The Need for Solar Power Energy Utilization in the Northern Part of Nigeria for Sustainability and Economic Growth (A case study of Nigeria)

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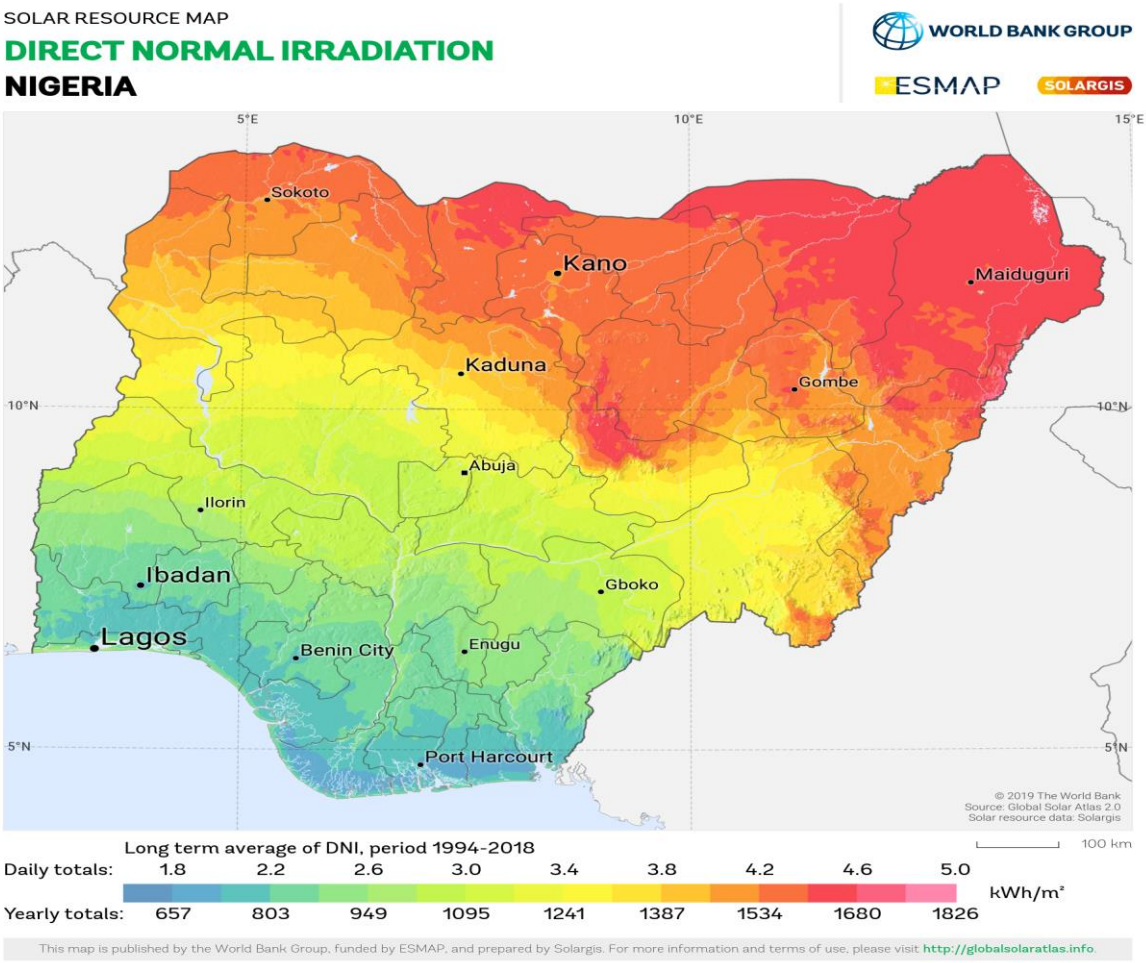
Abstract: Northern Nigeria is one of the most recognizable areas, having vast amounts of solar radiation and rapidly growing populations. Thus, there is an opportunistic aspect of the use of solar power in this region. Since this region enjoys all-year sunshine, it is one of the best places for the integration of solar energy. With huge problems of energy she presently faces such as irregular supply of electricity, people's growth and thus demand, solar power presents an immediate usable, reliable, and sustainable solution. The energy demand in northern Nigeria is expected to sharply increase from about 48 billion kWh in 2024 to 64.5 billion kWh by 2034. This escalated energy requirement directly puts a demand for an efficient and sustainable source of energy, and as such, the promise of steady and renewable energy supply through solar power makes it very appealing. The average regional solar radiation exceeds 6 kWh/m² per day, which points towards a very vast potential for solar energy generation. But to meet the energy requirements that will arise in the future from solar, it would call for a tremendous investment in infrastructure. This is because it is estimated that approximately 246,000 km² of solar panels might be needed by 2034 in order to be able to cover the energy needs of the country. However, this massive area is required, but the benefits of solar energy do not stop there at solving shortages of energy. Solar power would increase economic activities due to job creation, stimulation of local industries, and the end reliance on fossil fuels. It has implications on environmental sustainability as it reduces greenhouse gas emissions and promotes cleaner practices of energy consumption. Northern Nigeria will unlock a stable and reliable source of power through investment in this infrastructure. This is important for economic development, thereby eventually improving the quality of life. Indeed, the integration of solar power addresses the immediate needs of satisfying energy challenges but builds a foundation for sustainable growth and environmental stewardship over the long term. Solar power in northern Nigeria is important for ensuring future demands for energy and significant economic development while emphasizing sustainability within the environment. A lot still has to be tapped into by tapping into the solar resources that are available.

Key words: Solar Energy,Sustainability,Economic Growth,Energy Demand,Renewable Resources

Introduction:

