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HARNESSING SOLAR ENERGY POTENTIAL AS AN ALTERNATIVE SOURCE OF ELECTRICAL ENERGY IN NORTH CENTRAL, NIGERIA

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ABSTRACT: *The demand for electrical power to drive the economy of Nigeria as a nation is on the rise geometrically, while its availability is either stagnant or in a decline due to inefficient or decay in the available sources of power energy generation and the interconnectivity to form national grid. This work examines the potentials of solar energy that could be tapped as an alternative source of power energy generation in North central states of Nigeria using experimental approach of measuring daily solar radiations across all the study area at interval of one hour using light meter (LX 101A) from which daily and monthly mean were then evaluated. The results obtained showed that north central states has an average solar radiation value of 9.8MJm^{-2} (2.7 kWhm^{-2}) and 27 MJm^{-2} (7.5 kWhm^{-2}) as minimum and maximum, obtain in August and December respectively in 2018 and with 0.1% of land mass of states dedicated as solar panel farms, North Central, Nigeria has the potentials of generating 29,168.29 MW of Electrical energy which is far more than the current power energy demand of the Nation.*

KEYWORDS: Solar Energy Potential, Power Energy Generation, North Central, Nigeria

INTRODUCTION

The sun is the world's largest power plant as it provides more energy to the earth in one hour than that produced by all nations in a year. However, solar power statistics showed that we only use 0.1 % of sun for our electrical needs (Chen, 2011). Solar energy usage was accepted in Nigeria, though with snail pace growth (Mungai, 2007). Using energy off grid due to its failure as nation’s source of electricity generation, people are gradually drifting towards the usage of solar energy as an alternative source despite the high manufacturing costs of PV cells and the large land area needed to collect sunlight, in the case of high energy demand for communities. Despite the advances in solar power technology, its cost of installation compared to other forms of energy generation like coal, gas or nuclear sources, is five (5) times much higher to produce electricity, Murat *et al*., (2007) argued that as energy prices continue to increase, the future looks bright for solar power.

According to Nafi’u *et al*., (2012) solar energy is one of the oldest renewable energy sources in the world. This energy is taken from the sun in the form of solar radiation. The usage of sun’s energy is basically in three ways: a) Solar cells in which photovoltaic or photoelectric cells are used to convert light directly into electricity. b) Solar water heating in which the heat from the sun is used to warm the water in glass panels of solar energy system therefore no longer requiring gas or electricity to heat the water. c) Furnaces that use mirrors to capture the sun's energy into a concentrated place to produce high temperatures. These solar furnaces can be used to cook food.

Folayan (1988) stated that sun is, in effect, a continuous fusion reactor with its constituent gases as the "containing vessel" retained by gravitational force. Solar radiation is an electromagnetic wave emitted by the sun's surface that originates in the bulk of the Sun where fusion reactions convert hydrogen atoms into helium. Every second, 3.89×10^{26}J of nuclear energy is released by the sun's core. This nuclear energy flux is rapidly converted into thermal energy and transported towards the surface of the star where it is released in the form of electromagnetic radiation.

Holladay (2006) states that the power density emitted by the Sun is of the order of 64MW/m^2 of which 1370W/m^2 called the solar constant reach the top of the earth's atmosphere with no significant absorption in the space. Radiation reaching the Earth's surface is altered by a number of factors namely: the inclination of the earth's axis and the atmosphere that causes both absorption and reflection of part of the incoming radiation. Due to absorption by the atmosphere, reflection from cloud tops, oceans, terrestrial surfaces and rotation of the Earth (day/night cycles), the annual mean of the solar radiation reaching the surface, is 170W/m^2 for the oceans and 180W/m^2 for the continents, of which about 75% is direct light, while the balance is accounted for as scattered by air molecules, water vapour, aerosols and clouds (Ndaceko *et al.*, 2014).

