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CLIMATE CHANGE MITIGATION THROUGH DECENTRALIZED SOLAR ENERGY OPTION IN NIGERIA

***Victor N. Dike, Okey K.Nwofor, Chidiezie T. Chineke and Ugochukwu K. Okoro**
Atmospheric Physics Group,
Department of Physics and Industrial Physics
Evan Enwerem University, P.M.B 2000 Owerri, Imo State, Nigeria

ABSTRACT: Potential climate change impacts on our environment are being accentuated by the continued accumulation of greenhouse gases in the atmosphere which is expected to severely affect the precipitation patterns and Agricultural production in Nigeria. Mitigation studies indicate that it will not be possible to stabilize climate Change without reducing the growth of these emissions and explicit implementation of renewable technologies for energy generation. In this work, we have assessed the potential of Solar Energy in Nigeria by comparative analysis of solar radiation estimates based on the dataset provided by National Aeronautic and Space Administration (NASA) and Photovoltaic Geographic Information Systems (PVGIS) for Nigeria in response to the call for increased reliance on renewable energy for power generation. The results showed a high level potential of solar energy in the region which is an indication that a decentralized renewable energy involving the solar option can be optimized in the country, this will reduce over dependence on conventional energy system for electricity generation.

KEY WORDS: Climate Change, Mitigation, Decentralized Renewable Energy, Solar Energy, Geo-political Zones of Nigeria.

INTRODUCTION

It is a known fact that the present system of energy production is heavily dependent on the use of conventional energy sources (fossil fuels) which have proven to be highly effective drivers of economic process but on the other hand, highly damaging to the environment and human health. In Nigeria, oil and gas account for about 90 percent of primary energy consumption. The combustion of this fuel is assumed to be the primary source of carbon dioxide (CO_2) emissions, which are growing at the rate of 0.5% per year. According to the intergovernmental panel on climate change, the present level has grown from 270 ppmv to 340 ppmv at the dawn of the industrial revolution two centuries ago [1].

Greenhouse gases emitted mostly from the production and use of energy are altering atmosphere processes in ways that are affecting the climatic patterns. Evidently, the increase in air temperature observed over the last fifty years is attributable to human activities and that significant climate change will result if 21st century energy needs were met without a major reduction in the carbon emissions of the global energy system during this century [1]. Current CO_2 emission trends, if not controlled will enormously increase the atmospheric concentration before year 2050, relative to pre-industrial levels. In Nigeria changes have already been observed in climate patterns that correspond to scientific projection, based on increasing concentration of green house gases. It is clear that efforts to reduce atmospheric CO_2 concentration to the level observed in the pre-industrial era cannot be accomplished in oil and gas dominated economies.

Obviously this is a serious challenge to sustainable development and the main strategies to mitigate it include increased reliance on emerging clean/renewable energy sources.

Although there have been several criticisms to the IPCC report on the mitigation possibilities and cost, these efforts did not dispute the need and desirability of diversifying and scaling up renewable energy [2]. Global warming and sustainable development groups have proposed a 100% Renewable Energy Source supply, without fossil fuels and nuclear power [3]. It has been suggested that a nation can power itself entirely by renewable energy. [4] This is important in Nigeria as the country is committed in terms of policies to finding a long lasting solution to its energy crisis as well as the present concerns of the effect of climate change in the country. In this work we strongly make a case for increased reliance on renewable energy sources and a well designed Decentralized Renewable Energy (DRE) using PV cells to build a mitigation and adaptive capacity in view of the abundance of solar radiation in the country.

Evidence of Climate Change in Nigeria

The result from a detailed statistical analysis of the annual mean air temperature from 30 synoptic stations between 1901 and 2005 collected from the Nigerian Meteorological Agency (NIMET), Lagos and Meteorological Department in some Airports showed that air temperature is steadily increasing especially from the 1970s [5]. Between 1901 - 1935 and 1936 - 1970 climatic periods, temperature anomalies were below the 1970 - 2005 normal, but 22 years (63%) out of the 35 years were above the normal between 1971 and 2005 [5]. The temperature anomalies shows that climate change signal is stronger as from the 1970s.The rate of temperature increase is higher in the semi-arid region than the coastal areas of Nigeria. The current available pieces of evidence showed that Nigeria, like most parts of the world, is experiencing the basic features of climate change [5]. In addition to this a Director in the Federal Ministry of Environment, when contacted by Daily Trust News papers said that "the rains being

***Corresponding Author:** E-mail: asldikvin@yahoo.com

experienced in different parts of the country at the time when it is not expected is an indication of serious climate change in the society, which may be linked to global warming.