Nigeria is the African continent's most populous country and one of the largest economies facing a critical energy challenge affecting its overall development and quality of life[1]. In the context of a rapidly growing population and expanding industrial sector, this need has never been as acute[2]At present, the energy supply pattern in Nigeria is dominated by fossil fuels with the vast majority of people not having electricity at regular intervals. This is still more pronounced in the north with significantly lesser development of energy infrastructure compared to its southern counterpart. North Nigeria has arid and semi-arid climate conditions and is characterized by constant power cuts and poor supply mainly due to the outmoded infrastructure and over-reliance on diesel generators[3]. Apart from crippling economic activities, power cuts also contribute to environmental challenges since diesel generators emit effluents into the environment and result in greenhouse gasses[4]. In that respect, it seems to be a quite viable option in terms of producing power with solar energy. Northern Nigeria, due to its high irradiance level, provides a suitable area in which to tap into the store of solar power. As a source of non-conventional energy, the issue of accessing power and issues of the environment is dealt with in a completely sustainable and friendly manner[5]. It could transform the energy scenario of northern Nigeria, fuel economic growth, and contribute towards a more sustainable future if it were to tap into this enormous solar potential[6]. This explores the urgent need to utilize solar power energy in northern Nigeria now. This involves an overview of the current energy situation, benefits associated with solar power, problems inhibiting its implementation, and strategies that can popularize its diffusion. In this comprehensive analysis, I strive to show how solar energy can literally function as a catalyst for sustainability and economic development in one of Nigeria's most underserved regions. Northern Nigeria is characterized by expansive land, high solar radiation, and severe energy challenges. The region has a semi-arid climate with prevalent sunshine amounting to more than 6 kWh/m2 per day, which gives the high potential for the use of solar energy[7]. Despite such natural advantageous conditions in terms of utilizable solar energy, the region experiences extreme inadequacies of energy mainly owing to poor infrastructural provision and reliance on unreliable power sources. The interrupted power supply causes this loss of steady electricity in most places. Energy Challenges, the energy sector places an enormous burden on northern Nigeria to serve an exponentially large population. By 2024, the region will demand 48 billion kWh of energy. That amount is expected to rise to 64.5 billion kWh by 2034, this reflects populations with increased activities in the region. The current energy infrastructure has not been well prepared for such growth and thus there are always power outages and limited access to electricity for many of the residents. The dependency on fossil fuels by more people and lack of a clear strategy on energy further worsen the energy crisis. Additionally, the environmental implications of most conventional sources of energy, which feature high levels of greenhouse gas emission and ecological degradation, underscore the urgency of changing energy solutions[8]. Significance of Solar Energy is a good substitute for the energy challenges of northern Nigeria[9]. The northern region of Nigeria is blessed with high solar radiance that has been shown to be friendly for solar power projects. However, the benefits of solar energy are not only in its renewability and abundance but also in providing an environmentally cleaner source of energy compared to fossil fuel, It can reduce the level of greenhouse gasses that would otherwise be emitted with this result, reducing dependence on the use of nonrenewable sources, and more stable and reliable power supply[10]. Investments in solar energy spur economic growth through the creation of new job opportunities, local industries growth, as well as improving quality of life. Moreover, it is consistent with global sustainability goals besides promoting environmental conservation [11]. The use of solar power can complement traditional sources because it can be dovetailed into existing infrastructures hence making energy security generally better[12]. Objectives of the this paper shall achieve the following ends; analyze the current and future energy demands of northern Nigeria, assess the potential contribution of solar power to fulfilling those needs, analyze infrastructure requirements of employing solar power, and also describe the advantages of solar energy towards sustainability as well as economic development, formulate policy recommendations to facilitate the implementation of solar power.

Significance of the study area, is understanding the northern Nigeria solar potential is critical to relieving the energy challenges within the region. This aims at providing insight into how renewable energy can effectively support sustainable development and economic progress in the region by expounding on the potential feasibility of developing solar power projects in the region.This findings will be useful to policymakers, investors, and various stakeholders interested in clean energy solutions and better access to energy in this region.



(A MAP STUDY AREA (NORTHERN NIGERIA) A CASE STUDY)

Literature Review

Global Solar Energy Trends as a few decades have passed, with the industry experiencing significant growth. On one hand, improvement in efficiency with cost reduction has dominated solar power technology. According to the International Energy Agency, installed global solar photovoltaic capacity has risen sharply due to technological innovation, strong policy support, and environmental concerns. As a result, the levelized cost of solar electricity has reduced and, therefore, has become competitive with traditional sources of energy. Studies performed by the National Renewable Energy Laboratory (NREL) present the case that solar energy has been one of the most rapidly rising sources of renewable energy in the world. Improved designs of solar panels using new-generation thin-film and bifacial solar cells improve efficiency while reducing installation costs. The ability of solar energy to provide clean and renewable power has placed it at the core of efforts to establish a sustainable energy system globally. Regional Energy Challenges

Northern Nigeria is renowned for facing substantial energy setbacks that have hindered the region's economic and quality-of-life development. The power structure in the region is not only old but, most importantly, is sufficient with a host of recurrent outages and supply interruptions to the grid. Reports by the Energy Commission of Nigeria reveal that demand has outstripped supply due to old power plants, scanty networks, and inefficiency in energy supply. It has ensured dependence on fossil fuels, which only worsens the energy crisis, correlates to high greenhouse gas emissions and results in degrading environmental conditions. According to the U.S. Energy Information Administration (EIA), the region of northern Nigeria depends highly on imported oil and gas for energy, further straining regional economic resources. Again, this energy deficit stretches into critical sectors like health, education, and industry, limiting general socio-economic development. Northern Nigeria Solar Potential The north of Nigeria has tremendous solar potential as the region receives very high levels of solar radiation. According to the NASA Surface Meteorology and Solar Energy (SSE) project, in this region, the average level of solar radiation above 6 kWh/m2 per day on an annual basis is received. Therefore, it has a very good potential for the production of solar energy. Most of the studies carried out by the NiMET reveal the same trend. Northern Nigeria has some of the highest solar energy potentials in Africa. Several attempts have been made to establish the feasibility of solar energy in the region. For instance, a report from the World Bank stresses that large-scale solar installations could go a long way toward considerably fulfilling the energy requirements in the region. The findings would indicate that the deployment of solar power can improve energy shortage problems and make electricity a reliable source. Additionally, studies from the National Renewable Energy Laboratory reveal that income generation with the implementation of solar energy increases economic output. The use of solar energy reduces reliance on fossil fuels hence cutting down unnecessary reliance on other forms of energy. On that basis, IRENA has published various reports on a recount of successful solar projects in other African countries, thus giving the ideas on best practices and lessons learned. The report indicates key areas that foster adoption of solar energy, which include supportive policies, financial incentives, and local capacity building. In northern Nigeria, specific inhibition factors have been researched by local universities and institutions, among them are the high upfront investment, lack of infrastructure, and low technical capacity. All these need to be overcome for any successful solar power project. Thirdly, community participation and public-private partnership are elements that can fortify the effectiveness of the solar energy schemes.The literature review draws attention to the global developments in solar technology, the significant energy challenges that face northern Nigeria, and the significant potential of solar resources in the region. It underpins the earlier studies on the adoption of solar energy and also lays a basis for understanding the feasibility and benefits of solar power in meeting the needs of energy in the region. It consequently informs the subsequent analysis and discussion of solutions with regard to solar energy in northern Nigeria.