Ausubel (2007) averred that solar energy potential varies from 3.5 – 7.0 kWhm^{-2}/day (about 4.2 TWh /day) if 0.1% of Nigeria land mass is used as solar panel farm to generate electricity. Ndanusa *et al*., (2014) also averred the solar energy potential available ranges between 3.5 kWh - 6.8 kWh with mean values of 4.63 kWh in Niger State which is within the earlier range by Ausubel (2007). Nigeria receives an average solar radiation of about 7.0kWh/m^2 (25.2MJ/m^2 per-day). The estimated potential of solar energy in Nigeria, with 5% device conversion efficiency is 5.0×10^{14} KJ of useful energy annually which is equivalent to about 258.62million barrels of oil produced annually and about 4.2×10^5 GWh of electricity production annually, in the country. Aliyu (2005) averred that given an average solar radiation level of about 5.5 KWh (m^2 per day) at the prevailing efficiencies of commercial solar-electric generators, and if solar collectors or modules were used to cover 0.1% of Nigeria's land area of 923,763 km^2, it is possible to generate 1850×10^3GWh of solar electricity per year, which is over one hundred times the current grid electricity consumption level in the country.

Geographical Location of Study Area

This research covers the north central states of Nigeria -viz, Niger, Kogi, Kwara, Plateau, Benue, Nasarawa and the Federal Capital Territory (FCT) Abuja. They represent one of the six geo-political zones in Nigeria. Figure 1 shows the map of Nigeria with the six geo-political zones in the country. These states are located in the tropical region marked by two distinctive seasons: viz: Dry Season spanning November – March and Rainy Season which spans April – October of each year with August as the peak month of rainy season. The study area occupies a total of 243,884 km^2 which represent about 26.5% of Nigeria total land mass of 293,763 km^2. Figure 2 shows the north central states showing the state capitals, some major towns and cities and particular towns covered by the research. Three towns from each state were mapped out as the study area with at least one from each senatorial district of the state as represented in Table 1 with their respective coordinates and altitudes.

