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ASSESSMENT OF GLOBAL SOLAR ENERGY POTENTIAL ACROSS KOGI STATE

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Abstract:The amount of solar energy reaching a particular location on the earth surface determines the amount of energy that can be generated by any solar power system installation in the location. As a result of the variation of global solar energy with locations, there is need to have an idea of the solar energy potentials at various locations of the country. The aim of this work is to examine the variation of global solar energy at Lokoja, Ogaminana, and Kabba, all in Kogi State, North-central, Nigeria. The data of maximum and minimum temperature obtained from weather online limited, and Hargreaves-Samanni's model were used for this work. From the results, the global solar radiation predicted for the three locations: Lokoja, Ogaminana and Kabba, were 5.686 kwh/m2/ day, 5.463 kwh/m2/ day and 4.968 kwh/m2 /day respectively. This study serves as a guide on effective solar power system installation for maximum energy generation for the study locations.

Keyword: Extraterrestrial, Global solar energy, Locations, Temperature, Photovoltaic.

1. INTRODUCTION

Solar energy is the energy emitted from the sun to the surface of the earth. It is a free form of energy and is abundant in almost all parts of the world. The interest in renewable energy sources has been on the increase, because according to (Moriaty & Honnery, 2012), if economic growth continues to rise, as seen in the past decades, the world energy demand is expected to rise to about 1000 EJ or more in 2050, both resource depletion, pollution, green house gas emission and possible climate change will necessitate a shift from our continuing use of conventional fossil and nuclear fuels. Solar energy is a radiant light and heat from the sun, that is Harnessed using a range of ever-evolving technologies such as solar heating, photovoltaic, solar thermal energy, solar architecture, molten salt power plants, and artificial photosynthesis (Anderson & Palkovic, 1994).The amount of solar radiation over a place determines the type of crops that can survive in such a place. Also, in terms of animal rearing, the amount solar radiation over an area determines the type of animals or livestock that can be reared in the area. In terms of power supply, the amount of solar radiation available in an area is an important factor to be considered before the installations because the power output provided by a given installed solar photovoltaic system in one particular state in Nigeria may not be obtained when such system is installed in another state, with all other factors remaining constant. This is as a result of variation of solar radiation with locations, as well as topography (Ayegba, et. al., 2016). Osueke et.al, (2013), studied the global solar radiation for Enugu, Lagos, Abuja and Maiduguri and observed that, Maiduguri experienced the greatest solar irradiance range of 5.5-6.7 kwh/m2/day, except for the months January, November, and December.Mathias, (2013), reported that, 174 pet watts (PW) of energy come in form of solar radiation (or insolation) to hits the atmosphere. Almost one-third of this is reflected back into space. The rest, 3850000 exajoules (EJ) of energy is absorbed by the atmosphere, clouds, oceans, and land. Solar energy source is not only a sustainable form of energy for human consumption, but it is also renewable, (at least until the sun runs out in billions of years). Solar power can be used to generate electricity; it is also used in relatively simple technology of heating water. According to Annette et.al., (2008), wind power is the most sustainable renewable energy technology but has high relative capital cost. Saeed & Olivia (2006) reported that, solar power is the best choice for sustainability and renewability of energy in developing countries, as it can be used in the remote regions with high sun's rays. Solar energy is one of the best renewable sources with least negative environmental impacts, and solar energy policies plays a significant role in motivation and interest for the development and use of renewable energy technologies (Solangi, et.al, 2011). Many researchers, scientists and engineers have carried out related works in various parts of the country but the present ecological problem as well as global warming makes the work a continuous one. Chiemeka & Chineke (2009), made use of minimum and maximum temperature data obtained from 1st - 30th November, 2007 using the maximum and minimum thermometers placed in the Stevenson screen at 1.5 m above ground level and observed that, the mean solar power potential obtained for the period over Uturu was 2.45 ± 0.29 kwh/m2/day. Adedoja et.al., (2015), in their study of the seasonal variation of global solar radiation reported that, the surface temperature is not a direct measurement of sun temperature on earth, but a measure of the atmospheric response to solar radiation. The aim of this study is to determine the global solar energy potential of the study areas, (Lokoja, Kabba, and Ogaminana), for maximum solar energy generation.

2.0 STUDY AREAS

The three study areas are Lokoja, Ogaminana, and Kabba, all in Kogi state, North –central part of Nigeria. Lokoja is the head quarter of Lokoja local government, as well as the capital city of Kogi state. Lokoja is also known as the confluence city, because that is where rivers Niger and Benue meet. Kabba is the head quarter of Kabba/Bunu local government, while Ogaminana is the headquarters of Adavi local government. The location of Lokoja is on Latitude 7.80236, longitude 6.743; Kabba is on Latitude 7.8287, longitude 6.0731, while Ogaminana is on Latitude 7.51 and longitude 6.21.

3.0 MATERIALS AND METHODS

3.1. Materials

The material used for this research work includes; a GPS receiver to take the coordinate of the study location and the data of maximum and minimum temperatures for the month of April, 2017, obtained from the website of weather online limited. It also makes use of Microsoft excel package.

