Original Research Article

SOLAR ENERGY POTENTIALS OF SOME SELECTED LOCATIONS IN NORTHEASTERN NIGERIA.

Abstract

Gombe (latitude 10° 16' 59.9988" N and longitude of 11° 10' 0.0012" E), Jalingo (latitude 8° 53' 34.2672" N and Longitude 11° 22' 37.74" E) , Damaturu (Latitude 11° 44' 49.1856" N and Longitude 11° 57' 58.2912" E) and Bauchi (latitude 10° 18' 50.9724" N and longitude 9° 50' 46.6152" E) are towns located in northeastern Nigeria. The solar energy potentials of a location varies with latitude, altitude and climatic condition. In this work the solar energy potentials of these four locations are obtained from a monthly solar irradiation data obtained for a period of 10 years, a monthly, daily and annual solar irradiation is obtained for each of these locations. An average daily solar irradiation of 5.8977kWh/m^2/day, 5.9026 kWh/m^2/day, 6.0337 kWh/m^2/day and 5.9821kWh/m^2/day and an annual values of 2154.44kWh/m^2/yr, 2056.17kWh/m^2**yr,** 2202.30kWh/m^{2}yr and 2150.60kWh/m^{2}yr for Gombe, Jalingo, Damaturu and Bauchi respectively. These locations has very similar atmospheric conditions and hence a closer range of solar energy potentials compared to places like Lagos, Onitsha and Sapele in Delta state with (4.42kWh/m^2/day), (4.43kWh/m^2/day, and 5.31 kWh/m^2/day respectively. Renewable energy like solar can be harnessed for the generation of cheap, clean and environmentally friendly energy using photovoltaic cells to generate electricity or thermal heat collectors and concentrating solar collectors for cooking and solar water heating, for domestic and industrial use.

Keywords : Renewable Energy, Solar Energy Potentials, Solar Irradiations, Solar Energy, Sunlight.

1.0 Introduction

Solar energy is one of the renewable sources of energy; energy that continues to replenish faster than the rate at which they are utilized, renewable energy are clean, cheap and environmentally friendly (Shaikh *et. al.,* 2017). Wind, biomass and hydro-electric energy are other example of renewable energy sources.

The extraterrestrial solar insolation of 1367W/m^2 is constant throughout but atmospheric scattering, absorption and reflection by air molecules, dust particles and water vapour affects the intensity of the incoming sunlight irradiation. The intensity of sunlight energy vary from one location to another, it depends on some factors like latitude, altitude of the locations, climatic factors and atmospheric conditions, all affects the amount of solar energy of any geographical locations (Rathod, 2016). Locations with higher latitude tends to have higher solar irradiation and higher ambient temperatures than locations with higher latitude; around the north poles and south poles of the globe (Chiang *et. al.*, 2019).

Altitude also affects solar energy potentials of a location, location at higher altitude; far above the sea levels, tends to have lower ambient temperature whereas location with lower altitude tends to have higher temperature (Panjwani and Narejo, 2014). Ambient temperature affects the efficiency of a photovoltaic solar panels by a decrease of 0.5% per degree rise in panel temperature (Revati and Natarajan, 2016). Atmospheric absorption and scattering of solar irradiance by dust, air particles and water vapour affects the intensity of solar irradiance.

Clouds and other shading effects affects the intensity of solar irradiation at any locations, rainy seasons tends to have lower solar irradiations than dry seasons (Sarkar, 2016). Blowing winds also aid in the cooling of solar photovoltaic panels and hence winter months with higher wind speed is more favorable for PV systems than summer months with lower wind speed (Muzaffar, 2017).

Most locations have variation of these parameters (latitude, altitude, wind speed, atmospheric temperature, humidity and cloud covers) that determine solar energy potentials. Therefore there is a need to ascertain the amount of solar energy potentials for individual location for example Maiduguri has solar irradiations of 6.176kW/m^2/day (Muhammad et. al., 2015), Kano (6.08kWh/m2/day), Onitsha (4.43kWh/m^2/day) in south eastern Nigeria and Lagos (4.42kWh/m^2 /day) in south western Nigeria were evaluated by Chiemeka *et. al.* (2016).