Methodology:

Data Collection

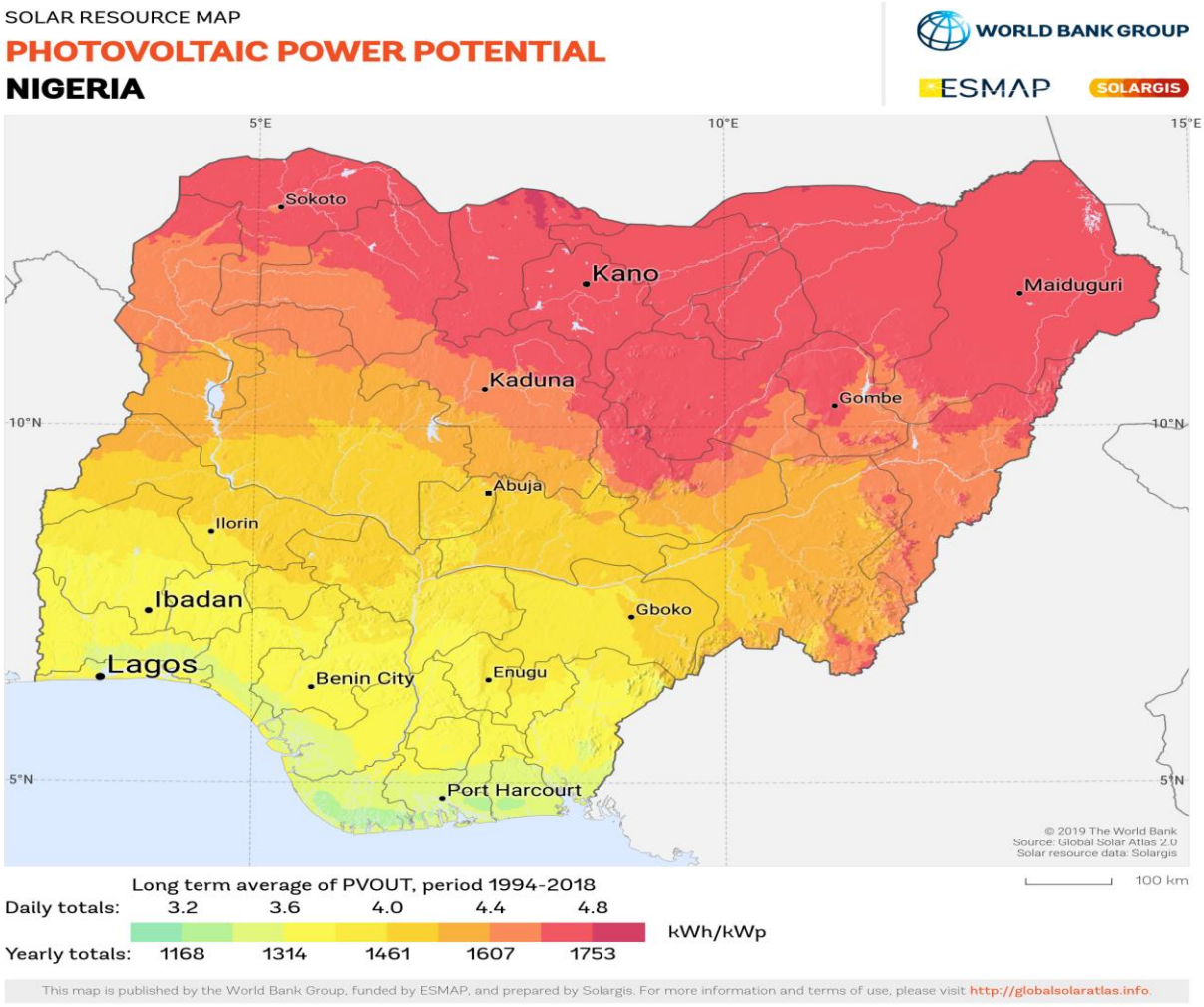
To assess the potential of solar energy in northern Nigeria, various data sources were utilized:

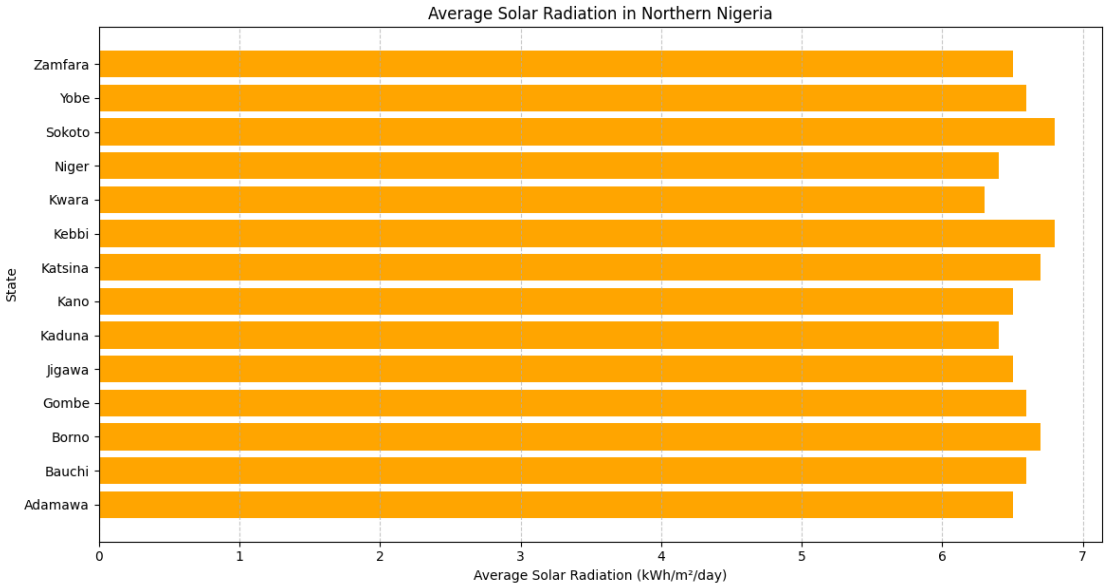
Solar Radiation Data: The solar radiation data was taken from NASA's SSE project, which provides measurements of the regions' solar irradiance. This is necessary in order to approximate the solar energy potential in northern Nigeria and to determine the feasibility of various solar power projects in the area.