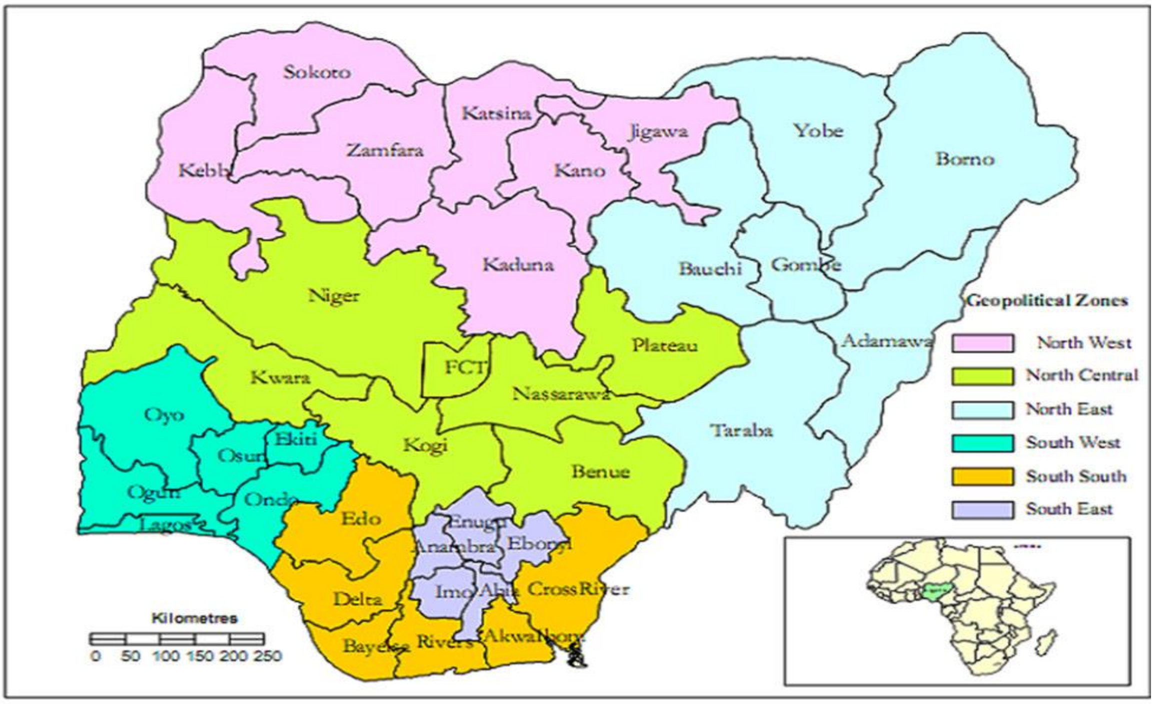

Figure 1: Map of Nigeria showing the six geo-political zones (NASDRA, 2013)

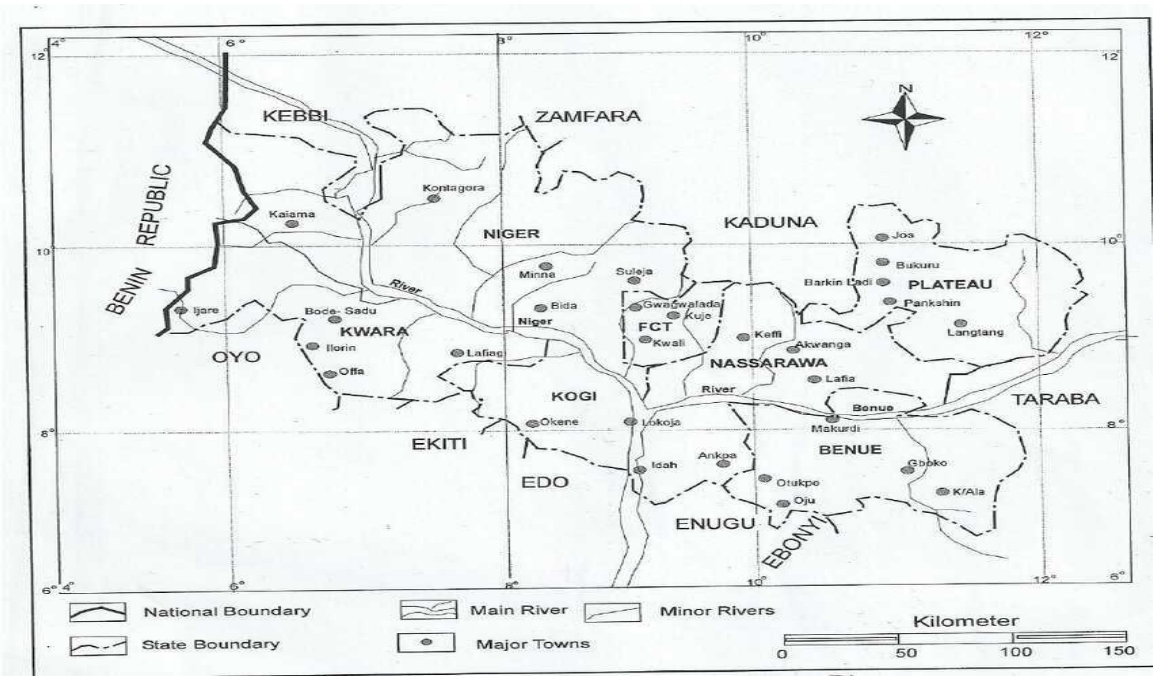

Figure 2: Map of North Central States Showing the Study Area (NASDRA, 2013)