Yola in northeastern Nigeria has between A maximum and minimum of 6.68kWh/m^2/day (in April) and 4.98kWh/m^2/day (in August) (Esbond and Funmilayo, 2020). Jos has between 7kWh/m2/day and 6.7kWh/m^2/day for the month of January (Ayegba and Tochukwu, 2017) while Abuja has maximum value of 6.27 kWh/m^2/day and minimum value of 4.19 kWh/m^2/day in the months of March and August respectively (Osueke *et. al.*, 2013). The purpose of this work is to determine the solar energy potentials of Gombe, Jalingo, Damaturu and Bauchi and in the process obtain the daily, monthly and annual solar irradiation data for these four locations in northeastern Nigeria. Renewable energy sources like solar has environmental and health benefits, it provide cheap, clean and environmentally friendly energy, a good sources of electricity for remote use in agriculture and for rural settlements: street lighting, sources of water for farm animals and irrigation, egg incubation in poultry farming, electrical fending and vaccine refrigeration among others.

2.0 THEORETICAL BACKGROUND

2.1 Variation of Solar Power Output

The amount of solar irradiance incident on surface per unit area called insolation vary from one location to another with latitude, altitude, atmospheric absorption and scattering by air particles and water vapours (Rathod, 2016). Location with lower latitude; closer to the equator tends to have higher solar irradiations than location far away from the Equator, the equatorial region of the globe comparatively have more sunlight hours and average ambient daily temperatures than locations far away from the equator like the tundra in other polar regions of the globe (Chiang *et. al.*, 2019).

The amount of sunlight intensity reaching a place depends on the latitudes, altitudes, atmospheric scattering and absorption by water vapour, gaseous particles and dust particles (Rathod, 2016). The thickness of the atmosphere during a time of the day or season of the years affects the sunlight energy potentials at any point. The thicker the atmosphere; the more the presence of water, vapour and dust particles (to scatter and absorb incoming solar rays) the lower the solar irradiance and lighter the atmosphere (absence of water vapour and dust particle) the higher the solar irradiance. Presence of cloud cover, cloud cover will out-rightly block the solar irradiance received and hence months of the wet season tends to have less irradiance than months of the dry season (Sarkar, 2016).

2.2 Photovoltaic Effects

Photovoltaic system is a process where sunlight energy is converted to electricity directly when a solar panel is exposed to sunlight. A phenomenon where electric voltage or current is generated when solar cell or PV cell are exposed to sunlight. Solar cells do not need fuel to produce electricity or have any mechanical part before they can generate electricity. The amount of electric power that can be generated by a solar panel depends on the incoming solar irradiance and the temperature of the solar panel. The efficiency of a solar panel increases with a decrease in cell temperature by about 0.5% per a degree rise in temperature and degrade also by about 0.5% annually as it ages (Revati and Natarajan, 2016). The most common types of solar cell are the silicon types but other technologies like cadmium telluride (CdTe), copper indium gallium selenide (CIGS) among others (ohorhoro *et. al.,* 2016).. Photovoltaic system can generate clean, cheap and free energy when harnessed.

2.3 Solar Thermal System

The sunlight energy come inform of heat and light, the heat part can be harnessed and utilized for domestic use. Thermal collector are devices absorb sunlight light energy and convert to heat which can be used for cooking, boiling and drying (Kasaeian *et. al., 2017)*. Common example of devices using sunlight energy for cooling and heating are solar cookers, solar oven, solar water heaters, solar dryers among others. Solar heating can be used in industries like pharmaceuticals and drug, paper, leather and textiles. A concentrating solar system uses a reflecting surfaces to concentrate the sunlight to a single spot or comparatively small area. These are system that uses larger reflecting mirrors or lenses to concentrate a large area of sunlight into a receiver(Blanco and Santigosa, 2016). Electricity can be generated when the concentrated heat is used to heat a steam turbine connected to electric generator. A concentrating system are far more efficient than flat plate collector, can concentrate temperature to about 200^{o}C (Maio *et. al.*, 2020) which several times higher than ambient temperature. A good example of concentration solar system are the parabolic through and dish solar water system.

2.4 Sunlight Energy

Sunlight is the primary source of energy on the earth, the sun utilizes nuclear process to generate enormous amount of energy, several million tons of mass of atom is converted to energy in a nuclear fusion reaction in the sun, where hydrogen atoms are converted to helium atoms (Paul, 2019). About 1.08×10^{8} GW of energy from the sun reaches the earth on a day bases which is about 8000 times of the energy needed on the earth for industrial, commercial and residential use (Paul, 2019). Therefore the energy of the sun is sufficient for global energy requirement. The energy of the sun comes in two form; visible light spectrum and infrared (heat) spectrum. The visible part of the solar spectrum can be converted to electricity using photovoltaic principle where sunlight energy is converted directly into electrical energy. The infrared part is converted into heat energy using solar thermal collectors.

