Scholars Journal of Engineering and Technology
Abbreviated Key Title: Sch J Eng Tech
ISSN 2347-9523 (Print) | ISSN 2321-435X (Online)
Journal homepage: https://saspublishers.com

Potentials of Solar Photovoltaic Generation for Developing Countries

Precious C. Udeh[1]*, Anyaka B.O.[1]

[1]Department of Electrical Engineering, University of Nigeria, Nsukka, Enugu State, Nigeria

DOI: https://doi.org/10.36347/sjet.2025.v13i12.002 | **Received:** 13.08.2025 | **Accepted:** 05.10.2025 | **Published:** 08.12.2025

***Corresponding author:** Precious C. Udeh
Department of Electrical Engineering, University of Nigeria, Nsukka, Enugu State, Nigeria

Abstract **Original Research Article**

Potentials of solar photovoltaic generation for developing countries refer to the capacity or capabilities of harnessing electricity from the sun. Photovoltaic (PV) power generation holds significant potential for developing countries. As energy access, PV systems can provide electricity to remote and off-grid areas where traditional grid infrastructure is lacking, improving energy access for communities. Reduced dependence on fossil fuels, developing countries often rely on costly fossil fuel imports. PV can reduce this dependence, leading to energy security and potential cost savings. Solar power offers multiple benefits: it is clean and renewable, reducing emissions and improving air quality; it creates jobs across the PV industry and supports economic growth in key sectors; it diversifies energy sources to enhance resilience and reduce climate risks; it expands electrification in rural areas, raising living standards; and it contributes to grid stability, helping reduce outages. In this project, an estimation was done of a load used in two different scenarios and sized the components that are suitable going to be used to carry out the project for effective, efficient, and maximal use of the energy from the sun. The method in this project can as well be applied in cases with same or different loads with all considerations made. With an estimation of real-time load data, we compared with proper utilization of the solar output in the form of electricity with the fossil fuel grid supply and observed that, aside from initial cost, with proper utilization and maintenance, the solar electric power generation would be a preferred solution to the unmet power demands in developing countries like Nigeria.

Keywords: Power, Grid, Renewable, Energy, Fossils, Electricity.

INTRODUCTION

Given all various methods of energy production and consumption, all the countries require cheap, large, and clean energy sources [1]. In a world where most energy production comes from non-renewable resources; people are trying to find efficient and price-effective ways to use renewable energy. One of the great leaps in renewable technology has been the solar panel, which is composed of several solar cells that convert light into electricity [2].

Selecting a solar panel with high efficiency helps in the estimation of harvestable incident energy at a particular location for the proper sizing of a photovoltaic system, so as to minimize cost and also to harness the maximum harvestable energy incident at that particular location at any time. Of note, the conventional power generation system which primarily relies on fossil fuels such as coal, natural gas, and oil, has faced continuous failures and shortfalls due to limited resources, as fossil fuels are finite resources that are being depleted at an unsustainable rate. As these resources become scarcer, their extraction becomes more challenging and costlier, leading to energy price volatility and potential supply disruptions [3].

Another limitation is environmental impact because fossil fuel-based power generation is a significant contributor to greenhouse gas emissions, leading to climate change and air pollution. The release of carbon dioxide (CO2), sulfur dioxide (SO2), nitrogen oxides (NOx), and other pollutants from the combustion of fossil fuels has detrimental effects on the environment, human health, and ecosystems [4]. More so, reliance on imports in most developing countries heavily relies on imported fossil fuels, which can create geopolitical and economic vulnerabilities. Dependence on foreign energy sources can lead to political tensions, trade imbalances, and vulnerability to price fluctuations in the global energy market. Also, water consumption as conventional power plants, such as coal and nuclear power plants, require substantial amounts of water for cooling purposes. This can strain local water resources, especially in areas with water scarcity or drought conditions.

Finally, land use and habitat destruction as coal mining and fossil fuel extraction activities can cause habitat destruction, deforestation, and land degradation. Additionally, the construction and operation of large-scale power plants often require vast land areas, impacting ecosystems and wildlife habitats. [5]

MATERIAL AND METHODS

The methods adopted in this research were chosen because they proved to be the best alternative in aiding the realization of the project's objectives and adequately providing the most effective means through which the project's submissions are tested and questions answered. This project is of exploratory research design. This design was adopted considering the project's objective, which is to 'clarify' understanding around Solar PV as an alternative source of clean energy when there is a need to, 'gain new insights, assess phenomena, ask questions and clarify and sustainable energy, and how it works or operates as a system. The exploratory design is used understanding of a problem. The exploratory research design adopts literature review as a means of conducting research, clarifying gaps, boosting knowledge, understanding, and awareness around a specific area or topic. This has been done in the course of producing this project; specific and related literature have been reviewed in coming up with the necessary informative and educative resource.