Since the Nigerian government has a policy on checking climate change and solving the energy problems with the target of increasing the present 5000MW generation capacity to 16000MW by the year 2015 [6] by the adoption of Renewable Energy Master Plan (REMP) [7]. Solar energy represents one of those renewable energy options that are best suited to help Nigeria realize its target on energy generation. This is reiterated in this paper as we have assessed and analyzed the potential of solar radiation receivable in each geo-political zone of Nigeria.

Solar Energy

Solar energy has been harnessed in Nigeria since ancient times using a range of ever-evolving technologies. Solar technologies are broadly characterized as either passive solar or active solar depending on the manner solar energy is captured, converted or distributed [8]. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Solar energy can be used in many ways [6].

METADATA

Renewable energy development/utilization vis-à-vis solar radiation programme must start with assessment of energy potential at the site or region of interest. This is important in the planning, sizing and pointing of solar devices [9]. In this work we have used NASA Surface and Solar Energy and Photovoltaic Geographic Information System (PVGIS) estimates to analyze the potential of solar energy in two cities for each geo-political zone of Nigeria.

NASA Surface and Solar Energy data

National Aeronautic Space Administration (NASA) through its science mission directorate has continued to support satellite measurements, providing data important to the study of climate and climatic processes. These data include long-term estimates of meteorological quantities of solar energy fluxes [8]. The satellite modeled data has been shown to be accurate enough to provide reliable solar and meteorological resource data over regions where surface measurements are sparse or nonexistent. NASA continues to support the development of Surface meteorology and Solar Energy (SSE) dataset, which has been formulated specifically for photovoltaic and renewable energy system design. Many journal articles have been published based on these datasets. In this article, a solar radiation data of 22 years average from 1983-2005 has been obtained from NASA online data store (http://eosweb.larc.nasa.gov/sse/). The sites used within the Six Geo-political zones of Nigeria with their latitudes and longitudes are listed in Table 1, their location in the Nigerian map are shown in figure 7.

PVGIS Data

The photovoltaic geographic information system (PVGIS) provides a map-based inventory of solar energy resources and assessment of the electricity generation from photovoltaic systems in Europe, Africa and southwest Asia [10]. It is part of the solar electricity action that contributes to the implementation of renewable energy, in the European Union, as a sustainable and long-term energy supply. PVGIS allows a very specific calculation of the amount of energy that can be generated in any location in Europe and its neighboring regions. This calculation is based on the geographic distribution of sun's energy, different terrain across Europe and Africa. The values represent long term monthly and yearly averages of solar radiation for the period 1985-2004 (19 years average). This provides a wealth of information about the development of photovoltaic technology up-to-date research on photovoltaic and links to world-wide databases of solar technology and data. The PVGIS is a powerful tool that can be used for the development of new solar power plants that will obviate climate change and promote sustainable development [11, 12]. So many journal articles have been published based on the PVGIS data.

RESULTS AND DISCUSSION

Figures 1a&b shows the monthly variation of solar radiation (kWh/m^2/day), for the selected South Eastern cities of Owerri and Enugu. Owerri recorded maximum solar radiation of 5.59 kWh/m^2/day in the month of February and 5.61 kWh/m^2/day in January from the NASA and PVGIS data respectively and minimum solar radiation of 3.77 kWh/m^2/day in August and 3.33 kWh/m^2/day in September. However, Enugu recorded the highest solar radiation of 5.74 kWh/m^2/day and 5.81 kWh/m^2/day of February from both NASA and PVGIS data where as, it recorded the least solar radiation of 3.91 kWh/m^2/day in August and 3.66 kWh/m^2/day in September from NASA and PVGIS data respectively. Figures 2a&b represent the monthly variation of solar radiation (kWh/m^2/day) for the selected South Western cities; Akure and Ibadan. Akure showed a high potential of solar radiation for the month of February (NASA 5.77 kWh/m^2/day and 5.87 kWh/m^2/day). While the minimum solar radiation is observed in the month of August and September (NASA 3.78 kWh/m^2/day and 3.46 kWh/m^2/day PVGIS respectively). It is observed that Ibadan has high potentials of solar radiation in the month of February in which NASA recorded 5.70 kWh/m^2/day while PVGIS recorded 5.91 kWh/m^2/day. The least values were observed in August and September (NASA 3.79 kWh/m^2/day and PVGIS 3.23 kWh/m^2/day respectively).