3.0 Materials and Method

3.1 Materials

1. HP laptop computer.
2. PVGIS CODE..
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3.2 Method

A solar irradiation data is obtained from PVGIS-CODE for a period of 10 years from 2007 to 2016. Monthly solar irradiation and annual solar irradiation were obtained for each year from 2007 to 2016. Annual daily average is then obtained by dividing the annual solar irradiation by number of days in a year, leap years are taken into consideration. Mean monthly and annual is then obtained for each of the four locations. The input parameters are the latitude and longitude of the location in decimal forms.

3.3 PVGIS CODE

Photovoltaic geographical information system is a renewable simulation package that can predict the photovoltaic power output of any solar panel in Africa, Europe and Asia (Huld *et. al.,* 2006).. It has two solar radiation database, the surface solar radiation dataset-Heliosat (SARAH) and surface application facility on climate monitoring (CMSAF) database.

3.4 Description of the Study Area

3.4.1 Bauchi

Bauchi is located in northeastern Nigeria, on latitude 10° 18' 50.9724" N and longitude 9° 50' 46.6152" E, has an elevation of 616 m above sea level.. Bauchi has two season, the wet and dry season, the wet season lasting for about 4.6 months starting the 16^{th} of May o the 3rd October and a dry season lasting for about 7.4 months starting from 3^{rd} October to 16^{th} of May. Bauchi has an annual average temperature of 57°F to 100°F and is rarely below 51°F or above 104°F (Weathersparks, 2022).

3.4.2 Gombe

Gombe is located in northeastern Nigeria, on latitude 10° 16' 59.9988" N and longitude of 11° 10' 0.0012" E, has an elevation of 461 m above the sea level. Gombe has two seasons, rainy and dry season, the rainy season lasts *4.5 months*, starts from May 22 *to* October 6, and the dry season lasts *7.5 months*, starts from *October 6* to *May 22*. Gombe has an annual average temperature ranging from *57°F* to *100°F* and is rarely below 52°F *or above* 105°F (Weathersparks, 2022).

3.4.3 Jalingo

Jalingo is located in northeastern Nigeria, on latitude 8° 53' 34.2672" N and Longitude 11° 22' 37.74" E, has an elevation of 220 m above the sea level. Jalingo has two seasons, the wet and dry seasons, the wet seasons starts last for *6.1 months*, starts from *April 18* to *October 21 and the dry season* lasts *5.9 months*, from October 21 *to* April 18. Jalingo has an has an annual average temperature ranging from *61°F* to *99°F* and is rarely below 56°F or above 105°F (Weathersparks, 2022).

3.4.4 Damaturu

Damaturu is located in northeastern Nigeria, on latitude 11° 44' 49.1856" N and Longitude 11° 57' 58.2912" E, has an elevation of 371m above season level. Has two season, the wet seasons and dry season, the wet season lasts 3.9 months, starting from June 3 *to* September 30 while the drier season lasts 8.1 months, from September 30 *to* June 3. *The temperature typically varies* from *58°F* to *104°F* and is rarely below 52°F or above 109°F (Weathersparks, 2022).

4.0 Results and Discussion

4.1 Results

The monthly solar irradiation data for a period of 10 years (2007-2016) as well as the daily average and annual values for Gombe (latitude 10° 16' 59.9988" N and longitude of 11° 10' 0.0012" E), Jalingo (latitude 8° 53' 34.2672" N and Longitude 11° 22' 37.74" E) , Damaturu (Lattitude 11° 44' 49.1856" N and Longitude 11° 57' 58.2912" E) and Bauchi (latitude 10° 18' 50.9724" N and longitude 9° 50' 46.6152" E) are obtained and presented in table 1, 2, 3 and 4 respectively. The daily average as well as the annual values are also obtained.

Table 1: The Monthly Solar Irradiation Data For Gombe From 2007 To 2016.

