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Study of Solar Energy Resources in Port Harcourt, Nigeria: An Assessment of Economic Viability

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Abstract: Port Harcourt in Rivers State of Nigeria is blessed with copious energy resources which can increase economic growth and create the capacity to equate with the upcoming electricity demand. As at today, most residents in Rivers State and Nigerian at large do not have the opportunity to make use of electric power due to less concern in electrification within the remote areas. The value of the daily generated electricity in mega-watts for the entire country is not enough to carry the domestic loads, industrial loads, factories and commercial sectors, thereby slowing the rate of growth or progress in the country. In order to ease these difficult challenges, create job opportunities for the youth and boast the economy of the nation, alternative source of power supply mainly renewable energy such as solar energy, wind energy, biomass etc. are proffered to remedy the situation within the rural area and the area of less electricity supply in different cities. This research is centered on the study of solar energy resources in Port Harcourt, Nigeria; an assessment of economic viability, the technologies developed to harness solar energy. It also deals with the benefit of solar energy to our economy using Cost-Benefit Analysis approach which include job opportunities, reduction of energy bills, the impact on the environment and us, and calculations showing the annual solar energy output of a photovoltaic system. It also contains the quantity of energy one's electrical devices consume over a length of time, estimation of solar power requirement and the quantity of energy solar panel can produce over a particular interval of time.

Keywords: Renewable Energy, Non-renewable Energy, Photovoltaic Cell, Economic Viability, Cost-Benefit Analysis, Temperature, Solar Panel, Port Harcourt

1. Introduction

1.1. Background of the Study

Port Harcourt in Rivers State which is located in the region of Niger-Delta of the South-South geopolitical zone of Nigeria is abundantly blessed with almost all energy resources, with oil and gas the most paramount. Rivers state have a lot of energy resources, both renewable and non-renewable which can comfortably give the state enough capacity to meet up the demand of both rural and urban parts of it. The state has high qualities of different energy resources like gaseous hydrocarbons (natural gas) and crude oil in which 91% of the Nigerian economy depends on. Nigeria at large is also blessed with enough renewable energy and non-renewable resources for example biomass, solar, wind and hydropower. Solar resources assessment gives the method to correctly calculate the availability of sun radiation resources for growing, deploying and operating cost-effective solar energy technologies per the sun shot goals. Many people view the solar industry as a rich man's thing as money happens to be one of the basic issue most people cannot switch to solar. In the last few years, solar energy cuts its price in whooping large percent and at once became a viable source of energy and also a source of economic benefit as well. Solar became globally in use as it became less expensive than other sources of electricity. It is also an option for those who want to save money on their utilities, so while solar cut down harmful emission, it also became a valuable source of income globally.

The electric power generated from water has the greatest energy strength (potential), which amount to $10{,}000MW$ for considerable hydropower and $742\ MW$ for small or minor hydropower (NHP). In addition, Renewable energy (RE)

sources like energy from the wind with a potential of over 150,000 Terra Joule per year. Still and all, the exploration of these resources are yet to be determined [12].

Nigeria is located in western part of Africa on the gulf of Guinea and has entire area of $923{,}769Km^2$, population of over 184 million. Rivers state have a total area of $11{,}077km^2$ $(4277\ sq.mi)$ and population of over 5,198,716 million, with Port Harcourt $369km^2$ of area and 2.343 millions of population [5].

More than half of the state indigenes live in the Island and rural areas which are difficult locations, fast means of electricity grid and fossil fuel because of bad roads and sea. Most of these rural areas and towns in Port Harcourt are just far from the closest common link point of utility grid system.

The energy from the sunlight gives lesser cost (less expensive) and enough energy for regions whose link to the national grid may be very costly because of the rural areas from the closest grid link points. Solar energy is an attractive source of energy in urban and rural location of Port Harcourt, Nigeria. It helps and supports the quick growth of little-scale industries and minimizes the remote-urban drift.

The energy from the sunlight can be considered as the anchor behind different kinds of renewable energy. It anchors hydropower where the sun controls the hydrological cycle and wind power where there is movement of air because of the heating effect of the sun on the air. Generally, all these forms of energy such as heat, chemical, electrical and kinetic energy can be provided through the conversion of solar energy. Solar energy consumption takes its source in the ancient days when solar energy (sun) was used to check time (clock), as a cardinal direction or compass, for preservation of food etc. [13].

Solar energy resources are also the fundamental source of energy that drives other types of renewable energy sources like biomass, wind, hydropower and waves. Nigeria is just increasing its capabilities to make use of sun energy via its National Energy Policy (NEP) [12].

Solar energy simply means the solar radiation from the sun to the earth surface which transforms its energy directly into electricity or heat. The yearly average daily solar radiation in Nigeria is about $5.25KWh/m^2/day$ which varies between $3.5KWh/m^2/day$. At the riverine areas of Rivers state [5].

1.2. Statement of the Problem

In Port Harcourt, Rivers State and Nigeria at large, the constant power supply needs with the increase in electricity tariff, highly estimated electricity bills and inadequate power supply have particularly drawn much concern to the demand of renewable energy resources like solar photovoltaic systems. As a result of these inconsistent power supply, most customers, the residence and the government have resolved to take decisions on getting alternative source of power supply through installation of solar PV energy systems to supply power for general community water pumping, health centres, etc.

1.3. Aim and Objective of the Study

The aim of this research centres on the study of solar energy resources in Port Harcourt, Nigeria; an assessment of economic viability. The objectives of the study are as follows;

1. To study solar energy resources in Port Harcourt, Nigeria as an assessment of economic viability.
2. Determine the benefit of solar energy to our economy.
3. To calculate annual solar energy output of a Photovoltaic system.