Study design

The data for this research were qualitative; specific literature in the form of journals, articles, research papers, and publications has been reviewed to obtain the necessary information and data needed to satisfy and fulfill the objectives. The study focuses on rural areas in Nigeria. It is restricted to the potentials and the impact of solar electric generation, the strategies for generating electric energy from the sun hence the data analysis will follow a quantitative plan where we will be looking at a PV design for a 3 bedroom flat while calculating the energy usage, wattage for the solar panels, Battery sizing and sizing of the solar modules, charge controller and battery sizing respectively while determining the sizing of the inverter.

Table 1: A PV design for a 3-bedroom apartment

Appliance	Power Rating	Quantity	Total Power (Watt)	Backup Time (Hr)	Total Energy Demand (Wh)
TV set 65"	120	1	120	8	960
Home theatre	120	1	120	6	720
Digital decoder	40	1	40	8	320
Fridge (300L)	150	1	150	18	2700
Lighting points	14	15	210	5	1050
Miscellaneous	30	1	30	3	90
Total instantaneous power			**670**		**5840**

Total energy demand (Wh) = 20% of 5840 = 1168 1168 + 5840 = 7008Wh (This is done and added by recommendation because of system losses)

Sizing of the solar modules:

Average Sunshine hours in a day = 6

Total Wattage of PV module = Total Energy Demand ÷ 6 =7008 ÷ 6 = 1168W

This implies use of 6 panels each of a 200W rating = 6 × 200 = 1200W

Sizing of the inverter:

To size the inverter, we assume an extreme case scenario here which means we assume all the loads or appliances are running at the same time. We want the inverter to be able to power all the appliances at the same time though not in reality because at some time some appliances are not in use. Because of the fact that inverters have losses and a degree of efficiency too, we check the manufacturers' inverter converting efficiency also by recommendation we can use 50% as the inverter efficiency. Size of inverter = Total power÷0.5 = 670 ÷ 0.5 = 1340W (Available 1500W

Sizing of the Battery:

Factors that determine the battery size are: Total energy demand = 7008Wh Battery losses, usually most batteries has a 15% loss. This means we have a battery efficiency of 85% Depth of discharge: we don't want the battery to always drain or discharge to zero (40% is recommended) this implies we have 60% to calculate the size of the battery bank needed.

Nominal Battery voltage = 12V Days of Autonomy: days of tolerance when there will be no sunshine, the weather is cloudy or on rainy days. This also implies number of days required for uninterrupted power supply without getting sunshine after the battery is fully charged, we assume this to be a day or 2 days Battery size =Total energy demand × days of autonomy / Battery efficiency × depth of discharge factor × Nominal battery voltage = 7008 × 1÷(0.85 × 0.6 × 12) = 1145Ah We will be using 6 batteries of 200Ah rating per one = 6 × 200 = 1200Ah

Sizing of the charge controller:

According to standard practice the sizing of a solar charge controller is to take the short circuit current of the PV array, add 30% of the short circuit current which is basically multiplying a constant 1.3 then multiply number of strings or parallel paths. Solar charge controller = $I_{sc} \times 1.3 \times$ number of strings A string is an arrangement of modules connected in series. Here we have 6 panels connected 3 each in series making up 2 strings = $7.5 \times 1.3 \times 2 = 19.5A$ (we use 20A that is the rating available in the market).

RESULTS

The project carried out the selection of the most efficient solar panel, which was chosen to be a monocrystalline solar panel. The total estimated power was 670W and the total energy demand was 7008Wh. We used 6 solar panels each 200W, amounting to a total of 1200W panels. An inverter size of 1500W, 6 batteries of 200Ah rating one resulting in a total size of 1200Ah. And a charge controller Pulse width modulation (PWM) type, though the Maximum Power Point Tracking (MPPT) is better because this type of charger helps to get the optimum charging power for any given point of time and offers better efficiency than PWM. Though the MPPT charge controllers enable you to have better efficiencies and provides more power than compared to PWM for similar condition, the main cause of not opting for MPPT is for the sake of cost optimization. MPPT charge controllers are more expensive than PWM controllers. Keeping this parameter in mind, this project will be using a PWM charge controller to realize the concept. To select the size of the charge controller, one must know the voltage level of the system and the maximum operating current. It is a usual practice to oversize the controller for safety reasons.

