needs to be done in the area of collating environmental data and statistics. This is necessary for evaluation of the impact of different electric power stations on the environment in which we all live.
2. It is recommended that for solar energy technology to gain accelerative pace in Nigeria, the government should pay more devoted attention to this energy technology. And this may be actualized by the formulation of a detailed energy policy as opposed to the general statements on energy found in the national Science and Technology Policy. Also, adequate funding and research is critical to the success of such a policy.

CHAPTER SIX:

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