1.4. Significance of the Study

To improve power supply.

Enlightenment on more studies of solar energy resources in Port Harcourt.

Manage solar energy resources in Port Harcourt, Rivers state and other parts of the states.

1.5. Scope of Research

The scope of this research covers the Port Harcourt areas in Rivers State and can be used as a reference to other parts of the states and Nigeria at large.

2. Literature Review

2.1. Theoretical Overview Related to This Work

Solar energy is one of the alternative sources of energy which support or supplement the convectional energy sources especially in Port Harcourt, Rivers State of Nigeria. It is also a renewable-energy-based system, which contribute beneficially to the environment than convectional power in terms of human life (health) because of its clean nature, minimizing of air pollution like carbon black or soot, reducing of noise pollution, and it is cost effective etc. The human population growth in the world has caused so many issues in which one of them is climatic change or global warming due to relatively great quantity of Carbon IV oxide (CO_2) in the air, and the gases that occur from the manufacturing industries or factories like Ammonia (NH_3), Carbon II Oxide(CO), Hydrogen Chloride (HCl), Nitrogen trifluoride (NF_3), Sulphur IV Oxide(SO_2), Nitrous Oxide (N_2O) that mixed up in the atmosphere, depletion of Ozone layers (O_3). Many of these gases are generated from gas and power plants burning fossil fuel all over the globe.

2.2. Natural Energy Resources in Port Harcourt, Nigeria

In Nigeria, energy resources can be categorized into;
Renewable and Non-renewable.

2.2.1. Renewable Energy and Non-Renewable Energy

Renewable energy resources are those resources that can be generated or produced rapidly via natural processes. The level at which renewable energy resources are utilized does not have any effect on their availability in future and as such cannot be finished. All the parts in the world have reasonable

access to one or more forms of renewable energy supply because the resources are generally well distributed all over the globe, even at wide spatial and temporal variation. Many of the renewable resources can be depleted by human use, but may also be replenished thus maintaining a flow. The types of renewable energy that occur are as follows; wind energy, solar energy, hydro energy, Biomass energy etc. [10].

In their work used the Scenario-based international atomic energy models. They presented and analyzed the projected energy demand and supply structure of the nation through 2030 and stated that Nigeria will surmount her current energy unstable situation if she seek the vast or copious renewable energy resources in the entire states [2].

Non-renewable energy resources are those resources that cannot be produced, generated, grown or used on a scale that can sustain its consumption rate because they will not be available for future need once they are depleted. They are consumed much faster than nature can do, thus their rate of formation is extremely slow. The type of non-renewable energy resources that occur are as follows; Coal, Natural gas and Petroleum [10].

Agaptus Nwozor et al. [1] presented that Nigeria is a major oil producer with extremely large hydrocarbon reserves. It has four refineries with a net installed capacity to refine 445,000 barrels daily. It has what it takes to increase the capacity in order to gain self- sufficiency in refined petroleum products but these refineries have never refined up to 20% of its capacity thereby causing the country to import 90% of its needed petroleum products. Their studies included that Nigeria needs about 98,000 mega-watts ($98{,}000MW$) to gain national electricity [1]. However, its thermal and hydropower station have a joint installed capacity of only $12{,}522MW$ but produce between $3000MW$ and $4000MW$ and occasionally less than $3000MW$.

Niger-Delta in Nigeria is blessed with an annual average daily sunshine of $6.25hour,$ ranging from $3.5hours$ and annual average daily solar radiation of about $5.25KW/m^2/day$ (coastal area). Nigeria receives about $4.85 \times 10^{12}KWh$ of energy per day from the sun. These huge energy resources from the sun are available for about 26% only of the day. Niger-Delta has an average of $1.804 \times 10^{15}KWh$ of incident solar energy annually. This annual solar energy radiation (insolation) value is about twenty-seven times ($27times$) the total convectional energy resources in energy resources in energy unit of the Niger-Delta and it is more than $117{,}000\,times$ the quantity of electric power produced in the Niger-Delta in 1998. In other to annually receive from the sun the quantity of energy equal to the convectional energy reserves of Niger-Delta, about thirty-seven percent (37%) of land area in Rivers State is needed to be exploit or utilized [12].

In their work showed the economic viability of a $30MW$ power plant in Bonny Island, Rivers state, Nigeria and presented a table with Bonny Island average air temperature which stated that relative humidity usually fluctuate between $80\%\ and\ 95\%$ during the rainy season. While during the dry season, the relative humidity usually fluctuate between $50 - 55\%$ at noon and $90 - 95\%$ at night [14].

According to [15] in their studies on Comparative Analysis on Economic Viability of Independent Power Producing System in Nigeria, the best approach to derive the best economic power generating technology are via localized cost of electricity generation (LCOE), Net Power Value (NPV), Internal Rate of Return (IRR) and Simple Payback Period (SPBP).

Mustapha Mukhtar et al. [8] used Time-series regression model to analyze the effect of electricity usage on economic development and environmental sustainability. According to Mustapha Mukhtar et al. [8], unlike other present studies that examined the effect of electricity usage on economic development or environmental sustainability for distinct nations, the current work will further show a techno-economic analysis of a proffered remedy to the imminent electricity challenges using RETScreen professional software. This software determine the feasibility of a $500kVA$ micro-grid solar PV system integrated for electricity production.