Figures 3a&b shows the monthly variation of solar radiation (kWh/m^2/day) for selected South Southern cities; Calabar and Port Harcourt. It is seen that Calabar recorded maximum levels of solar radiation in the month of February from both data sources(5.70 kWh/m^2/day NASA and 5.96 kWh/m^2/day PVGIS) while the minimum was recorded in the month of August (3.11 kWh/m^2/day for NASA and 2.97kWh/m^2/day for PVGIS). Nonetheless Port Harcourt had similar potentials as was in Calabar having 5.24 kWh/m^2/day for NASA and 5.62 kWh/m^2/day from PVGIS in the month of February and January respectively whereas the least level of solar radiation of 3.24 kWh/m^2/day was recorded in the month of July from NASA and 3.17 kWh/m^2/day in the month of September from PVGIS.

However, figures 4a&b are showed the monthly variation records for the selected Northern Eastern cities; Maiduguri and Bauchi. At Maiduguri, NASA data recorded the maximum level of 5.07 $kWh/m^2/day$ in the month of February whereas PVGIS data had 6.92 $kWh/m^2/day$ in April while a minimum level of 3.8 $kWh/m^2/day$ from NASA and 5.89 $kWh/m^2/day$ from PVGIS were observed in July and December respectively. Bauchi recorded high levels of solar radiation of 5.32 $kWh/m^2/day$ in February and 6.86 $kWh/m^2/day$ in April from NASA and PVGIS data respectively. The lowest level in solar radiation of 4.28 $kWh/m^2/day$ from NASA data was observed in October and a record of 5.35 $kWh/m^2/day$ from PVGIS data in August respectively.

Figures 5a&b list the monthly variation of solar radiation $kWh/m^2/day$ for selected North Western cities; Katsina and Dutse. At Katsina, NASA and PVGIS data showed a high potential for solar radiation of 6.82 $kWh/m^2/day$ and 6.43 $kWh/m^2/day$ respectively in the month of April while it recorded the least potential in the month of December (NASA 5.19 $kWh/m^2/day$ and PVGIS 5.05 $kWh/m^2/day$). Dutse showed high potential for solar radiation of 5.32 $kWh/m^2/day$ for NASA and 6.49 $kWh/m^2/day$ for PVGIS in the month of February and April respectively. The least potential of solar radiation is observed in October (4.26 $kWh/m^2/day$ NASA) and August (5.30 $kWh/m^2/day$ PVGIS). Figures 6a&b showed monthly solar radiation ($kWh/m^2/day$) variations for selected North Central cities of Lokoja and Jos. At Lokoja, NASA and PVGIS recorded the maximum potential of solar radiation in the month of February (5.84 $kWh/m^2/day$ for NASA and 6.21 $kWh/m^2/day$ for PVGIS) with a minimum of 4.13 $kWh/m^2/day$ in the month of August and 4.07 $kWh/m^2/day$ in the month of September for NASA and PVGIS respectively. It is also observed in figure 6b that Jos recorded the highest potential of solar radiation of 6.35 $kWh/m^2/day$ and 6.96 $kWh/m^2/day$ in the month March for NASA and PVGIS repectively. While NASA and PVGIS data respectively recorded the minimum solar radiation of 4.21 $kwh/m^2/day$ and 4.95 $kWh/m^2/day$ in the month of August.

It is important to note that the observed intermittent behavior of solar radiation is heightened by the seasonal variation. Like the entire region within West Africa there are two seasons; the wet and dry seasons which differ by the level of precipitation, temperature and humidity, with wet season recording higher precipitation, humidity and lower temperature than the dry season. The wet season spans from April to September while the dry season lasts from October to March of the succeeding year [13]. This is important in planning energy budget.