Though off grid solar poor generation on the onset is expensive but compared to the running cost and its efficiency it has a higher advantage over the grid supply. Looking at the total demand for the appliances per day, the grid would, in rare cases, or will not be able to efficiently sustain these loads for the number of hours they are required to be operated, and when needed due to epileptic power generation and distribution in Nigeria. Likewise, the clean and green nature of the generation using solar cannot be matched to the fossil or nuclear fuel effects in regards to pollution.

Table 2: Cost analysis

Items	Quantity	Estimated Cost (Naira)
200W solar panel	6	30,000 × 6 = 180,000
1500W inverter	1	60,000
200Ah, 12V Battery	6	235,000 × 6 = 1,410,000
20A charge controller	1	8000
Total		**1,658,000**

DISCUSSION

Solar power is an immense source of directly useable energy and ultimately creates other energy resources: biomass, wind, hydro power, and wave energy. Most of the Earth's surface receives sufficient solar energy to permit low-grade heating of water and buildings, although there are large variations with latitude and season. At low latitudes, simple mirror devices can concentrate solar energy sufficiently for cooking and even for driving steam turbines. The energy of light shifts electrons in some semiconducting materials. This photovoltaic effect is capable of large-scale electricity generation. However, the present low efficiency of solar PV cells demand very large areas to supply electricity demands. Direct use of solar energy is the only renewable means capable of ultimately supplanting current global energy supply from nonrenewable sources, but at the expense of a land area of at least half a million km².

Technical analysis considerations when sizing a photovoltaic (PV) system

Below are some considerations when sizing a PV System;

Energy Consumption: Determine the amount of electricity the system needs to generate based on the household or facility's energy consumption patterns. This involves examining historical energy bills and load profiles. Solar Irradiance: Assess the amount of sunlight the location receives throughout the year. Solar irradiance data helps estimate the potential energy output of the PV system. Panel Efficiency: Consider the efficiency of the PV panels in converting sunlight into electricity. Higher efficiency panels generally produce more power within a limited space. Orientation and Tilt: Determine the optimal orientation (south-facing in the northern hemisphere) and tilt angle of the PV panels to maximize energy production throughout the year. Shading Analysis: Identify potential shading sources such as nearby buildings, trees, or structures that could obstruct sunlight and reduce system efficiency. Tools like shade analysis software or hardware can help assess shading impact. Inverter Capacity: Select an appropriate inverter capacity that matches the expected output of the PV panels. Oversizing or under sizing the inverter can impact system performance. Battery Storage: If the system includes battery storage, assess the required battery capacity based on the desired energy autonomy and load-shifting capabilities. Climate and Temperature: Account for temperature variations and climate conditions that might affect panel performance. High temperatures can reduce panel efficiency. System Longevity and Maintenance: Factor in the expected lifespan of the components and the maintenance requirements to ensure the system's long-term viability. Financial Considerations: Analyze the return on investment, payback period, and overall cost-effectiveness of the system. This involves considering initial installation costs, incentives, tax credits, and potential energy savings. Load Profile Matching: Ensure that the PV system's energy production aligns with the building's energy consumption patterns to maximize self-consumption and minimize grid dependency.

By conducting a comprehensive analysis that takes these factors into account, one can size a PV system that meets energy requirements efficiently and effectively. It's often a balance between maximizing energy production and optimizing the system's overall performance and cost.

CONCLUSION

This project sets out to stimulate understanding and knowledge around Solar PV, as a critical arm of renewable energy. Emphasis was made on expatriating its concept, processes, and components, and how these put together, enable the clean generation of electric power as a viable alternative to fossil or nuclear fuel. The objective of the research is premised on the hypothesis that there is a gap driven by a relative dearth of literature disseminating basic knowledge around the topic area, i.e., a preponderant number of literatures inadvertently focus on technicalities, technologies, and other advanced and complex aspects of Solar PV.

There is a cost associated with electrifying houses in rural areas that increases with the distance between the grid and the houses. In such instances where the cost of electrification becomes enormously high one can always use an off-grid PV system. Both type of systems viz. grid-tied and off-grid PV systems have their own advantages and disadvantages. Depending solely on the need, one can decide what they would want to go for. One trend that one can observe is that the grid-tied system is mostly found in urban and suburban settings where electrification of the area has already been achieved. The off-grid system is more suited to areas where the electrification is yet to be accomplished and/or the consumer chooses not to supply back the energy generated at his/her end.

ACKNOWLEDGMENTS

I must acknowledge the assistance and resilient support from my colleagues in same department that answered most of my curiosities. Much of my appreciation goes to my parents for giving me enthusiasm, encouragement, and invaluable assistance to ensure that i had the time and energy to accomplish this work. This acknowledgement will not be complete without including herein my deepest gratitude to Almighty God, who in His great mercy sustains us in all that is good.