Energy Demand Projections: Reports of the International Energy Agency and the Energy Commission of Nigeria were relied upon for the energy demand data and projections. This, therefore, gives the information that points to current actual consumption figures as well as future forecasts of demand. Such information would be basic in forming the foundation for this study into the regional energy requirements; such information is required to establish an understanding of the region.

Population Data: Population statistics was obtained from the World Bank and the United Nations Department of Economic and Social Affairs, UNDESA. This will be crucial in describing population growth and its nexus with energy demand, which has a very significant bearing on future energy requirements in northern Nigeria.

***Infrastructure Data*:** Information about energy infrastructure and available sites for erecting a solar installation was obtained from the reports of local governments and studies done by the energy sector. Those data include current structures for energy facilities, energy transmission networks, and areas having high potential for solar energy sources.





Solar energy radiation in northern Nigeria states.

Data Source: NASA Surface Meteorology and Solar Energy (SSE), 2023

Analytical Methods

The base and peak energy demands of current as well as the projected demand are analyzed statistically to understand the growth trends and future demands. Energy consumption patterns are thoroughly evaluated based on historical data, demographic changes, and other aspects. Future energy needs have been estimated using forecasting models that consider growth in population, urbanization, and economic development. Assessment of Northern Nigeria's solar potential was determined from NASA's available solar radiation data. This comprised the computation of average daily solar irradiation, together with computation of the potential energy harvested through solar panels. Assessment was done on the different types of solar technologies, such as PV and CSP that could best fit the area. The land area needed for solar panels was computed with projected energy demand and discussed with an estimate of the infrastructure needed to deploy solar power into the market. It was calculated considering that it requires a certain amount of land area relative to the efficiency of the solar panel and the amount of available solar radiation. Infrastructure needs include energy storage, integration into the grid, and maintenance. Economic and Environmental Impact, economic benefits of solar energy were measured by assessing the jobs created, investment opportunities it would provide, as well as economic development. The impacts concerning a decrease in greenhouse gas emission and more ecological benefits were also determined. Cost-benefit analysis was used in the investment of solar energy against benefits as well.

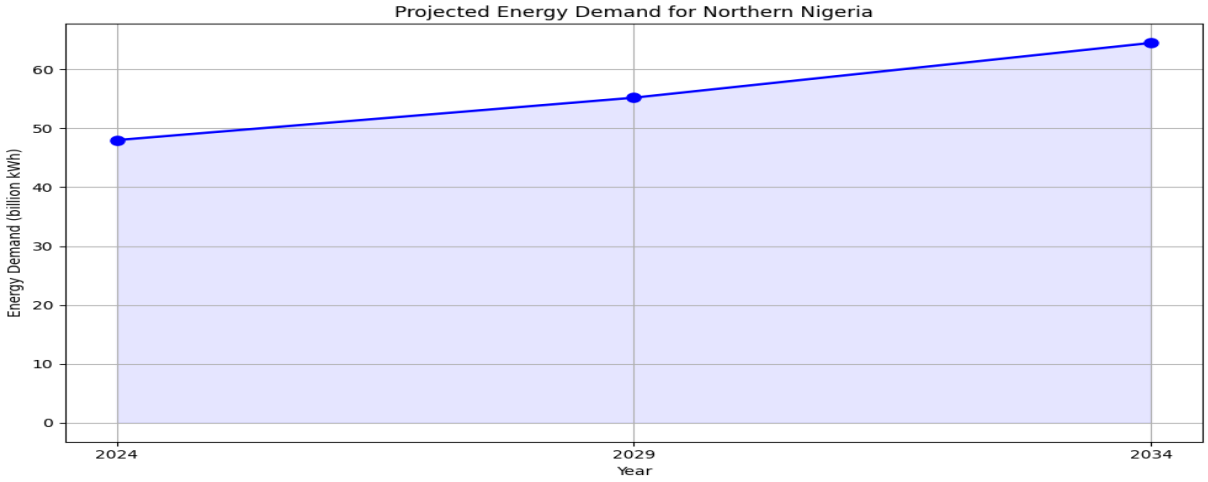
Several assumptions were made during the analysis: ***The efficiency:*** Average efficiency rates for solar panels were assumed based on the current technology used. This will influence the calculation of the required area for solar installations. ***Energy Storage:*** Energy storage solutions have been assumed to be integrated with these systems to counter the intermittency problem and deliver a reliable power supply at all times. ***Economic Factors:*** The future economic conditions of the project are maintained at constant inflation rates and investment costs. Any variation in these factors could affect the feasibility of the project for utilizing solar energy. ***Policy Environment:*** A good policy

environment is assumed to exist in the government policies wherein support and incentives would have been built by the government to encourage renewable source development. Changes in policy could adversely affect the initiatives for the implementation of the solar power projects.

Limitations: ***Data Accuracy:*** The data on solar radiation and energy demand projections may not be accurate and thus may influence the reliability of the result. ***Infrastructure constraints:*** The project implementing solar energy may be constrained by the availability of an otherwise feasible area and extant infrastructure. ***Future Uncertainties:*** The analysis is based on further changes in technology, economic conditions, and policies of the government. The methodology of research applied in this study will therefore give an all-inclusive approach for an appraisal of the potential of solar energy utilization in northern Nigeria. Through the adoption of several sources of data and various kinds of analytical methods, the research shows the feasibility of solar power projects in the region and their impacts on sustainability and economic growth.

Results

Current Energy Demand: the recent estimates of statistics report the energy needed in 2024 for the northern region of Nigeria will be about 48 billion kWh. Energy demand is very much driven in a region that is highly populated and booming in many economic activities and fast-growing urbanization. However, the energy sector cannot easily keep pace with this demand, which in turn often raises power outages and insecurity. These should indicate population density, industrial activities, and seasonally periodic changes. Major cities and industrial centers have more significant energy requirements than rural areas. The level of energy demand at such urbanized centers and industrial centers makes it impossible to meet all the needs of the current energy infrastructure, which is heavily based on fossil fuels, leading to deficit levels of energy supply and subsequently causing economic distress.



Simulated energy demand for northern Nigeria.