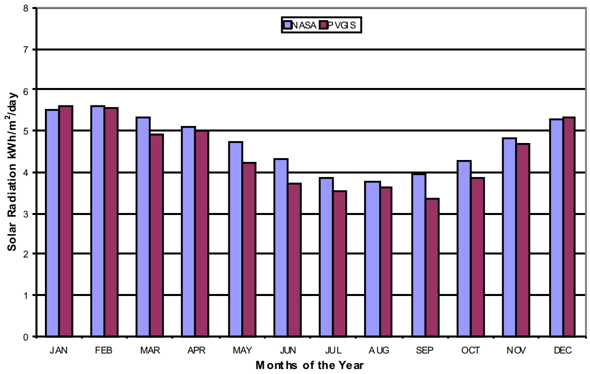
Table 1 shows the difference in the annual average of solar radiation for the locations. Despite the little differences, it is important to note that the estimates from both data source present a high potential of solar energy in Nigeria all year round.

Decentralized Solar Electric Power Scenario in Nigeria

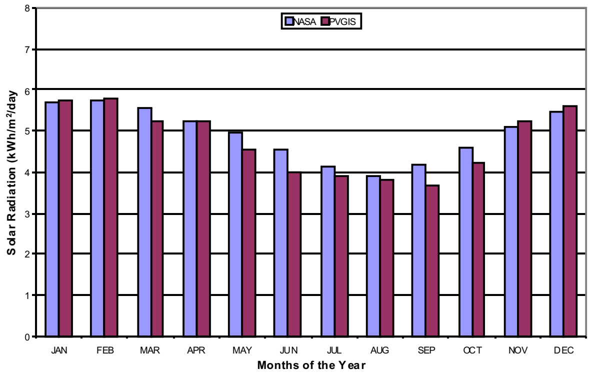
Decentralized solar electric power is simply electric power produced at the point of use. Solar electric power provides energy independence, economic value and environmental security. Decentralized solar electric (Photovoltaic (PV) Modules) have the potential to supply a significant portion of the nations electric energy requirements. PV is however, already accepted in many applications, and is being applied in electrification projects such as stand alone Street lighting systems, Water pumps and vaccine refrigerators. PV is still a relatively "young" industry. Total world wide manufacturing capacity is less than that of a medium capacity turbo generator. The technology is at an advanced stage and requires higher penetration rates to increase manufacturing volumes and decrease costs. Applications of PV technology range from small stand alone systems to mega watt scale fully integrated utility interconnected systems; there is a need to scale up the solar energy technology in Nigeria. PV and other renewable distributed resources are considered as some of the best technology for electrification in developing countries, especially where the cost of electrification (distribution and control systems) exceed the benefits to sparsely populated areas with small users, and do not provide a return on investment to utilities.

CONCLUSION

1. Nigeria is located in the tropics between 3^0 to 14^0 longitude East and 4^0 to 14^0 latitude North and endowed with an annual average daily sunshine of 6.25hrs ranging between about 3.5hrs at the coastal area and 9.0hrs at the Northern boundaries. Similarly, it has annual daily solar radiation of about 5.25$kWh/m^2/day$ varying between 3.5$kWh/m^2/day$ at the coastal area and 7.0 $kWh/m^2/day$ at the Northern boundary [14,15] and is abundant enough for optimization.
2. It is also observed that the Northern Nigeria has higher potential of solar energy more than the southern Nigeria. This can be attributed to proximity of Northern region to the arid sahel and Southern region to the coast known for level of humidity making them more vulnerable to incessant cloudy conditions and rainfall.
3. Renewable energy can be particularly suitable for Nigeria. In rural and remote areas, transmission and distribution of energy generated from fossil fuels can be difficult and expensive. Producing decentralized renewable energy locally can offer a viable alternative.
4. Renewable energy projects in many developing countries have demonstrated that solar energy can directly contribute to poverty alleviation by providing the energy needed for creating businesses and employment. Solar energy technologies can also make indirect contributions to alleviating poverty by providing energy for cooking, space heating, and lighting. Renewable energy can also contribute to education by providing electricity to schools.
5. Accelerated development and deployment of new and advanced energy technologies, energy efficiency improvements and fossil fuel technologies that produce near-zero harmful emissions will address the countries climate change mitigation needs.