REFERENCES

1. V. Arı. Energy sources, energy planning and energy strategies of Turkey [M.S. thesis], Department of Mining Engineering, Institute of Natural and Applied Sciences. University of Cukurova, Adana, Turkey. 2007.
2. B.C Howard. The Evolution of Solar Technology. Retrieved from https://blog.nationalgeographic.org:https://blog.nationalgeographic.org/2012/05/30/theevolution-of-solar-technology/ [Assessed:19August 2023].
3. G. Adewale, A. Adetunji, Y. Ahmed, T. Olukan A Comprehensive Review on Biomass and Solar Energy for Sustainable Energy Generation in Nigeria. Renewable & Sustainable Energy b Reviews, 69, 620-641; 2017. https://doi.org/10.1016/j.rser.2016.11.1600
4. H. Gujba, Y. Mulugetta, A. Azapagic Environmental and Economic Appraisal of Power Generation Capacity Expansion Plan in Nigeria. Energy Policy, 38, 5636-5652. 2010. https://doi.org/10.1016/j.enpol.2010.05.011
5. K. Shahzad, B. Thomos An Ecological Feasibility Study for Developing Sustainable Street Lighting System Kingdom of Saudi Arabia. Journal of CleanerProduction,175,683-695. 2018.https://doi.org/10.1016/j.jclepro.2017.12.057
6. M, Boxwell Solar Electricity Handbook - 2018 Edition: A Simple, Practical Guide to Solar Energy - Designing and Installing Solar Photovoltaic Systems. Coventry: Green stream Publishing. 2018. Ehsanul Kabir “Solar energy: potential and future prospects”, Article in renewable and sustainable energy reviews, 894-900.2017.
7. Okoye 'Solar PV: Investigating the Gap in Renewable Energy Policy Formulation and Implementation in Nigeria'. Advances in Social Sciences Research Journal. Vol. 5. No. 5.Pp 398 - 412. 2018.
   B. Seger Global Energy Consumption: The Numbers for Now and in the Future. 2016, September 23. Retrieved from LinkedIn: https://www.linkedin.com/pulse/global-energy consumption-numbers-now-future brian-seger/
8. Vera, L. Langlois. Energy indicators for sustainable development. Energy, 32(6), 875-882. 2007. doi: http://dx.doi.org/10.1016/j.energy.2006.08.00
9. E. Franklin Solar Photovoltaic (PV) Site Assessment.2017, August Retrieved from Cooperative extention: https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1697-2017.pdf
10. M. Shabaan, J. O. Petinrin Renewable energy potentials in Nigeria: Meeting rural energy needs. Renewable and Sustainable Energy Reviews, 29, 72 – 78. 2014.
11. Vasseur, R. Kemp The adoption of PV in the Netherlands: A statistical analysis of adoption factors. Renewable & Sustainable Energy Reviews, 41, 483-494. 2015.
12. M. Patil, Deepak Santosh R Madiwal “Design and development of solar tree for domestic applications”, ENDNOTE, ISSN: 2277-9655. 2010.

13. The Guardian Time to shine: Solar Power is fastest - growing source of new energy. Retrieved from https://www.theguardian.com/environment/2017/oct/04/solarpowerrenewables-international-energy-agency.
    Sara Jo Viraldo, V. Shiga "Is solar power a cost-effective energy alternative to traditional energy? A benefit-cost analysis on taylor country solar facility in Georgia", Vol-6, spring 2016.
14. Moses, Emetere: "A simple technique for sustaining solar energy production in active convective coastal region", International Journal of Photo energy, Volume 2016, Article ID3567502, 11 Pages.
    Shubojit Dawn, Prashant Tiwari, Arup Kumar Goswamy, Manash Mishra: "Recent development of solar energy in India: Perspectives, Strategies and Goals", Renewable and Sustainable Energy Review, 215-235. 2016. JayminGajjar: "Solar PV energy generation map of Karnataka India", smart grid renewable energy, No-6, 333-342. 2015.
15. Gango: "Wind and solar energy for reducing electricity deficits", Current Science Col-111, No-5, 10 Sep-2016.
16. K. Ajao, O. Oladosu, O. Popoola Using HOMER power optimization software for cost benefit analysis of hybrid-solar power generation relative to utility cost in Nigeria. International Journal of Research and Reviews in Applied Sciences, 7(1), 14. 2011.
17. Oparaku Photovoltaic systems for distributed power supply in Nigeria. Renewable Energy, 25(1), 31-40. 2002.
    U. S. Akpan, S. R. Isihak, Y.-O. N. Udoakah Electricity access in Nigeria: Viability of offgrid photovoltaic system. Paper presented at the AFRICON.