Data Source: International Energy Agency (IEA) and Energy Commission of Nigeria, 2023

Solar Radiation and Energy Needs For northern nigeria

NOTE: (*THE TEXT MATH SOFTWARE WAS USED FOR THE WRITING OF CALCULATIONS, ACCURACY AND FORMULAS*)

Solar Radiation Data: Northern Nigeria receives high solar radiation, with an average of about **5.5 *to* 7.0 *kWh/m²/day*.** *For estimation, we'll use an average value of* **6.0 *kWh/m²/day*.**

Energy Consumption Data

- *Northern Nigeria Population Estimate* (2024) = 40 *million.*
- *Total Energy Consumption (per capita): Assuming an average of* 100 *kWh/person/month (as a rough estimate for developing regions).*
- *Energy Consumption Calculation for Annual Energy Consumption: Annual Energy Consumption (kWh)=**Population×Monthly Consumption*×12.**

Energy Consumption For Northern Nigeria:

- *Annual Energy Consumption=***40,000,000** *people×***100** *kWh/person/month×***12 .**
- *Annual Energy Consumption=***48,000,000,000** *kWh/year.*

Solar Energy Production Calculation

Solar Panel Efficiency and Capacity: Assume an average solar panel efficiency of **15%** *and a system capacity factor of* **0.8** *(considering losses and variations).*

- *Solar radiation average*: **6.0 *kWh/m²/day*.**
- *Daily solar energy production per square meter*: **6.0 *kWh*×0.15×0.8=0.72** *kWh/m²/day.*
- *Annual solar energy production per square meter*: **0.72 *kWh/m²/day*×365 *days*=262.8** *kWh/m²/year.*

Total Area Needed Solar Energy Production

- *Total Area Needed=**Annual Energy Consumption / Annual Solar Energy Production per m²***
- *Total Area Needed=***48,000,000,000** *kWh* **/ 262.8** *kWh/m²/year*
- *Total Area Needed=***182,357,687** *m²*
- *Total Area Needed≈***1823** *km²*

***Therefore Northern Nigeria*:** *Approximately* **1,823** *km² of solar panels needed to meet the annual energy consumption.*

Solar Radiation and Energy Needs For the whole nigeria

The current estimate for the population of Nigeria is about 223 million. These are projections and information obtained from different sources, among which are the National Population Commission of Nigeria and international databases such as the United Nations and World Bank.

Here's a detailed calculation using this population figure, considering the average data for energy consumption and solar power needs;

Energy Consumption CalculationFor the whole nigeria

- **Assumptions**: *Average Energy Consumption per Person*: **100** *kWh/person/month Number of Months*: **12**

Total Annual Energy Consumption for Nigeria

- *Annual Energy Consumption*=***Population* × *Monthly Consumption* × 1.**
- *Annual Energy Consumption*=**223,000,000** *people* × **100** *kWh/person/month* × **12.**
- *Annual Energy Consumption*=**267,600,000,000** *kWh/year*.

Solar Energy Production Calculation Assumptions

- *Average Solar Radiation*: **6.0** $kWh/m^2/day$.
- *Solar Panel Efficiency*: **15**%.
- *System Capacity Factor*: **0.8** (*considering losses and variations*).

Daily Solar Energy Production per Square Meter

- *Daily Solar Energy Production*= **6.0** $kWh/m^2/day$×**0.15×0.8 .**
- *Daily Solar Energy Production*= **0.72** $kWh/m^2/day$.

Annual Solar Energy Production per Square Meter

- *Annual Solar Energy Production*=**0.72** $kWh/m^2/day$×**365** *days*.
- *Annual Solar Energy Production*=**262.8** $kWh/m^2/year$

***Total Area Needed for Nigeria* Solar Panels :**

- *Total Area Needed*=***Annual Energy Consumption/Annual Solar Energy Production per* m^2**
- *Total Area Needed*=**267,600,000,000** *kWh/* **262.8** $kWh/m^2/year$
- *Total Area Needed*≈**1,018,563,809** m^2
- *Total Area Needed*≈**1,019,000** km^2

Therefore:

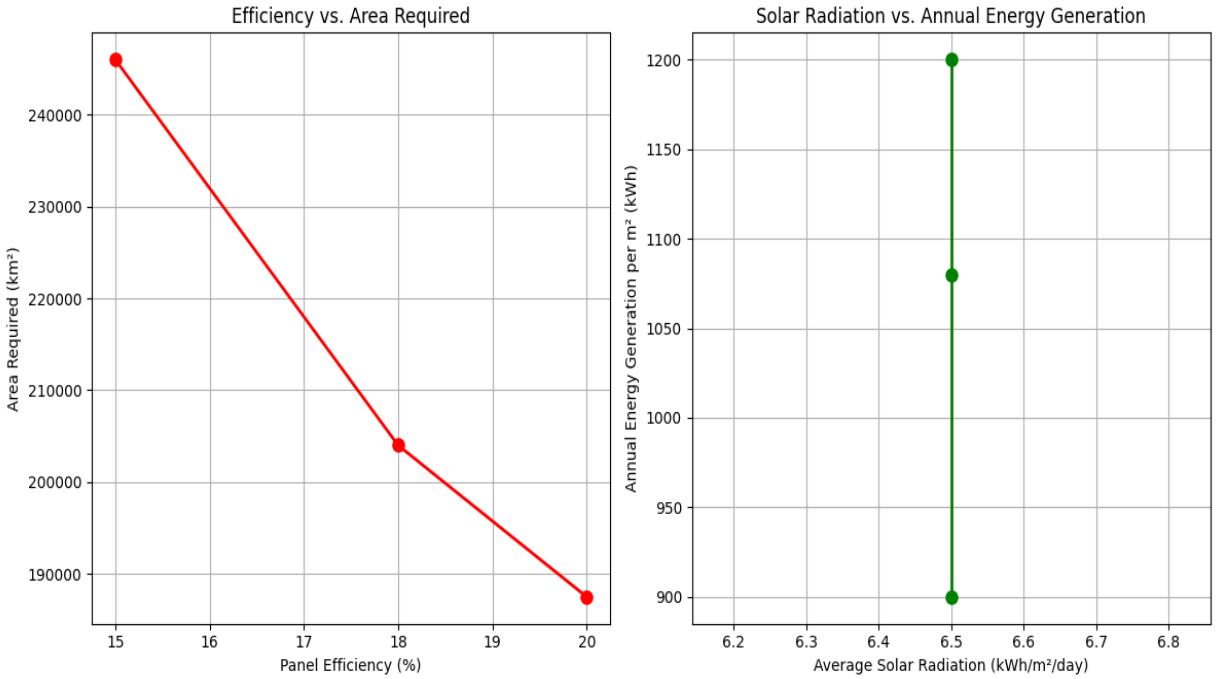
- *Current Population of Nigeria* (2024 *Estimate*): ***Approximately* 223 *million***
- *Annual Energy Consumption*: ***Approximately* 267.6 *billion kWh***
- *Total Area Needed for Solar Panels*: ***Approximately* 1,019,000 km^2**