Months|Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean Monthly
January	205.57	198.71	205.22	208.27	211.09	211.67	200.2	201.8	206.8	211.33	206.066
February	182.19	204.46	192.62	195.73	174.2	199.51	197.18	193.58	193.23	207.53	194.023
March	215.13	208.64	205.04	204.78	215.65	213.66	206.97	190.04	202.3	194.53	205.674
April	178.33	170.45	166.63	181.94	183.24	193.6	177.2	183.23	206.18	196.97	183.777
May	161.45	173.37	166.27	165.08	173.71	172.81	175.21	167.59	184.56	176.33	171.638
June	157.04	151.37	153.27	153.14	156.01	164.48	154.57	165.41	157.84	163.3	157.643
July	139.76	149.23	150.04	135.3	155.35	147.99	157.99	149.91	161.38	147.45	149.44
August	124.25	132.85	142.4	133.81	123.37	142.88	126.49	138.76	154.12	146.34	136.527
September	161.88	160.36	170.8	151.44	154.64	167.59	167.39	156.66	152.6	168.51	161.187
October	194.98	200	169.92	180	173.48	184.97	190.58	189.27	188.65	198.24	187.009
November	186.44	197.85	192.09	194.71	203.18	194.03	197.21	199.53	198.86	201.37	196.527
December	204.28	207.52	207.54	206.63	209.97	208.39	203.97	203.3	198.06	199.67	204.933
Annual	2111.3	2154.81	2121.84	2110.83	2133.89	2201.58	2155	2139.08	2204.58	2211.57	2154.444
Daily	5.784384	5.88746	5.81326	5.7831	5.84627	6.01525	5.904	5.860493	6.039945	6.042541	5.902586301

Table 2: The Monthly Solar Irradiation Data for Jalingo From 2007 To 2016.

Month	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean Monthly
January	213.03	205.6	208.98	213.85	216.86	215.59	207.6	206.13	219.27	217	212.392
February	188.17	210.02	192.85	200.84	170.75	193.65	197.8	196.72	190.92	209.98	195.165
March	209.45	202.07	200.74	204.69	217.42	218.28	206.2	191.53	189.06	184.45	202.389
April	174.69	167.29	161.1	183.47	176.14	183.78	174.5	181.95	203.31	183.68	178.987
May	164.08	166.43	162.04	152.61	150.79	164.53	171.3	159.06	170.1	158.82	161.978
June	131.58	131.24	143.5	142.71	141.48	148.12	145.8	147.84	132.19	142.19	140.661
July	124.97	133.37	136.53	116.52	132.9	124.19	125	116.57	134.13	134.5	127.867
August	112.7	119.16	124.56	118.02	114.5	117.79	100.7	108.82	126.3	127.27	116.986
September	144.46	137.6	151.52	125.28	122.26	139.41	151.1	139.94	135.2	153.7	140.05
October	170.76	189.21	158.62	155.06	167.94	172.7	176	173.54	168.78	181.21	171.378
November	191.24	202.76	190.22	191.56	207.58	198.9	200.2	192.91	198.6	203	197.695
December	212.24	213.93	214.96	213.54	215.23	213.38	203.5	211.39	202.01	206.06	210.626
Annual	2037.37	2078.68	2045.62	2018.15	2033.85	2090.32	2059.6	2026.4	2069.87	2101.86	2056.174
Daily	5.581836	5.67945	5.60444	5.52918	5.57219	5.71126	5.6428	5.551781	5.670877	5.742787	5.633353425

Table 3: The Monthly Solar Irradiation Data For Damaturu From 2007 To 2016.

Month	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean Monthly
January	205.87	197.06	203.79	209.77	209.25	212.57	200.8	199.73	206.7	211.97	205.748
February	190.01	205.13	197.65	196.71	177.29	204.49	198.2	197.92	194.46	209.11	197.099
March	219.22	218.89	218.36	213.57	222.15	223.16	209.1	192.7	208.96	200.92	212.704
April	178.66	187.42	180.49	188.54	192.04	195.56	187.6	187.47	210.02	192.39	190.017
May	175.75	176.07	174.94	182.84	181.36	175.51	180.1	170.22	187.33	178.48	178.259
June	156.48	154.75	156.04	161.13	162.26	160.85	162.8	169.94	168.32	158.77	161.138
July	151.31	149.59	154.71	130.65	166.61	151.85	159.6	152.24	159.33	153.97	152.985
August	131.76	140.15	148.89	142.66	141.11	151.37	141.2	153.53	161.05	153.14	146.482
September	168.15	164.41	177.08	155.72	158.38	178.3	169.4	162.61	168.51	175.34	167.794
October	199.41	204.38	169.91	183.28	182.01	189.14	197.7	191.81	196.45	202.95	191.703
November	187.99	203.88	189.26	193.24	204.2	197.46	196.6	193.6	199.14	198.17	196.356
December	200.92	205.54	204.53	203.95	207.44	206.27	198.9	200.68	197.45	194.53	202.018
Annual	2165.53	2207.27	2175.65	2162.06	2204.1	2246.53	2202	2172.45	2257.72	2229.74	2202.303
Daily	5.932959	6.03079	5.96068	5.92345	6.03863	6.13806	6.0328	5.951918	6.185534	6.092186	6.033706849