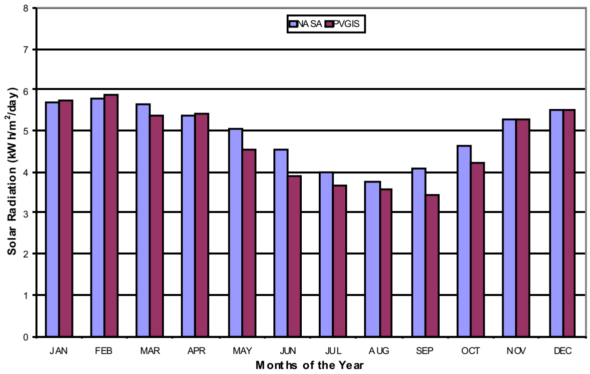


1a Owerri

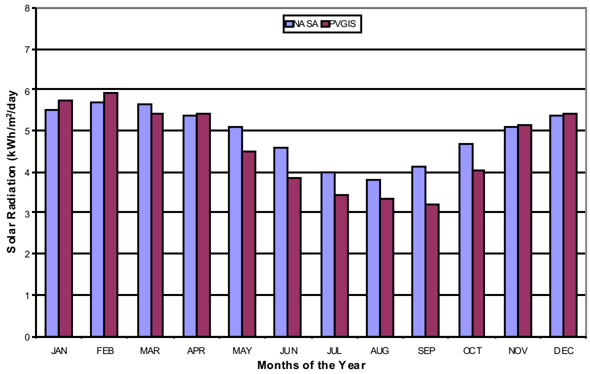


1b Enugu

Figures 1a&b the monthly variation of solar radiation kWh/m^2/day for selected South Eastern cities

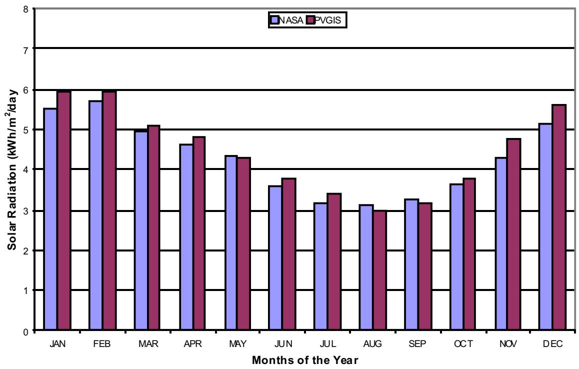


2a Akure

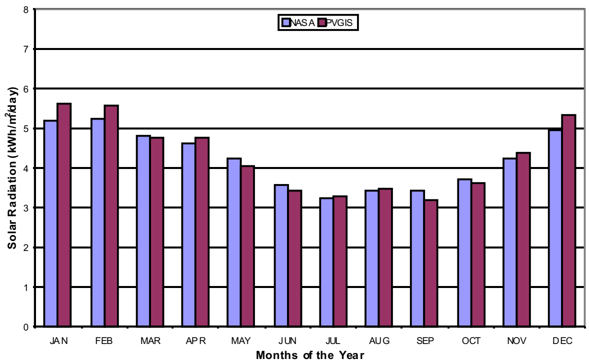


2b Ibadan

Figures 2a&b the monthly variation of solar radiation kWh/m^2/day for selected South Western cities