Solar energy is also the basic energy source that move other renewable resources like wave, wind, biomass and hydropower. Although the present solar energy installation in Niger-Delta is relatively insignificant compared with that of Sokoto, Kano, Jigawa, Adamawa and Kebbi State etc. Some African countries have more than 20,000 “off grid” installation of photovoltaic panel like South Africa, but Nigeria is just growing its strength to utilize solar energy through its National Energy Policy (NEP). Some countries such as USA, Japan and Germany have raised the interconnection of photovoltaic panels with their national grid through motivating programs and their grid market at present is far larger than the off-grid market. Nigeria has good radiation sites that can boost the growth of solar energy, yet government attention and research efforts in that direction have produce very insignificant result. Effective policies need to be done to provide solar energy growth in Nigeria [12].

According to [4] in their study, the production of electricity using energy from the sun can be achieved using photovoltaic technology (PV technology). The solar PV cells functions on the principle of conservation of sunlight into electric energy (PV effect). For production of electricity in considerable amount, an array of solar PV cells is either put together in series or in parallel. Irrespective of the relatively enormous cost of the PV systems, solar energy is regarded as other source of energy in many part of the globe.

Michael. O. D. and Atul. K. [7] used a computationally logical methodology to estimate or evaluate the technical potential rooftop solar photovoltaic in the town or city residential buildings of Nigeria. In their studies, they also used PVSyst. Software to estimate the yearly energy production of rooftop solar PV in selected areas across the nation. Ogunjo. S. T. et al. [9] stated that the temperature and solar radiation data used in their work were acquired from Tropospheric Data Acquisition Network (TRODAN) campaign hosted by the Centre for Atmospheric Research, National Space Research and Development Agency (CAR-NARSDA), Nigeria. This obtained data were as a result of

using Campbell Scientific Weather Station with an integration time of 5 minutes in different places such as Abuja, Lagos, Minna and Port Harcourt. Then, they concluded that Abuja and Minna have a wider spread of temperature and solar radiation than Lagos and Port Harcourt due to the nearness to the coastal region.

2.2.2. Types of Solar Energy

There are types of solar energy which depends on;

How solar energy is converted into useful energy (Active and Passive solar energy).

The type of solar energy it is converted into. Concentrated solar power (Solar thermal energy) and photovoltaic solar power).

2.2.3. Passive Solar Energy

Passive solar energy does not involve the use of mechanical devices to harness the energy from the sun. South-facing window can be used to provide natural lighting. Heat from our home is an example of passive solar energy. Passive solar energy such as passive solar heating, passive cooling and day lighting are very beneficial to a house owner.

2.2.4. Active Solar Energy

Active solar energy uses mechanical devices for the collection, storage and distribution of solar energy in our various homes. For instance, in active solar energy water heating systems, pumps are used to distribute water through the system. Active solar space heating, Active solar water heating and Active solar pool heating are several active solar application that are very beneficial to a homeowner.

2.3. Technologies Developed to Harness Solar Energy

Photovoltaic solar technology.

Solar thermal technology (Concentrated Solar Power).

2.3.1. Photovoltaic Solar Technology

Photovoltaic solar technology is solar technology that uses panels produced from semiconductor cells to directly convert sunlight into electricity.

2.3.2. Solar Thermal Technology

Solar thermal technology takes heat from sun. The heat is used directly (low temperature solar thermal), changed or converted into mechanical energy and in turn electricity called Concentrated Solar Power (CSP).

2.4. Different Types of Installations Used for Solar Energy

Photovoltaic panels can power electrical devices while solar thermal collectors can heat hot water for homes or small communities.

Photovoltaic or concentrated solar power plants that cover large areas generate electricity on a large quantity which can be sent to the power grids. It concentrates on warmth of the ray of sun using collector to heat a transfer fluid such as gas, oil and molten salt to a high temperature. The fluid heats a network of water, which produces steam and drives a turbine that is mechanical energy, thereby giving electricity. Heat from the ray of sun is collected in large power plants where flat or curved mirrors are installed over vast areas like desert. The solar technology is best suited to countries where the sunlight is very severe or intense, such as in the desert areas.

2.5. Components of Solar Energy Resources

Solar electric system needs a complete solar component to generate electricity and convert power into alternating current used as home appliances, store excess electricity and maintain safety of lives and equipment. The components of solar energy resources include;

2.5.1. Solar Panels

Solar panels are most noticeable component of a residential solar electric system. The solar panels are set-up outside homes, typically on the building roof and convert sunlight into electricity. These solar panels are measured in Watts. This solar panel rating in *Watts* is the maximum power produced by the panel under perfect (ideal) conditions. The output per solar panel is between 10 and $300 Watts$, with a common configuration of $100 Watts$ [3].

2.5.2. Solar Array Mounting Racks

Solar panels are joined into arrays (orderly arrangement) and usually installed in one of three methods such as roofs, directly on ground and on poles in free standing order (arrays). The most common amongst the three is the roof mounted. The approach is clear and efficient. Maintenance is the main issue that occur in roof mounting and for high roofs, clearing snow and repairing the systems can also be an issue. Panels do not usually need much maintenance or repair.

Free standing pole mounted arrays can be put at height which makes maintenance easy. The benefit of easy repair evaluates against more or additional spay needed for the arrays.

Ground systems cannot be used in regions with steady accumulation of snow because they are low and simple. Mounts are either fixed or tracking regardless of the place or location the array is mounted and space is also put in consideration with these array mounts. Fixed mounts do not move and are present for height and angle. Tracking arrays move east with the sun and adjust their angle to maintain the optimum as the sun moves.

2.5.3. Mounting Equipment and Tracking Mounting

Installation of photovoltaic panels is extremely important. The panels need to be mounted where they will get highest quantity of sunshine throughout the year but the more difficult issue is to mount the panels with enough integrity that they will last for twenty-five years ($25 years$) or more. Tracking mounts mechanically move the photovoltaic panel over the course of a day so that they directly face the sun at all times. Double axis trackers change both azimuth (angle measured clockwise from the south or north) and elevation, while single axis trackers only match the azimuth (angular distance extending from the highest to the horizon).