Table 4: The Monthly Solar Irradiation Data For Damaturu From 2007 To 2016.

Month	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean Monthly
January	205.77	196.01	203.99	210.49	210.62	212.97	200.9	204.16	210.76	214.85	207.049
February	189.18	205.38	195.82	197.91	179.69	203	197	196.39	193.79	210.51	196.867
March	212.71	213.59	209.65	206.25	215.22	217.24	205.2	191.18	206.42	192.67	207.01
April	173.1	171.02	169.03	183.54	186.57	187.63	177.1	181.33	207.57	194.46	183.137
May	161.92	169.03	171.07	162.58	166.58	170.85	173.8	166.23	176.93	171.5	169.051
June	159.43	152.05	146.28	153.91	151.98	157.83	149.9	165.82	151.74	160.05	154.903
July	140.37	141.54	146.13	131.24	151.09	146.78	150.4	145.28	154	138.15	144.496
August	129.58	131.79	149.08	142	128.6	147.51	128.1	132.03	141.39	142.37	137.244
September	167.58	158.37	160.53	155.87	151.79	157.84	166.5	161.9	152.15	160.78	159.335
October	193.94	199.53	164.22	173.19	183.4	186.77	185.1	194.25	188.5	203.86	187.271
November	188.91	202.83	193.18	194.33	205.67	195.96	204	198.71	197.68	202.46	198.372
December	206.3	208.06	208.93	204.4	211.08	210.47	204.3	204.94	202.52	197.62	205.864
Annual	2128.79	2149.2	2117.91	2115.71	2142.29	2194.85	2142.3	2142.22	2183.45	2189.28	2150.599
Daily	5.832301	5.88822	5.80249	5.79647	5.86929	6.01329	5.8693	5.869096	5.982055	5.998027	5.892052055

4.2 Discussion

The average daily solar irradiance of Gombe, Jalingo, Damaturu and Bauchi is 5.8977kWh/m^2/day, 5.9026kWh/m^2/day, 6.0337kWh/m^2/day and 5.9821kWh/m^2/day respectively. The annual solar irradiance is 2154.44kWh/m^2/yr, 2056.17kWh/m^2**yr,** 2202.30kWh/m^{2}yr and 2150.60kWh/m^{2}yr for Gombe, Jalingo, Damaturu and Bauchi respectively. Gombe, jalingo and Bauchi has the month of January with highest solar irradiance while Damaturu has the month of March with the highest solar irradiance. The month of august has the least solar irradiance for all the four locations. Damaturu has the highest solar irradiance followed by Bauchi, Jalingo and least by Gombe.

4.2.1 Solar Energy Potentials of Gombe

The solar energy potentials of Gombe is 5.8977kWh/m2/day and an annual values of 2154.44kWh/m2/yr for Gombe on latitude 10° 16' 59.9988" N and longitude of 11° 10' 0.0012" E. Gombe has an average maximum monthly solar irradiation of 206.066kWh/m2 in the month of January and minimum average in the month August with a value of 136.527 kWh/m2. Gombe has a solar irradiation of 206.066kWh/m2, 194.023kWh/m2, 205.674kWh/m2, 183.777kWh/m2, 171.638kWh/m2, 157.643kWh/m2, 149.44kWh/m2, 136.527kWh/m2, 161.187kWh/m2, 196.527kWh/m2, and 204.933kWh/m2 for the months of January, February, March, April, May, June, July, August, September, October, November and December respectively. The 10 year data from 2007 to 2016 and mean monthly data as presented in Table 1.