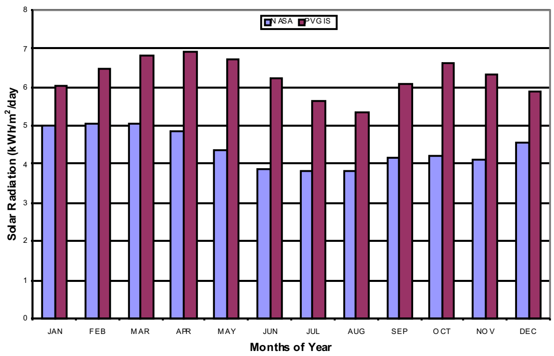


3a Calabar

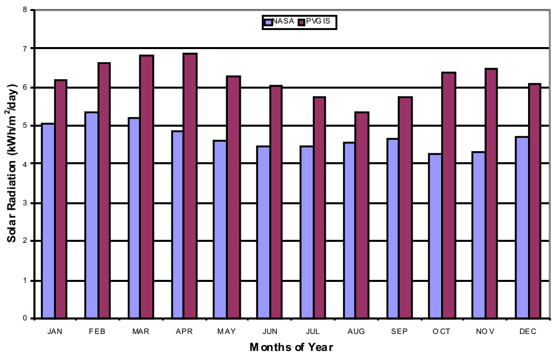


3b Port Harcourt

Figures 3a&b the monthly variation of solar radiation kWh/m^2/day for selected South Southern cities

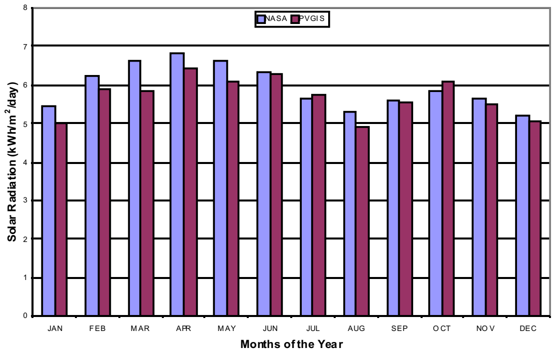


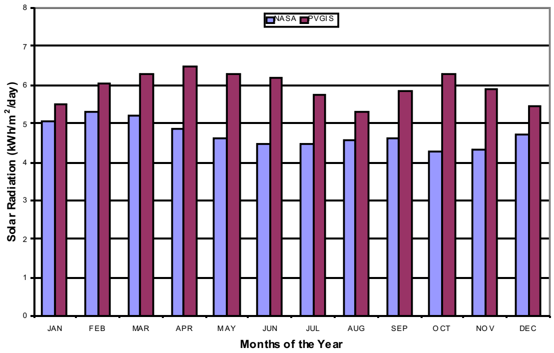
4a Maiduguri



4 b Bauchi

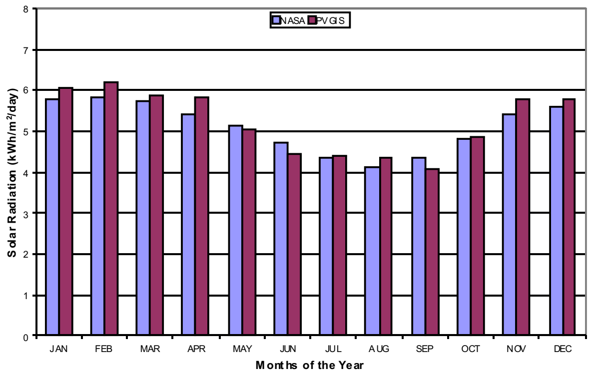
Figures 4a&b the monthly variation of solar radiation kWh/m^2/day for selected North Eastern cities

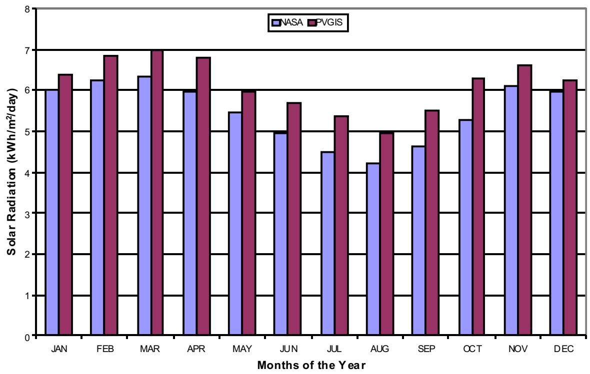




5a Katsina 5b Dutse

Figures 5a&b the monthly variation of solar radiation kWh/m^2/day for selected North Western cities





6a Lokoja 6b Jos

Figures 6a&b the monthly variation of solar radiation kWh/m^2/day for selected North Central cities