According to [11], the three layers of the PV panel are;

1. The N-layer (Silicon mixed with Phosphorus).
2. The P/N junction (Pure Silicon).
3. The P-layer (Silicon mixed with Boron).

When sunlight hits the N-layer, it knocks electrons loose. These electrons entered through the P/N junction (which is a one-way junction) into the P-layer. This produces an electrical field which then drives the electrons that have been "knocked-off" from the silicon, creating an electric current.

2.5.4. Types of Batteries for Solar Electric Systems

In renewable energy systems, batteries chemically store electrical energy. Solar batteries come in different voltages, but $6Volts$ and $12Volts$ are the most common varieties. The three types of batteries that are usually found in renewable energy systems include;

1. Flooded Lead-Acid Batteries (FLA).
2. Sealed Gel Cell Batteries.
3. Sealed Absorbed Glass Mat Batteries (AGM).

According to [6] in their work, the Flooded Lead-Acid Batteries are most economical variety (cost-effective). This particular type of solar battery opens hydrogen under heavy charging and must be stored in a ventilated enclosure. The main issue about FLAs is due to its maintenance nature. Sealed Solar Batteries do not need maintenance and do not need watering, nor do they typically vent any gasses. Sealed Absorbed Glass Mat Batteries (AGM) is more expensive and more sensitive to overcharging than Flooded Lead-acid Batteries (FLAs).

In their work, they found out that Sealed Gel Cell Batteries are also sealed like AGMs and therefore do not need maintenance, but tend to be much costlier than AGM and FLA type of solar batteries.

The advantages of all battery types is measured in units of time and it is directly related to number of charge cycles possible. Flooded batteries last longer than sealed batteries. FLA that is properly maintained last more than ten (10) years.

2.5.5. Battery Pack

Solar power systems generate electricity when the sun is shining (during the day time). At night or cloudy days when the sun is not shining, our homes need electricity by adding batteries to the system.

2.5.6. Array Dc Disconnect

The array DC disconnect is used to disconnect or isolate the solar arrays from the home for repairs. It is known as DC disconnect because the solar arrays generate DC (direct current) power. The direct current (DC) and alternating current (AC) disconnects of a photovoltaic system are manual switches that are capable of disconnecting (cutting off) power to and fro the inverter. Some inverter has disconnect switches integrated into their structure. There are capacitors in most inverters that can store a lethal charge for some minutes after incoming current is disconnected (cut-off). Disconnection prevents the current being generated from going beyond the cut-off (disconnect) point to a down utility grid or damage component [6].

2.5.7. Inverter

In their work stated that solar panels batteries generate DC power. Standard home appliances use alternating current (AC) [11]. An inverter converts the DC power which the solar panel and batteries generated into AC power and these are needed by the electrical appliances or most common electrical loads. Inverters take the low-voltage, high current signals from the photovoltaic panels and change them into $120VAC$ (or $240VAC$) which is directly compatible with grid power. Quality is a must in inverters because they are generally the weak link in any photovoltaic system. They also stated that 'Off-grid inverters' is a class of inverter that need batteries for storage. 'Straight grid-tied inverters' do not make use of batteries while 'Grid-capable inverters' can function either with or without batteries depending on how the system is designed. Some inverters have integrated AC chargers that make use of AC power from the grid to change (alternate) the batteries in the time of low sun.

2.5.8. Power Meter

Power meter takes the measurement of the quantity of power utilized from the grid and the amount or quantity of power the solar system transmit to the grid. That is, for systems that maintain a tie to the utility grid. Power meter also aid the system to achieve the maximum (peak) efficiency from the installed solar power system.

2.5.9. Backup Power/Generator

The backup power or generator used in solar system occur when the sunlight does not shine or the day light is extremely low and solar batteries are drained (empty). Most systems add some sort of support or backup power like in a stand-alone installation which is diesel generator. In a grid-connected system, the utility grid itself provides backup power via the converter. Wind turbine or a water-wheel is used as a portion of a small-scale hydro system that are not connected to the utility grid during the time of low system turnout because of bad weather, cloud cover or high household need.

2.6. Other Types of Renewable Energy

Solar energy is got from the sun as one of the types of renewable energy. Its main technologies are solar photovoltaic (used to convert sunlight directly to electricity) and solar thermal (used the heat from the sun). Other types of renewable energies include the following;

Wind energy: Energy generated from the wind or oceanic waves using wind turbines.

Biodiesel: Biodiesel is a type of renewable energy or biodegradable fuel generated from animal fats, recycle restaurant grease or vegetable oils.

Geothermal energy: This is a renewable energy source got from inside the earth as a result of heat within the earth. It is used to produce electricity.

Tidal energy: Renewable energy from the rise and fall of ocean current and tides. This type of energy happened as a result of gravitational interaction between the earth, the moon and the sun.

Hydraulic energy: Hydraulic energy is a hydroelectric power (hydroelectricity) generated from movement of rivers and other freshwater currents. It is also known as water energy which produces electricity due to the effect of kinetic and potential energy from water current and waterfalls.

Biomass: Energy extracted from living organism or organic material example plant like corn and soy. It is also known as Biogas energy.

Bioethanol: This is an organic fuel that has high octane number biofuel suitable for vehicles. It is generated from fermentation of vegetation, potatoes, corn, sugar cane etc.

3. Methodology

Solar panels are a very important way to offset loss of energy, minimize the effect of environmental impact on our dwelling places or houses and provide so much advantages like keeping local businesses from falling and adding to energy independence. The methodology used in this work for an assessment of economic viability of the study of solar energy resources in Port Harcourt is mainly Cost-Benefit Analysis method (CBA method).