Future Energy Needs:

Projections indicate that energy demand in northern Nigeria will increase tremendously in 2034. The estimated future demand will be about 64.5 billion kWh, including population growth, more economic activities, and expanded urban areas. In this sense, high intensity in increased demand for energy serves as an imperative for renewable, steady, and available sources. Future energy demands would depend on factors such as population growth- increased population with larger residential needs in terms of energy, economic growth, industrial and commercial activities increase, and more energy is consumed. Urbanization-eExpansion in the urban areas together with improvements in infrastructure requires additional energy. Analysis of Solar Potential Northern Nigeria has vast solar potential with average solar radiation over 6 kWh/m² per day. Accordingly, this region is quite favorable for solar energy projects as there is high irradiance. As outlined by the analysis, this amount of solar potential can significantly support regional needs in terms of energy supply. Some major findings are energy generation potential, it is estimated that the available northern Nigeria would generate considerable energy through solar power under average solar radiation combined with efficiencies of the current technologies of solar technologies. Therefore, for instance, taking average efficiency at 15%, one square meter of solar panels would be capable of generating about 900 kWh per year. For Solar Panel installation, considering the projection for 64.5 billion kWh energy in 2034, about 246,000 km² of land would be required to install solar panels. In the above calculation, there are considerations of panel efficiency, sunlight availability, and energy conversion rates. The aggregate area of the land to be occupied by solar farms will depend on the projected demand for energy as well as the efficiency of the solar panels. For energy reliability, the power system requires energy storage solutions, such as batteries, to store excess energy generated during periods of peak sunlight. These systems will supplement power during intervals of low sunlight or high demand. The integration of gargantuan solar-generated electricity requires an improved power grid infrastructure for carrying the new variable and integrated solar power. This includes better transmission and distribution networks to handle excess variability and integration of solar power. Economic Benefits, the infrastructure of solar energy will create employment opportunities at the manufacturing, installation, and later maintenance end. Similarly, this will stimulate the growth of local industries and attract investment, thus developing the economy. The analysis shows the potential to provide employment and effects on the economy comparable to other solar ventures in other parts of the world. Environmental benefits- solar energy has the advantage of minimizing greenhouse gas emission and environmental degradation as compared to fossil fuels. Northern Nigeria can, therefore, reduce their carbon footprint if they transition to solar power and thus contribute to mitigating global climate change.

Population Data Relevant to Solar Power Needs

Region	Population (2024 Estimate)	Percentage Lacking Reliable Electricity	Primary Energy Source
Northern nigeria	40 million	60-75%	Diesel generators, Biomass
Nigeria overall	223 million	50%	Grid power, Diesel generators

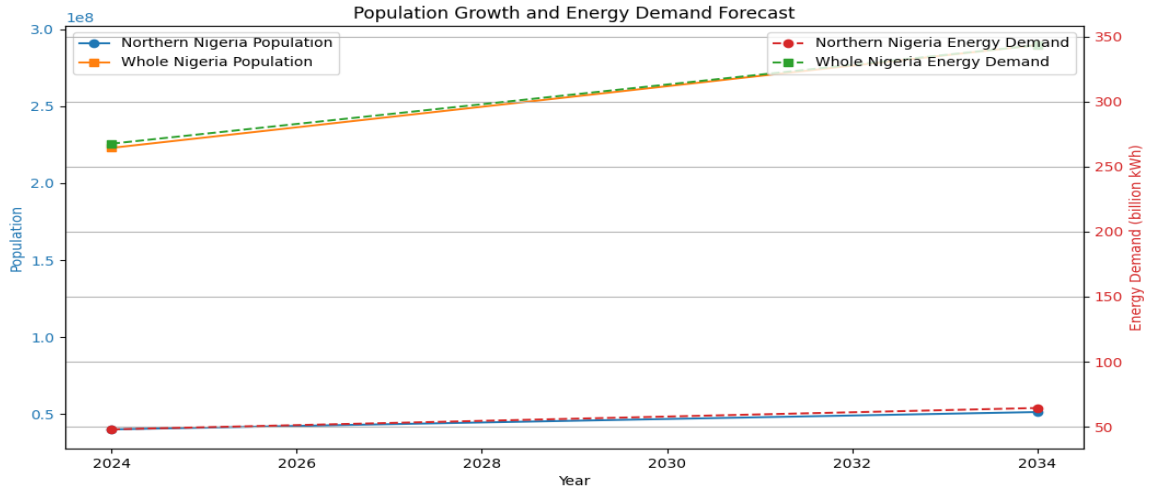


Simulated panel efficiency and solar radiation.

Source: National Renewable Energy Laboratory (NREL), 2023

Future forecasting analysis:

To forecast future growth and energy demand for northern Nigeria and the whole of Nigeria, population growth rates together with a potential shift in the per capita energy consumption should be taken into account. Below is a structured approach to how future energy demands can be forecast.



1. *Assumptions and Parameters*

- *Population Growth Rates*: *Northern region of Nigeria*: *Had an average annual population growth rate all through the year that stood at* **2.5%.**
- *Total Nigeria*: *Average annual growth rate of population*, **2.6** *percent*

***Energy Demand Growth Rates*:**

- *Northern Region of Nigeria*: *Assuming the per capita energy demand would grow by* **3%** *every year as a result of economic development and rising standards of living.*
- *Total Nigeria*: *Assume the per capita energy demand would rise annually by* **2.5%** *for similar reasons.*

Initial Data

***Current Population* (2024)**:

- *Northern Nigeria*: = **40 *million***
- *Whole Nigeria*: = **223 *million***

***Current Annual Energy Consumption*:**

- *Northern Nigeria*: **48 *billion*** *kWh*
- *Whole Nigeria*: **267.6 *billion*** *kWh*
- *Current Per Capita Energy Consumption*: **100** *kWh/person/month* (**1,200** *kWh/year*)

2. Forecasting Future Population and Energy Demand

***For Northern Nigeria*:**

***a. Population Forecast*:**

- *Future population =current population x* (1+ *growth rate*)^{n}*umber of years For each* 10 *year projection*
- *Future Population* **(2034): 40,000,000*x*(1+0.025)^10**
- *Future Population* **(2034)=40,000,000×1.282**
- *Future Population* **(2034)=51,280,000**

***b. Energy Demand Forecast*:**

- *Future Energy Demand=**Current Energy Demand**×(1+**Demand Growth Rate**)**Number of Years***