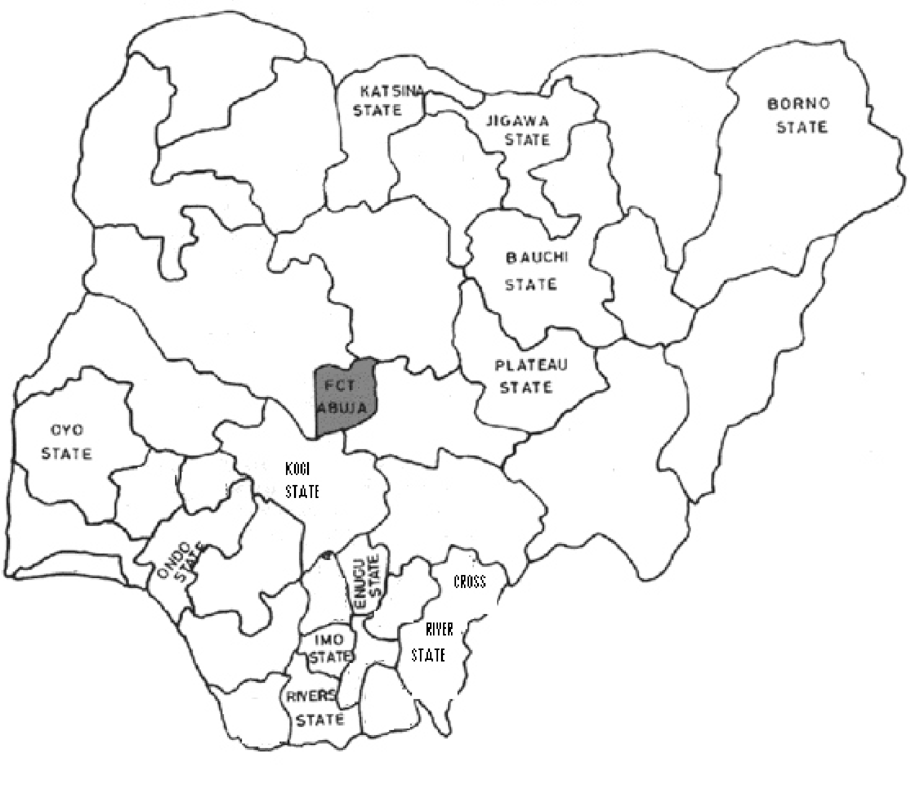


Figure 7 A sketch of the Map of Nigeria showing the study sites

Table 1: Study Sites, Annual Averages and Differences

STATE	SITE	LONG	LAT	PVGIS	NASA	AD
SOUTH-EAST						
Imo	Owerri	7.02	5.48	4.45	4.2	0.25
Enugu	Enugu	7.5	6.5	4.749	4.91	-0.161
SOUTH-WEST						
Ondo	Akure	5.2	7.25	4.702	4.93	-0.228
Oyo	Ibadan	3.9	7.38	4.609	4.9	-0.291
SOUTH-SOUTH						
Cross River	Calabar	8.32	4.95	4.454	4.26	0.194
Rivers	Port Harcourt	7	4.75	4.27	4.2	0.07
NORTH-EAST						
Borno	Maiduguri	13.15	11.83	6.256	4.4	1.856
Bauchi	Bauchi	9.83	10.32	6.208	4.69	1.518
NORTH-WEST						
Kastina	Kastina	7.6	12.98	5.697	5.93	-0.233
Jigawa	Dutse	9.28	11.73	5.935	4.69	1.245
NORTH-CENTRAL						
Kogi	Lokoja	6.82	7.75	5.218	5.09	0.128
Plateau	Jos	8.9	9.92	6.117	5.46	0.657

Legend: AD = Annual Difference

Table 1 Study Sites, Annual Averages and Differences

RECOMMENDATIONS

The threat posed by climate change may be as horrible as those posed by nuclear weapons, efforts to check/mitigate climate change should be intensified as it is imperative since this change is evident in our temperature and precipitation patterns. We strongly recommend increased reliance on renewable energy for energy generation in Nigeria because of its multiplier effect on checking climate change, job creation and sustainable electric power generation.

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