Sun energy is got due to the radiation of sun and this can be transformed to electric power or thermal energy (heat). The sun is a strong source of solar energy and this source of solar energy can be tied or achieved by the installation of solar panels. The quantity of insolation the sun gives to the globe for an hour can absolutely satisfy the world's energy demand for complete twelve months. Though, we have been able to utilize at most 0.001% of the solar power. For some years now, we have been conversant with the use of solar energy. One of the types of renewable energy we human beings ever developed is the solar energy. For over ten years, Coal, hydro, gas, etc. have been our major source of electricity.

3.1. Benefit of Solar Energy to Our Economy

The advantages of solar energy are ever growing with distinct technologists coming up. The research and development of various solar plants will certainly make a sense of equality amongst different economic groups in the universe. There are so many benefits of using solar energy and that can make it more successful in Port Harcourt, Nigeria. These include.

3.1.1. The Effect on Us and the Environment

Solar energy has the smallest negative effect on our surroundings unlike any other source of energy. It does not generate any gas that absorb and emit radiant energy within the heat infrared area (Greenhouse Gases, GHG), that is, it reduces oil industry's GHG emission and improve its public image. The effect of solar power system to the environment does not cause any pollution to the water unlike organic chemicals that cause water and air pollution. Solar energy also needs a very small quantity of water for its maintenance and preservation, contrary to hydroelectric plants, atomic power plants. For instance, hydropower plant is very much expensive and it require dams to generate electricity unlike the solar power system that is less costly and does not need water or building of dams to generate power. The production of electricity via solar energy system does not generate any noise. This is the main advantage or importance, since major installation of solar energy systems are in urban or metropolitan areas. Solar energy system creates clean and pure energy from the sun. The installation of solar panels on our residential roofs help to fight greenhouse gas emissions and minimizes our dependent of organic or fossil fuel (saving of hydrocarbon resources). Fossil fuels have been our traditional source of electricity like coal and natural gas. Fossil fuel emit toxic gases that are basic causes of air pollution and world climatic change when they are burnt to generate electricity. Fossil fuel is not only harmful to the environment, but they are also limited resources. This is why the price is frequently changing and can go up in a short length of time.

Renewable energy also enhances public health. Fossil fuel (Coal and Natural gas) contaminate the environment and thereby generate water and air pollution which is bad to human health. Substituting fossil fuels with renewable energy sources, like solar energy or solar power can minimize premature death and in addition overall health care costs. Solar power also functions or works at any time of draught or thermal wave. Coal and natural gases use large quantity of water for cooling. During heat waves or severe drought, electricity production is at danger but solar power systems do not need water to generate electricity.

3.1.2. Reduce or Eliminate Outrageous Energy Bill

When one generates her own electricity from the sun with a solar system, this signifies that the energy consumption rate will be less from the utility grid. As a result of this less consumption of energy from the grid, this will quickly help to reduce high electricity bill one receives monthly or weekly. One can also make enough money by marketing the unutilized power. The more solar power one generates, the smaller the quantity of electric power one consumes from the electricity suppliers. This will definitely increase ones' energy self-reliance.

3.1.3. Production of Energy Matches the Duration of High Demand

Energy demand tends to increase between the hours of (11:00-16:00) and then towards the evening time. This is always the time the cost of the electricity naturally gets very high. Sun energy gets to its highest production capacity during these hours of the day. The solar power generated between these hours of the day (11:00-16:00) has a higher advantage than when it is produced during the evening and night. In addition to the input of solar energy, the cost of energy within the time frame drastically go down to a degree equal to those of night hours.

3.1.4. Creation of Job Opportunities

Jobs created in solar energy industries have exceptionally

added a whopping of twenty percent (20%) for more than five years (between 2013 till date). Employment in solar energy industries keep growing every day. Solar energy systems have tremendously added to the economy and positively affect the rural area or communities. Solar distributors have also played a vital role in solar industries as it helps solar energy system producers to do business with professionals and capable solar installers thereby creating more employment for people. Solar distributors do not only assist solar industries to do business better, they also assist those in need to access solar technology. Therefore, while solar distributors help people to gain employment on solar jobs, they also enlighten individual households on how solar energy help can them and how they can use it.

3.1.5. Less Electricity Lost During Long-Distance Transport

As power is produced from the generation companies, about 3-5% of the energy is lost in the course of transmission (transportation) and distribution. The farther the distances from the generation station to the distribution (supply points), the more energy is lost on the transmission and distribution lines. Those losses on the power lines might look negligible but they can make impact on the performance of the installation in areas with high population density. Solar panels mounted on the rooftop of a building or in the site seriously minimizes this far distance of power transportation, thereby improving the effectiveness of the electrical system.

3.1.6. Improve Grid Security

The grid is less exposed to the vandals, overload and natural disasters if there are lots of power plants dispersed within the areas. A utility grid with high penetration of solar energy has a lot of energy generation locations which are broadly dispersed. This enhances the reliability of the grid in case of overload, natural-caused catastrophe or man-made-caused disasters.

3.1.7. Solar Energy Is Applicable Everywhere

Solar energy can be deployed at any location as long as there is sunshine. This is specifically useful for rural locations or disconnected urban areas that has no way to access any other source of electric power. There are many people around the universe who have no means to electricity. Independent solar energy systems can be sent to those communities to enhance the lives of many people over the areas. In addition, solar energy is very useful to power up space crafts and watercraft (boats), Power up oil and gas company's wellhead control panels (WCP), provide power for chemical injection pump (CIP) in oil and gas industries, Provide power to supervisory control and data-acquisition systems (SCADA) in remote areas and can also be used in cathodic protection station (CPS) along cross-country pipelines (CCPs).