4.2.2 Solar Energy Potentials of Jalingo

The solar energy potentials of Jalingo (latitude 8° 53' 34.2672" N and Longitude:11° 22' 37.74" E) 5.9026 kWh/m^2/day and an annual value of 2056.17 kWh/m^{2}yr with a peak monthly value in the month of 212.39 kWh/m^2 in the month of January and lowest value of 116.99 kWh/m^2 in the month of August.

Jalingo in Taraba state has a monthly solar irradiation value of 212.39 kWh/m^2 195.167 kWh/m^2, 202.39 kWh/m^2, 178.99 kWh/m^2, 161.98 kWh/m^2, 140.66 kWh/m^2, 127.867 kWh/m^2, 116.986 kWh/m^2, 140.05 kWh/m^2 kWh/m^2, 171.38 kWh/m^2, 197.70 kWh/m^2 and 210.63 kWh/m^2 for the months for the months of January, February, March, April, May, June, July, August, September, October, November and December respectively. The 10 year data from 2007 to 2016 and mean monthly data as presented in Table 2.

4.2.3 Solar Energy Potentials of Damaturu

The solar energy potentials of Damaturu (Latittude 11° 44' 49.1856" N and Longitude 11° 57' 58.2912" E) 6.0337 kWh/m^2/day and an annual value of 2202.30kWh/m^{2}yr with a peak monthly value of 212.70kWh/m^2 in the month of March and lowest value of 146.48kWh/m^2 in the month of August. Jalingo in yobe state has a monthly solar irradiation value of 205.748 kWh/m^2, 197.099 kWh/m^2, 212.704 kWh/m^2, 190.017 kWh/m^2, 178.259 kWh/m^2, 161.138 kWh/m^2, 152.985 kWh/m^2, 146.482 kWh/m^2, 167.794 kWh/m^2, 191.703 kWh/m^2, 196.356 kWh/m^2 and 202.018 kWh/m^2.for the months of January, February, March, April, May, June, July, August, September, October, November and December respectively. The 10 year data from 2007 to 2016 and mean monthly data as presented in Table 3.

4.2.4 Solar Energy Potentials of Bauchi

The solar energy potentials of Bauchi (latitude 10° 18' 50.9724" N and longitude 9° 50' 46.6152" E) 5.9821kWh/m^2/day and an annual value of 2150.60kWh/m^{2}yr with a peak monthly value of 207.05kWh/m^2 in the month of January and lowest value of 137.24kWh/m^2 in the month of August. Bauchi in Bauchi state has a monthly solar irradiation value of 207.05 kWh/m^2, 196.87 kWh/m^2, 207.01 kWh/m^2, 183.14 kWh/m^2, 169.05 kWh/m^2, 154.90 kWh/m^2, 144.50 kWh/m^2, 137.24 kWh/m^2, 159.33 kWh/m^2, 187.27 kWh/m^2, 198.37 kWh/m^2 and 205.86 kWh/m^2 for the months of January, February, March, April, May, June, July, August, September, October, November and December respectively. The 10 year data from 2007 to 2016 and mean monthly data as presented in Table 4.

5.0 CONCLUSION

The solar energy potentials of Gombe is 5.8977kWh/m^2/day, Jalingo has solar energy potentials of 5.9026 kWh/m^2/day, Damaturu has 6.0337 kWh/m^2/day while Bauchi has 5.9821kWh/m^2/day. These lies within the range of 3.5kWh/m^2/day to 7.0kWh/m^2/day for coastal areas and far northern Nigeria (Lloije, 1997).

These four locations in northeastern Nigeria has very similar atmospheric conditions and hence a closer range of solar energy potentials compared to places like Lagos, Onitcha and Sapele in Delta state with (4.42kWh/m^2/day), (4.43kWh/m^2/day, (Chiemeka *et. al.*, 2016) and 5.31 kWh/m^2/day (Ohorhoro *et. al.,* 2016) respectively. Maiduguri in same northeastern Nigeria has 6.176kWh/m^2/day (Muhammad *et. al.*, 2015).

Renewable energy sources like solar can be harnessed for the generation of cheap, clean and environmentally friendly energy using photovoltaic cells to generate electricity or for solar cooking and heating using thermal heat collectors and concentrating solar collectors. Photovoltaic system can be used remotely in street lighting, electrical fencing for crops and animals, provision of water for drinking by farm animals and irrigations.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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