***For a* 10-*year projection*:**

- *Future Energy Demand* **(2034)=48,000,000,000×(1+0.03)^10**
- *Future Energy Demand* **(2034)=48,000,000,000×1.343**
- *Future Energy Demand* **(2034)=64,464,000,000 *kWh/year***

3. ***For Whole Nigeria*:**

***a. Population Forecast*:**

- *Future Population*=***Current Population*×(1+*Growth Rate*)*Number of***

Years For a* 10-*year projection

- *Future Population* **(2034)=223,000,000×(1+0.026)^10**
- *Future Population* **(2034)=223,000,000×1.297**
- *Future Population* **(2034)=289,811,000**

***b. Energy Demand Forecast*:**

- *Future Energy Demand*=***Current Energy Demand*×(1+*Demand Growth Rate*)*Number of Years***

For a* 10-*year projection

- *Future Energy Demand* **(2034)=267,600,000,000×(1+0.025)^10**
- *Future Energy Demand* **(2034)=267,600,000,000×1.282**
- *Future Energy Demand* **(2034)≈343,367,000,000 *kWh/year***

4. Area Required for Solar Power

***Using the same solar energy production assumptions* (262.8 *kWh*/m^2/*year*), *calculate the required solar panel area for* 2034:**

***For Northern Nigeria*:**

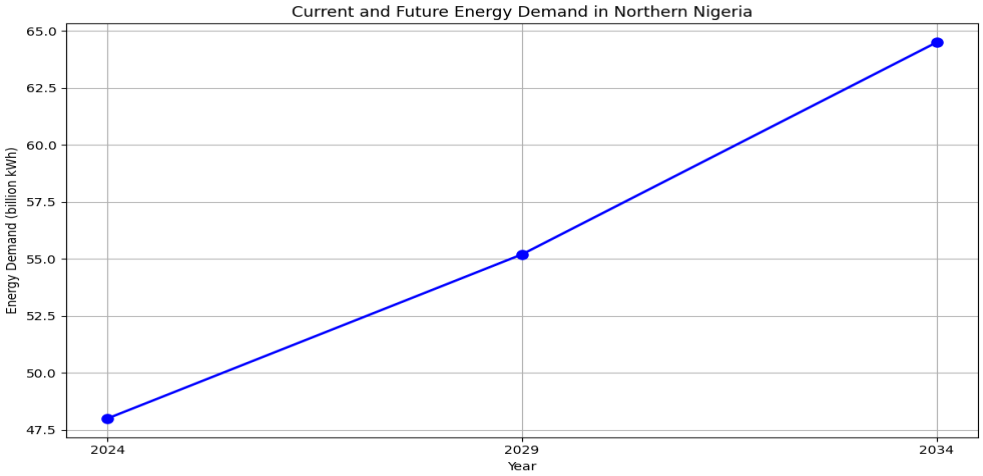
- *Total Area Needed*= **64,464,000,000***kwh* / 262.8 *kwh* /m^2/*yr*
- *Total Area Needed*=**245,774,000** m^2
- *Total Area Needed*≈**246,000** km^2

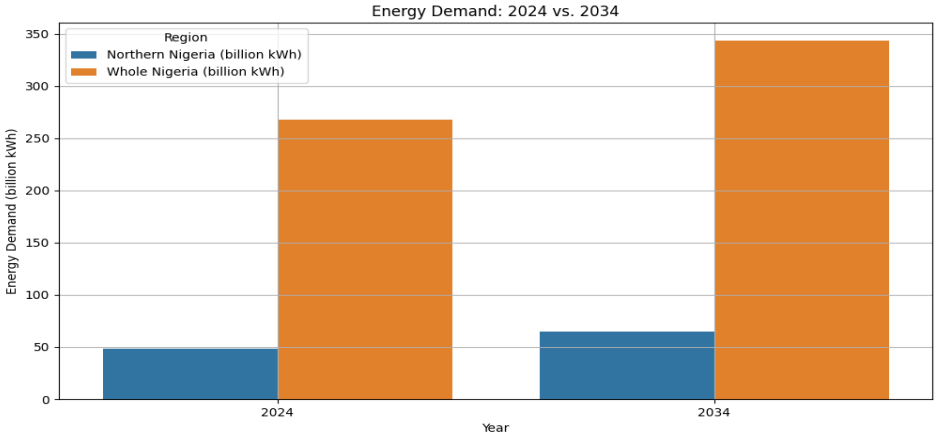
***For Whole Nigeria*:**

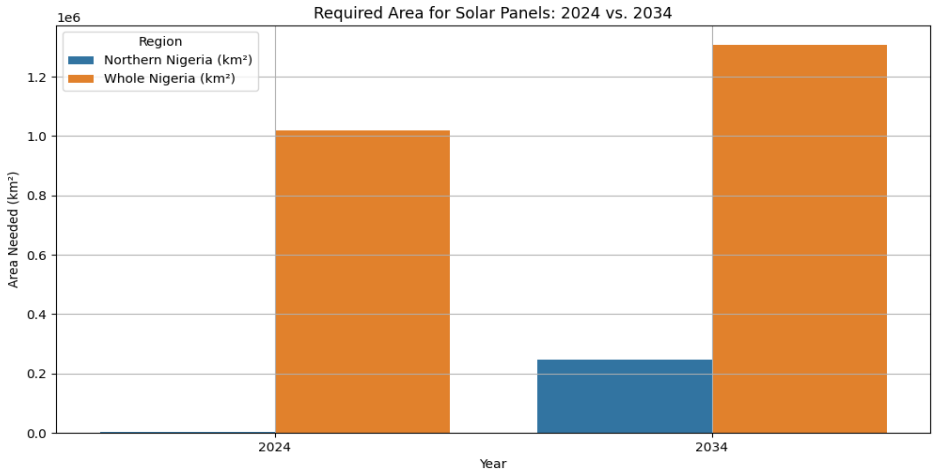
- *Total Area Needed*= **343,367,000,000** *kWh*/**262.8** *kWh*/m^2/*year*
- *Total Area Needed*≈**1,307,131,000** m^2
- *Total Area Needed*≈**1,307,000** km^2

Future Energy Needs

Region	Population (2034 Estimate)	Annual Energy Demand (2034 Estimate)	Per Capita Energy Consumption (2034)
Northern Nigeria	51.3 million	64.5 billion kWh	1,260 kWh/year
Whole Nigeria	289.8 million	343.4 billion kWh	1,185 kWh/year


Current and Future Energy Demand in Northern Nigeria
Energy Demand (billion kWh)
65.0
62.5
60.0
57.5
55.0
52.5
50.0
47.5
2024
2029
2034
Year


Energy Demand: 2024 vs. 2034
Region
Northern Nigeria (billion kWh)
Whole Nigeria (billion kWh)
Energy Demand (billion kWh)
350
300
250
200
150
100
50
0
2024
2034
Year


Required Area for Solar Panels: 2024 vs. 2034
1e6
Region
Northern Nigeria (km²)
Whole Nigeria (km²)
Area Needed (km²)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2024
2034
Year

The results indicate a huge potential of solar energy in northern Nigeria towards meeting the current and future requirements of the region. Of course, the area covered by solar installations is vast, however the economic and environmental benefits of using solar power are huge. In general, the results present a rather strong case for investment in solar energy infrastructure as the solution to the region's energy challenges and as a spur to sustainable development.