3.2. Methods of Estimating Solar Power Requirement

The three main methods to consider in order to choose a solar power or solar system include;

1. The quantity of energy the solar battery can save.
2. The quantity of solar energy appliances use over a specific range of time.
3. The quantity of energy a solar panel can generate in a particular range of time.

3.2.1. The Quantity of Solar Energy the Solar Battery Can Save

The capacity of solar battery is measured in $Amp\ Hours\ (AH)$ and required to be changed to $Watt\ Hours$ by multiplying the AH values by the battery voltage. That is,

$$X \times Y = Z \tag{1}$$

Where;

$X = Battery\ size\ in\ AH$ (Quantity of charge in AH);

$Y = Battery\ Voltage\ in\ Volt$;

$Z = Power\ available\ in\ Watt\ hours$;

For example; to determine the amount of energy in $Watt - Hour$ a battery can store for a $25AH$ and $12V$ battery, we have;

$$Battery\ size\ in\ AH = 20AH$$

$$Battery\ voltage = 12V$$

$$Power\ available\ in\ Watt - Hour = 25AH \times 12V$$

$$= 300WH$$

The above result shows that the battery supplies $300W$ for $1\ hour$, $150W$ for 2hours or even $2W$ for 150 hours. That is, the more energy this take, the faster the battery discharges. Car batteries are not good for solar as leisure batteries because it is designed to discharge and recharge. (That is, it is designed to provide much power quickly).

3.2.2. The Quantity of Energy Appliances Use over a Specific Range of Time

To calculate the quantity of energy appliances utilized over a range of time, multiply the power consumption of the appliances given in $Watts$ by the hours of intended use, that is, $E = Pt$. When making use of electric bulbs, the easiest way to minimize power usage is to replace halogen bulbs with light emitting diode (LED) types because it commonly use about 80 $per\ cent$ less energy for a similar capacity like ($12V\ LED$ light).

For instance, the quantity of energy consumed per day from these appliances include.

$$Energy = Power\ in\ Watts \times time\ in\ hourper\ day$$

$$TV\ 22W\ on\ for\ 2hours\ per\ day = 22W \times 2 = 44Wh\ per\ day$$

$$Water\ pump\ (25W)\ on\ for\ 20mins\ per\ day = 25W \times (20\ /\ 60) = 8.33Wh\ per\ day$$

$$Radio\ 12W\ for\ 5hours\ per\ day = 12W \times 5 = 60Wh\ per\ day$$

$$Spot\ light\ 15W\ on\ for\ 1\ hour\ per\ day = 15Wh\ per\ day$$

$$Main\ light\ 25W\ on\ for\ 3\ hours\ per\ day = 25W \times 3 = 75Wh\ per\ day$$

$$Total\ Energy\ appliances\ used = 202.33Wh\ per\ day.$$

3.2.3. The Quantity of Energy a Solar Panel Can Generate in a Particular Range of Time

The last part of sizing solar system is the solar panels. The unit of power produced from a solar panel to the battery is given by $Watts$. Theoretically, the easiest method to find out the quantity of energy that can be supplied to the battery is to multiply $Watts$ (power of the solar panel) by the $hour$ exposed to the sun.

3.2.4. Estimation of Annual Solar Energy Output of a Photovoltaic System

The general equation to estimate the quantity of electricity generated in output of a photovoltaic system is given by;

$$E = A \times r \times H \times PR \quad (2)$$

Where E=Energy in Kilowatt-hour (KWh)

A = Total solar panel area in square meter (m^2)

r = solar panel yield or efficiency of the solar panel in Percent (%)

H = Annual average solar radiation on tilted panels (shadings not included)

PR = Performance Ratio coefficient for losses (ranging between 0.5 to 0.9, its default value = 0.75)

$$The\ yield\ of\ the\ solar\ panel = \frac{Electrical\ power\ (in\ KWp)\ of\ one\ solar\ panel.}{Area\ of\ one\ panel.} \quad (3)$$

$$r = \frac{P\ (in\ KWp)}{A} \quad (4)$$

The unit of the nominal power of the photovoltaic panel is called 'Watt-peak' (Wp or KWp =1000Wp or MWp= 10^6 Wp)

The nominal ratio for standard test condition (STC) is given by; $Radiation = 1000W/m^2$

$$Cell\ temperature\ = 25°C\ (Celsius)$$

Wind speed =1m/s

Air Mass coefficient of solar energy $(A.M)\ =\ 1.5$

For instance; the *solar panel yield* of a PV model of $250Wp$ with an area of $1.6m^2$ is 15.6%.

That is,

$$P = 250\ Wp = 0.25kWp$$

A=$1.6m^2$

Then

$$r = \frac{P}{A} \times 100\% \quad (5)$$

$$r = \frac{0.25}{1.6} \times 100\%$$

$$r = 15.6\%$$

3.2.5. Performance Ratio (PR)

Performance ratio (PR) is used to compute the quality of a photovoltaic installation because it gives the performance installation ratio and does not dependent on the orientation and inclination of the panel. Performance ratio (PR) includes all losses and depends on the site, the technology and the sizing of the system. Some of the detailed losses that gives the performance ratio values are;

1. $Inverter\ losses\ (4\% - 10\%)$,
2. $Temperature\ losses\ (5\% - 20\%)$,
3. $DC\ cables\ losses\ (1\% - 3\%)$,
4. $AC\ cables\ losses\ (1\% - 3\%)$,
5. $Shadings\ 0\% - 80\%\ (specific\ to\ each\ site)$,
6. $Losses\ at\ weak\ radiation\ (3\% - 7\%)$
7. $and\ Losses\ due\ to\ dust, snow\ (2\%)$.