Table 1: Towns Under the Study Areas and Their Locations

SNO	STATE	TOWN	LOCATION	ALTITUDE(m)
1	BENUE	Gboko	7.325°N / 9.005°E	335
		Makurdi	7.741°N / 8.512°E	104
		Otukpo	7.333°N / 8.750°E	127
2	KOGI	Ankpa	7.300°N / 7.633°E	70
		Lokoja	7.800°N / 6.740°E	55
		Okene	7.550°N / 6.233°E	270
3	KWARA	Bode-Sadu	8.933°N / 4.783°E	152
		Ilorin	8.500°N / 4.540°E	290
		Lafiagi	8.867°N / 5.418°E	74
4	NASARAWA	Akwanga	8.917°N / 8.367°E	359
		Keffi	8.843°N / 7.871°E	338
		Lafia	8.492°N / 8.517°E	290
5	NIGER	Bida	9.083°N / 6.017°E	152
		Kontagora	10.400°N / 5.467°E	335
		Minna	9.614°N / 6.557°E	299
		Lapai	9.625°N / 6.570°E	162
6	PLATEAU	Jos	9.933°N / 8.883°E	1,208
		Langtang	9.133°N / 9.783°E	430
		Pankshin	9.333°N / 9.450°E	1371
7	FCT	Abuja	9.058°N / 7.489°E	840

(Nimet, 2015).

MATERIAL AND METHOD

Material

The primary material used in the collection of data from field is Luthon (LX 101A) light meter as shown Plate 1. This is used to record the amount of solar radiation in Lux.

Plate 1: LX 101A Light Meter Used in the Collection of Data From the Field

Methods

In order to record the solar radiation of the environment, the light meter shown in Plate 1 was used to record the solar radiation intensity (in Lux) at regular interval of one hour for the year under scrutiny (2018) with the help of research assistants attached to each location under the study area for sole purpose of data collection. The solar radiation intensity in Lux was then converted to solar irradiance in megawatts per square meter (MW/m^2) as well as in mega Joules per square meter (MJ/m^2), while for the purpose of generalization of harvestable power from solar radiation, the land mass of the states under study in km^2 was taken and converted to ft^2 to estimate the maximum solar energy generation in megawatts.

Conversion factors and Assumption:

Land mass in square feet (ft^2) = land mass in km^2 multiply by 10763900.

(Using 1km = 3280.8399 ft)

1 w/m^2 = 683 Lux at 555nm wavelength (Alex, 1988)

3.6 MJ/m^2 = 1 kWh/m^2

Solar panel sizing in watts per ft^2 = 9watts (1)

$$\text{Solar sizing for each state} = \frac{0.1\ \%\ of\ land\ mass}{solarpanel\ sizing\ per\ ft^2} \quad (2)$$

$$\text{Solar sizing in megawatts} = \frac{solar\ sizing\ of\ a\ state}{10^6} \quad (3)$$

1. Each of the state to seed 0.1 % of its land mass for panel farm to generate electricity.
2. 1ft^2 generates 9watts of solar energy

RESULTS AND DISCUSSION

Results

The results obtained from the fields were as shown in tables 2, 3, and4. Table 2 shows the monthly mean values solar radiation across the study area, Table 3 shows the monthly mean values of solar radiation per state while, Table 4 shows states and their land mass and annual mean values of solar radiation per day as well as proposed land space for panel farm. While Figure 3 and 4 are graphical representation of mean values of solar radiation for the study area and state under study respectively.

Table 2: Mean Values of Variation in Solar Radiation of the Entire Study Locations in 2018