Discussion

Solar Energy enhances environmental benefits, since it lowers reliance on fossil fuels, the total amount of greenhouse gas emitted to the environment is reduced. Compared to electric energy produced from coal or oil, solar power does not add to the environment any form of air pollutants other than carbon dioxide released during consumption. Furthermore, northern Nigeria, by accepting solar energy, is a part of an international effort in the reduction of climate change and the enhancement of local air quality. Utilizing solar energy would be in line with global targets in sustainability and preserve natural resources. Economic growth- the solar power projects can be an economic growth driver for northern Nigeria if developed, through employment, this industry can have massive employment in its manufacturing, installation, and other research and development work related to the panels. Various comparative studies of similar projects undertaken in other regions have portrayed significant job creation and economic activity. Creating solar infrastructure will attract domestic as well as foreign investment and, hence, pump the local economy. Public-private partnership and other incentives offered by the government to private parties can add more depth to investment in solar energy projects. Solar energy will eventually increase consumer savings for long-term energy uses as well as company savings. The cost of solar technology is decreasing and free sunlight resources, making solar energy an economic opportunity for the long-term. Energy reliability and security will be increased in northern Nigeria. The diversification of mixed energy resources as well as the reduction of fossil fuels dependence will allow for a more stable power supply from the solar energy sources. It can further enhance the reliability of the energy storage system through accumulation during periods of high irradiance or at times when there is a low amount of sunlight.

Challenges and Obstacles; The amount of capital that is required to set up an installation at its initial stage, is relatively very large in the case of solar power. It involves both the costs of solar panels, inverters, and energy storage systems, as well as the costs of building infrastructure. While the price of solar technology is getting reduced year after year, it remains a significant upfront investment and is still not feasible for many regions-especially the developing ones. In northern Nigeria, the existing infrastructures are not designed to support large-scale solar power projects. It needs strategic upgrading of the power grid, transmission, and distribution networks and the development of energy storage solutions to ensure it can integrate solar energy effectively. Infrastructure weakness can slow the rollout of solar power and make the project costlier. Overall success of the solar energy projects is dependent on technical expertise and skilled resources. Absence of local technical inputs and knowledge would defeat the purpose of development or maintenance work for the solar installations. Training programs and capacity-building initiatives are essential to overcome such constraints and ensure the smooth outcome of solar projects. The generation of solar energy requires support policies and regulations. But inconsistent or unclear regulatory frameworks cloud investors' future while failing to increase investors' confidence. Supportive policies need effective incentives and regulatory support for investments in solar energy and the execution of projects. Government policies and incentives form a very critical determiner of using solar energy. The recommended action is, Tax Credits and Subsidies- implementing tax credits, subsidies, and financial incentives for solar energy projects can be a means of reducing the initial costs and attracting investment. Feed-in tariffs and PPAs may be allowed in order to fetch stable revenues for the solar energy projects and encourage private sector participation. Regulatory framework- this can be defined more visibly, sequentially across the solar energy project as regards reducing uncertainties associated with the process of developing, approving, and executing solar projects.

Recommended measures:

Grid upgrades: Upgrade the existing power grid network to accommodate solar energy and deploy state-of-the-art technologies to manage the grid.

Energy storage: Invest in energy storage systems that will become the backbone of irregularity management to ensure power supply reliability.

Capacity building and technical expertise: Building capacities locally is vital in the successful implementation of solar projects. Through training programs, to develop a skilful workforce in the applications of solar technology and in project management.

Knowledge sharing: Encourage knowledge and international collaboration and interaction with local experts for expertise in the most technically sound best practices.

The discussion above has identified the various advantages solar energy can offer northern Nigeria in terms of environmental, economic and energy security advantages.Similarly, the challenges and barriers that limit or discourage the adoption of solar energy, such as higher initial costs, infrastructure limitations, and technical constraints have been highlighted. Policy recommendations are provided to aid in the successful execution of solar power projects and surmount some of the associated problems. Tapping the solar energy available and seeking to address these issues can aid northern Nigeria's realization of sustained development with improved energy infrastructure.

Conclusion

The Northern Nigeria region is characterized by an increased population, economic activities, and very old energy infrastructure. This situation thus increases the challenge in energy development. The total current demand for energy is approximately 48 billion kWh in 2024 and is projected to increase to about 64.5 billion kWh by 2034. This ever-rising nature of demand points to an urgent need for a sustainable and reliable energy source. Solar energy would thus emerge as an extremely viable means of addressing the said energy challenges. With average solar radiation that exceeds 6 kWh/m² per day, northern Nigeria already has a sizable solar potential. Analysis has shown that the contribution of solar power sources to the energy portfolio of the region would be enormous, with tremendous potential for the mass generation of electricity and clean, sustainable energy supply. Estimates from this research state that in order to meet projections of about 64.5 billion kWh in demand by 2034, it would amount to the need for some 246,000 square kilometers of land covering solar panels. Whilst this is an excellent area, however, the advantages of sun-powered energy are balanced against such difficulties through environmental conservation and better security on grounds of economic growth concerning energy supply. This holds much promise for the resolution of the energy challenges in northern Nigeria as, by exploiting this enormous solar potential, the region will benefit so much through this clean source of energy toward realizing great environmental, economic, and social impacts. It is, therefore, against such a backdrop that supportive policies, infrastructure development, and capacity building come to the fore in realizing the full potential of solar power. It will, therefore, be better placed with the use of solar energy in northern Nigeria as it strives towards a more sustainable and resilient energy future. It would lead towards economic development, meet requirements of energy, and contribute towards global sustainability objectives. Thus, the findings of this study provide a sound foundational research and action for such a kind of transition towards the cleanest source of energy as well as a reliable one.

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