3.3. Advantages of Solar Energy

The merit of solar energy include;

3.3.1. Renewable Energy Source

Solar energy is truly renewable energy source. It is always available for day-to-day activities and can be make use of in all locations of the universe. Solar energy is within reach in as much as there is presence of the sun. According to the scientist, sunlight will be available to us for at least 5 billion years before the non-existence of the sun anymore. Solar energy can never be used up, unlike some of the other sources of energy.

3.3.2. Solar Energy Reduces Electricity Bills

When one meets its energy demand via the solar power generated, the electricity bills will be small and affordable. The amount saved from the bill depends on the size of the solar power system and the electricity. Moreover, if more electricity is generated than the required quantity, the surplus will be exported to the grid and bonus payments will be received for that quantity (considering that one's solar panel system is connected to the grid). Savings can further increase if one sell enough power at a very high cost during the day and then buy electric power from the grid during the evening when the rates are lower.

3.3.3. Diverse Application of Solar Energy

Solar energy functions in several purposes. One can produce electricity (photovoltaic) or solar thermal. Solar energy can be used to generate electricity in regions where there is no means to connect to the energy grid, for water purification in areas where there are limited clear water supply and to power up satellites in space. Solar energy can also be integrated into the materials used for buildings. Transparent solar energy windows have been introduced by SHARP as also a separate or distinct application of solar energy.

3.3.4. Low Maintenance Cost on Solar Energy Systems

Solar energy systems generally do not need much maintenance. It only requires a few numbers of times in a year to keep clean but if in doubt, one can always depend on specialized cleaning companies as also a source of job creation. Most dependable solar panel producers offer $20 - 25\ years$ warranty. Solar energy systems do not experience wear and tear since these are stationary parts. That is, there is no moving part. The inverter is usually the only part that requires to be changed after $5 - 10\ years$ of service because it is frequently and regularly working to change solar energy into electricity (solar photovoltaic) and heat (solar thermal). The cables also require maintenance to ensure that the solar power system runs at the highest efficiency. One can expect a very insignificant or small spending on maintenance and repair work after getting the primary cost of building the solar system.

4. Results and Discussion

Renewable energy originates from biomass, biofuel, and sunlight, wind, geothermal and moving mass. Solar energy from sunlight represent clean renewable energy with a lower effect on nature and cost less. The power source of solar energy is free, and it is not expensive to install solar array than it does for drilling of oil.

The sun and other sources of renewable energy such as wind, biomass etc. do not varnish with use, as they frequently regenerate. Fossil fuel have a serious influence on the environment as noted across the whole world by the climatologists. It requires a lot of money to extract them from the earth, process them for use and distribute them to the end users. Fossil fuel add Carbon IV oxide, Carbon II Oxide, Ammonia and other greenhouse gases to the air during each one of these stages.

One of the major disadvantages of solar power system is that the sun does not regularly give a steady stream of energy. At night or on cloudy days, the quantity of energy solar system gain is less and removed altogether. This one after the other (in turn) influences the quantity of electricity the system generates throughout those times (cloudy or night). To avoid these disadvantages, landlords can take advantage of various procedures made available for solar energy storage. The various method available varies depending on whether one utilizes or solar heating applications.

For storage of solar power, homeowners produce solar power using a photovoltaic solar power system. Grid Inter-Tie and Battery Banks are the two fundamental techniques of storing energy with a photovoltaic solar power system. Battery Banks are mainly used to achieve 'One-way Solar Power Storage'. A solar battery power saving system is used in a grid-tied photovoltaic system with battery support (back up) and independent (stand-alone) photovoltaic system.

Battery banks, Solar Power system meter, Main DC disconnect and charger controller are the main components of a solar battery power system. Battery banks are set of batteries wired together in order to save energy in electrochemical form. These solar power batteries are like car batteries and it is mainly designed to carry on the type of charging and discharging require in a solar power system. Solar power system meter is mainly used to measure and display the solar photovoltaic system performance and condition. Under main DC disconnect, a DC rated miniature circuit breaker between the solar batteries and the inverter cause the inverter to trip rapidly from the battery bank when in service.

Grid-tied photovoltaic system is another kind of photovoltaic solar power system. With the use of Net-metering which credit solar energy system owners for the electricity contributed to the grid, the photovoltaic solar power system uses the grid as its solar energy saving system. This Net-metering is a billing mechanism that helps when one generates much solar energy and transport it to the utility grid. The meter will then rolls backwards. During the night when the system is not generating any electricity, one can get electric power from the utility grid, then the electric meter will roll forward. This is a method of saving solar electricity using the grid.

For storage of solar heat (thermal), the three major solar heating application comprises of *solar space heating, solar water heating and solar pool heating.* Each of these types solar heating application utilizes its own methods for the storage of sun heat.

Thermal mass and water tank are basic technique mainly used for solar energy storage in solar space heating system. Thermal mass known as *heat mass* has the ability to absorb and store heat during the day and gradually release heat during the night. Heat or thermal mass is applicable to both passive and active liquid systems. Water tank is applicable or used in active liquid systems. The heat transferred from the heat-fluid to the water in the tank is done by a heat exchanger.

Solar water heating system usually make use of water tanks for the storage of solar energy, mainly the active and passive solar water heating systems. The active indirect systems make use of a heat-exchanger to transmit the heat from the heat-transfer fluid. The other solar water heating system (passive) make use of the real domestic water. Therefore, they do not require a water tank with a heat-exchanger.

Solar pool heating system utilizes the natatorium (swimming pool) water for solar energy storage. Circulating swimming pool water via solar pool collectors, it will help to extend one's swimming season.