		SOLAR RADIATION (MJ/m^2)											
STATE	**LOCATION**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BENUE	MAKURDI	21.1	22.2	22.4	21.1	19.4	17.8	16.5	15.7	16.8	18.7	21.1	21.1
	OTUKPO	21.2	21.9	22.0	20.8	19.4	17.6	16.3	15.4	16.6	18.4	20.9	20.9
	GBOKO	21.1	22.2	22.4	21.1	19.4	17.8	16.5	15.7	16.8	18.7	21.1	21.1
KOGI	LOKOJA	21.2	21.9	22.0	20.8	19.4	17.6	16.3	15.4	16.6	18.4	20.9	20.9
	OKENE	21.2	21.9	22.0	20.8	19.4	17.6	16.3	15.4	16.6	18.4	20.9	20.9
	ANKPA	21.2	21.6	21.1	19.7	18.6	17.1	15.1	15.1	16.0	17.6	19.8	20.6
KWARA	ILORIN	24.5	22.5	20.7	18.2	17.0	14.6	11.7	10.2	11.7	16.5	23.6	25.2
	LAFIAGI	20.6	21.6	22.5	22.2	21.0	18.8	17.0	16.0	17.5	19.6	20.7	20.5
	BODE SADU	20.6	21.6	22.5	22.2	21.0	18.8	17.0	16.0	17.5	19.6	20.7	20.5
NASA-RAWA	AKWANGA	21.6	22.5	22.9	21.5	19.6	17.8	16.1	15.2	16.7	19.0	22.0	21.5
	KEFFI	21.6	22.5	22.9	21.5	19.6	17.8	16.1	15.2	16.7	19.0	22.0	21.5
	LAFIA	21.1	22.2	22.4	21.1	19.4	17.8	16.5	15.7	16.8	18.7	21.1	21.1
NIGER	BIDA	25.0	23.7	22.6	20.4	18.7	15.9	12.6	10.6	13.2	18.7	25.2	26.4
	KONT AGORA	20.1	21.7	22.6	22.7	21.7	19.7	17.2	16.3	18.4	20.3	20.9	20.2
	MINNA	20.7	21.8	22.8	22.7	21.4	19.4	17.5	16.1	18.4	20.3	22.0	20.8
	LAPAI	21.2	21.9	22.6	21.8	20.1	18.2	16.0	15.1	17.0	19.1	21.5	21.1
PLAT-EAU	JOS	20.7	22.4	23.0	22.0	21.2	20.4	18.9	17.8	19.6	21.1	21.6	20.6
	LANGTANG	20.9	22.5	22.8	22.3	21.2	19.6	18.1	17.2	18.3	20.2	21.4	20.8
	PANKSHIN	20.8	22.5	22.7	21.0	19.8	18.5	16.9	15.8	17.9	19.9	21.7	20.8
FCT	ABUJA	26.4	24.3	22.6	20.0	17.8	15.3	11.6	9.8	12.7	18.0	26.2	27.5

Table 3: Mean Values of Solar Radiation Per State in the Study Area in 2018

	BENUE	**KOGI**	**KWARA**	**NASARAWA**	**NIGER**	**PLATEAU**	**FCT**
JAN	21.1	21.2	21.9	21.4	21.8	20.8	26.4
FEB	22.1	21.8	21.9	22.4	22.3	22.5	24.3
MAR	22.3	21.7	21.9	22.7	22.7	22.8	22.6
APR	21.0	20.4	20.9	21.4	21.9	21.8	20.0
MAY	19.4	19.1	19.7	19.5	20.5	20.7	17.8
JUN	17.7	17.4	17.4	17.8	18.4	19.5	15.3
JUL	16.4	15.9	15.2	16.2	15.8	18.0	11.6
AUG	15.6	15.3	14.1	15.4	14.5	16.9	9.8
SEP	16.7	16.4	15.6	16.7	16.8	18.6	12.7
OCT	18.6	18.1	18.6	18.9	19.6	20.4	18.0
NOV	21.0	20.5	21.7	21.7	22.4	21.6	26.2
DEC	21.0	20.8	22.1	21.4	22.1	20.7	27.5

Table 4: Solar Energy Potentials Per State with Maximum Harvestable Power

STATE	Land Mass (km^2)	Mean Solar Radiation (MJ/m^2)	0.1% Of Land Mass (km^2)	0.1% Of Land Mass (ft^2)	sizing for panel ($watt/ft^2$)	solar sizing per state (MW)
BENUE	35,518	19.4	3,551.80	38,231,220,020.00	4,247,913,335.56	4,247.91
KOGI	29,833	19.1	2,983.30	32,111,942,870.00	3,567,993,652.22	3,567.99
KWARA	36,825	19.3	3,682.50	39,638,061,750.00	4,404,229,083.33	4,404.23
NASA-RAWA	27,117	19.6	2,711.70	29,188,467,630.00	3,243,163,070.00	3,243.16
NIGER	76,363	19.9	7,636.30	82,196,369,570.00	9,132,929,952.22	9,132.93
PLAT-EAU	30,913	20.4	3,091.30	33,274,444,070.00	3,697,160,452.22	3,697.16
FCT	7,315	19.4	731.50	7,873,792,850.00	874,865,872.22	874.87
	243,884					29,168.26

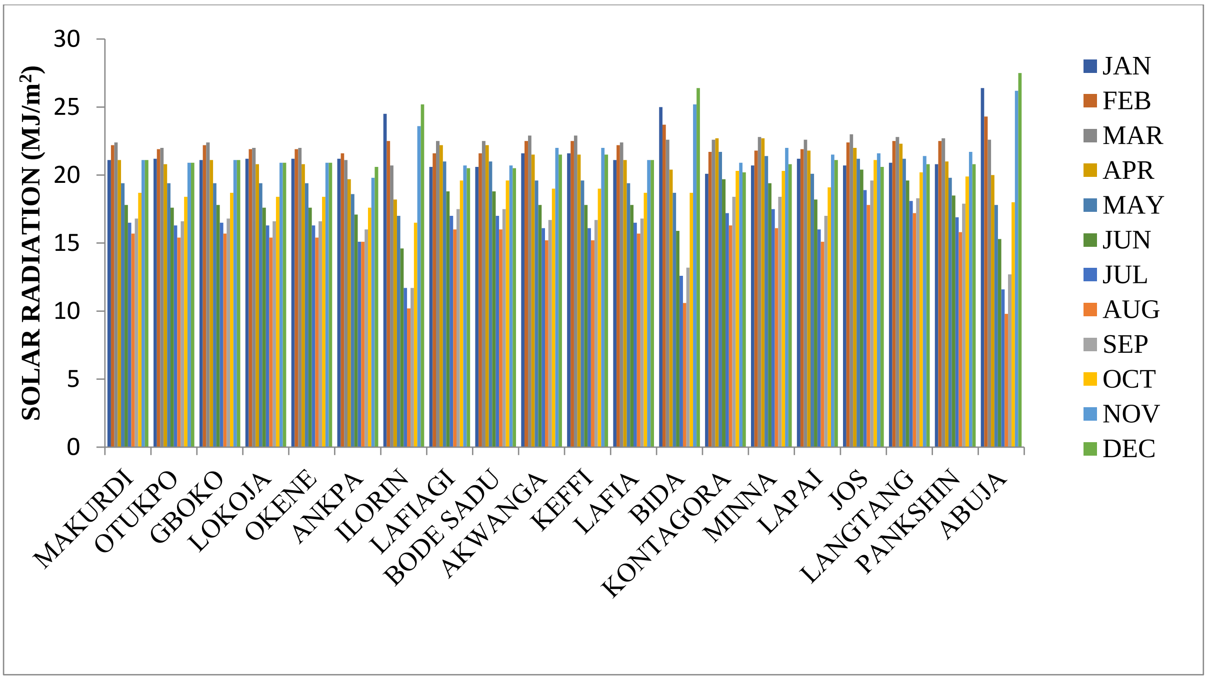

Figure 3: Mean Values of Solar Radiation of the Entire Study Locations

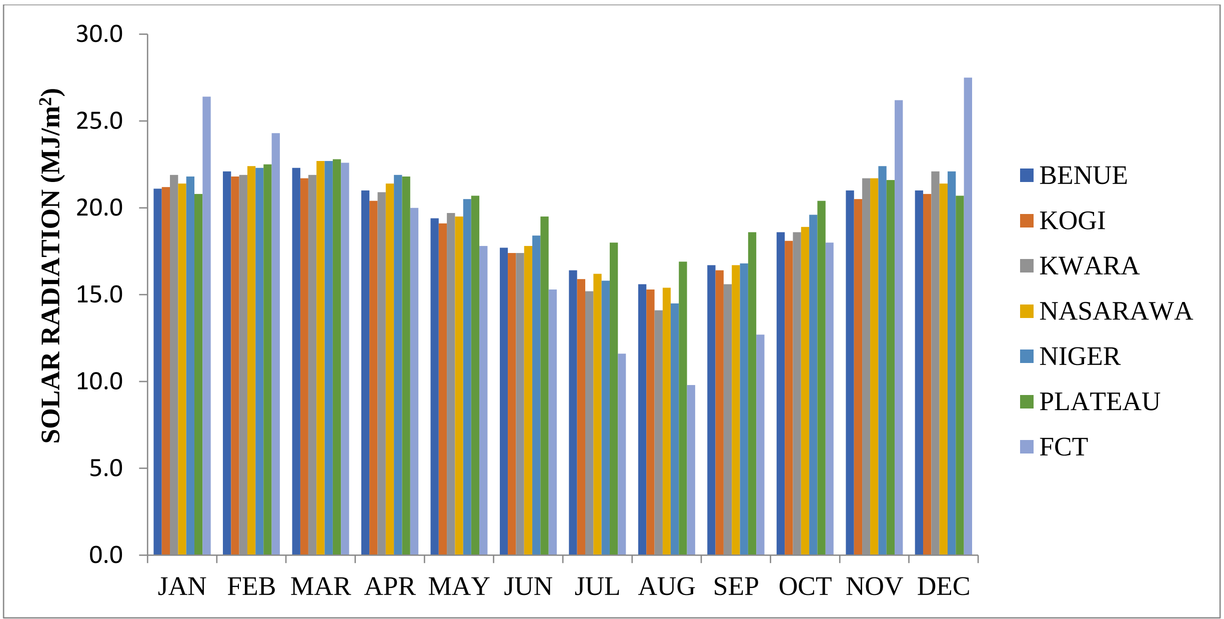

Figure 4: Mean values of Solar Radiation Per State in the Study Area

DISCUSSION

The results obtained showed that the study area have the potential of 12 hours daily for solar radiation with 4hours spanning between 12noon to 3.00 pm daily for peak radiation under normal situations per day with an average of 19.6MJ/m^2 (5.5KWh/m^2) per day throughout the year. Adopting the proposition of dedicating just 0.1% of land mass of each state as earlier made, as solar farm in such a manner that it does not affect the economic viability of each state or other sector of economy (Williams & Carl, 1990). North central states of Nigeria have the potential of generating a total of 29,168.26 MW of electrical energy which quadruplet of current installed capacity of other forms of energy generation. Niger state has the highest potential of generating a total of 9,132.93 MW of electrical energy closely followed by Kwara state with 4,404.23 MW then Benue state with 4,247.91 MW while FCT has the least potential of generation with 874.87 MW. From foregoing, it can be seen that amount of solar energy potentials in each part of the state is a function of land mass i.e. it is proportional to the land area of each state (Branosiki *et al*, 1995).

CONCLUSION

The trend of results obtained and analysis made thereof shows that solar energy potential of each location is a function of its land mass /area and with just 0.1% of land area sourced from non-economic viable locations across the states deployed as solar panel farm for solar energy for electrical energy generation, North central, Nigeria has the potential of generating 29,168.26 MW of electrical energy which by far is more than the current electrical energy demand of the entire country.

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