Solar energy savings for house owners involves solar electricity and solar heating. For solar electricity, it is saved

by utilizing either batteries or the grid, while for solar heating, it is stored by making use of thermal mass, water tanks or swimming pool water.

5. Conclusion and Recommendation

5.1. Conclusion

Rivers State is furnished with many resources like the renewable energy which when appropriately harnessed can strengthen the socio-economic growth of the state. Solar energy solves the problem of very high electricity bills and electricity lost during long-distance transportation as in the case of convectional power while storing the solar energy from the sun with a remarkable advantage of environmental quality, growingly take up as a clean source of energy.

As per the geographical location of Rivers State, Port Harcourt stands to its benefit and has tremendous scope of generating solar energy. In Port Harcourt, solar power caters more than 60-65% of our entire need of power. Thus, we have to follow the future plans of installing large projects in Abuloma, Elelenwo and Trans-Amadi Riverine areas. Apart from the above, we also have to focus on Rooftop Solar Energy Generation that may cut down our need to more than 50% need of every household.

The growing need for solar energy and speedy depletion of convectional resources given rise to a threat to human life and their perseverance. Therefore, utilizing the renewable energy like solar is enough in the world to conserve. A lot of these renewable energy sources are inherently DC in nature. They can be harnessed in their original form with the DC appliances using simple power electronics.

5.2. Recommendation

Solar energy generation in Port Harcourt may be used as a renewable clean energy source. Rivers State must make effort to expand its energy source (with less emphasis on hydroelectric and thermal generation) and invest substantially in research and development on the exploitation of solar and other renewable energy technologies. An immediate decision is needed to be taken by Ministry of Power in Rivers State, as well as the Nigerian Government to implement solar energy production project as an alternative source of power generation to meet the electricity scarcity of the country.

Solar energy production technology should also be taken as pollution diminution as well as greenhouse gas reduction tool in making decision on implementing of solar energy production project in Rivers State and Nigeria at Large.

Limitation of the importation of fossil fuel should be considered in making the viability of the solar energy or solar projects. The state government should provide incentives for renewable energy uptake, develop integrated renewable energy planning and investment, ensure adequate and low-cost capital financing (cost-effectiveness), enhance general understanding of renewable energy, encourage partnership (collaboration) between renewable energy developers and policymakers and enlighten the masses (people) on the use of energy and its cost-effectiveness (efficiency).

References

[1] Agaptus Nwozor, Segun Oshewolo, Oluwaseun Ogundele, (2019), 'Energy Poverty and Environmental Sustainability in Nigeria: A Exploratory Assessment', IOP Conference Series: Earth and Environmental Science 331012033, doi: 10.1088/1755-1315/331/1/012033.

[2] Akorede M. F., Ibrahim O., Amuda S. A., Otuzie A. O., Olufeagba B. J., (2017), Current Status and Outlook of Renewable Energy Development in Nigeria, Nigeria Journal of Technology (NIJOTECH), Vol.36, No.1, January 2017, PP. 196-212.

[3] Chris (2010), 'Component of a Residential Solar Electric System', pp. 1-14.

[4] Emmanuel. P. Agbo, Collins. O. Edet, Thomas. O. Magu, Armstrong. O. Njok, Chris. M. Ekpo, Hitler Louis, (2021).' Solar Energy: A Panacea for the Electricity Generation Crisis in Nigeria', pp 1-21, www.cell.com/heliyon.

[5] Earth and Environmental science 95 (2017) IOP conference series, pp. 7-10.

[6] Kristen H, James C., (2012). Component for your solar panel (photovoltaic) system, pp. 1-18.

[7] Michael. O. D., Atul. K., (2018). Rooftop Solar PV for Urban Residential Buildings of Nigeria: A Preliminary Attempt towards Potential Estimation, Pp. 710.

[8] Mustapha Mukhtar, Sandra Obiora, Nasser Yimen, Zhang Quixin, Olusola Bamisile, Pauline Jidele, Young. I. Irivboje, (2021), 'Effect of Inadequate Electrification on Nigeria's Economic Development and Environmental Sustainability', https://doi.org/10.3390/su13042229.

[9] Ogunjo. S. T., Obafaye. A. A., Rabiu. A. B., (2020), 'Solar Energy Potentials in Different Climatic Zones of Nigeria'; IOP Conf. Series: Material Science and Engineering 1032 (2020) 012040, doi: 10.1088/1757-899x/1032/1/012040.

[10] Osueke C. O., Ezeugwu C. A. K (2011). Study of Nigeria Energy Resources and its Consumption, pp. 15-29.

[11] Rik DeGunther (2016). The Basic component of a home solar power system, pp. 6-17.

[12] Shaaban M., J. O Petinrin (2014). Renewable and Sustainable Energy, pp. 9-20.

[13] Tyagi V. V., Rahim A. A. N, Rahim N. A., Selvaraj J. A. (2013).'Progress in solar PV technology: Research and achievement'. Renewable and Sustainable Energy Reviews 20 (2013), Pp. 5-13.

[14] Uhunmwangho R., Chuks Emu, Kenneth E. Okedu, (2021), 'Assessment of Economic Viability of Wind Power Plant in Bonny Island of Rivers State of Southern Nigeria for Cleaner Electricity Generation', ISSN: 1663-4144, Vol. 53, pp 157-170, https://www.researchgate.net/publication/346733093

[15] Udoka Christopher, Barinyima Nkoi & Felix. E. Oparadike (2019), 'Comparative Analysis on Economic Viability of independent Power Producing System in Nigeria'. EJERS, European Journal of Engineering Research and Science. Vol. 4, No. 1, January 2019. Pp. 75-79.