3.2. Methods

This work makes use of the model called Hargreaves-Samanni model equation. The model uses data of minimum and maximum air temperatures on the location or study area. It is given as:

$$R_s = K_{RS}\left(\sqrt{T_{\max} - T_{\min}}\right)R_a \quad \text{--------------------- 1}$$

Where, T_{max} represents the maximum temperature, T_{min} represents minimum temperature, R_a represents the extraterrestrial solar radiation and K_{Rs} is the adjustment coefficient. K_{Rs} has an approximate value of 0.16 for 'interior' locations and 0.19 for ‘coastal’ locations, situated on the coast of a large land mass and where air masses are influenced by a nearby water body, Hargreaves & Samanni (1982).

3.2.1 Calculation analysis

2.2.1.1 Global solar radiation

To determine the Global solar radiation, the following steps are followed:

3.2.1.1 Calculation of solar radiation declination: Solar radiation declination is defined as the angle made between a ray of the sun, when extended to the centre of the earth and the equatorial plane. The solar radiation declination has the formula given as;

$$\delta = 0.409 Sin\left(\frac{2\pi}{365}J - 1.39\right) \quad \text{---------------------------- 2}$$

Where J is the number of the day in the year between (1 January) and 365 or 366 (31 December) and δ is solar radiation declination in radian.

3.2.1.2 Calculation of inverse relative distance Earth-sun: Inverse relative distance Earth-sun is the inverse distance of the sun relative to the earth at a location. Inverse relative distance Earth-sun is determined using the formula given as;

$$d_r = 1 + 0.033 Cos\left(\frac{2\pi J}{365}\right) \quad \text{---------------- 3}$$

3.2.1.3. Calculation of sunset angle: Sunset angle is the angle of the daily disappearance of the sun below the horizon due to the rotation of the earth. Sunset time is the time in which the trailing edge of the sun’s disk disappears below the horizon. It is calculated using the formula:

$$\omega_s = Cos^{-1}\left(-\tan(\varphi)\tan(\delta)\right) \quad \text{----------------- 4}$$

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Where ω_s is sunset angle in radian, δ is the solar radiation declination in radian, and φ is latitude angle of the location in radian.

3.2.1.4 Calculation of extraterrestrial solar radiation: Extraterrestrial solar radiation is the intensity or power of the sun at the top of the earth's surface. The extraterrestrial radiation has the formula given as;

$$R_a = \frac{24(60)}{\Pi} G_{sc} d_r \left[w_s Sin(\varphi) Sin(\delta) + Cos(\varphi) Sin(w_s) \right] \quad \text{------ 5}$$

Where R_a is extraterrestrial radiation, d_r is the inverse relative earth-sun distance, φ is the latitude angle, w_s is the sunset angle, and Gsc is solar constant = 0.0820 MJ m^{-2} min^{-1} or 1367wm^{-2}.

3.2.1.5 Calculation of Global Solar Radiation: Global solar radiation is the total amount of solar energy received by earth's surface. Global solar radiation is the sum of the direct, diffuse and reflected solar radiations. It is determined using the Hargeaves-Samanni equation given as;

$$R_s = K_{RS} \left(\sqrt{T_{max} - T_{min}} \right) R_a \quad \text{--------------------- 6}$$

In this work, Lokoja and Kabba have K_{Rs} value of 0.19, and Ogaminana has K_{Rs} value of 0.16 based on their locations or proximity to water body.

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

Table1: Maximum and minimum temperatures, Extraterrestrial solar radiation and global solar radiation of Lokoja, (Lat. 7.80236, Long. 6.743 and Ks = 0.19).

S/N	Tmax (^{0}c)	Tmin (^{0}c)	Ra(Mj/m^2day)	Rs(kwhr/m^2)
1	36	25	37.720	6.603
2	34	26	37.734	5.633
3	36	25	37.747	6.607
4	35	26	37.758	5.978
5	35	26	37.767	5.980
6	34	26	37.775	5.639
7	37	26	37.780	6.613
8	34	26	37.784	5.640
9	33	25	37.786	5.641
10	33	25	37.786	5.641
11	34	25	37.784	5.982
12	33	27	37.781	4.884
13	32	26	37.775	4.884
14	33	26	37.769	5.274
15	32	25	37.760	5.273
16	35	25	37.751	6.301
17	39	25	37.739	7.453
18	34	26	37.727	5.632
19	35	26	37.712	5.971
20	34	26	37.697	5.627
21	32	26	37.680	4.871
22	35	26	37.662	5.963
23	32	26	37.642	4.866
24	32	26	37.621	4.864
25	31	25	37.600	4.861
26	35	25	37.577	6.271
27	32	26	37.553	4.855
28	32	25	37.528	5.240
29	33	25	37.502	5.598
30	34	25	37.476	5.934

Table 2: Maximum and minimum temperatures, Extraterrestrial solar radiation and global solar radiation of Kabba, (Lat. 7.8287, Long. 6.0731, and Ks = 0.19).

S/N	Tmax (^{0}c)	Tmin (^{0}c)	Ra(Mj/m^2day)	Rs(kwhr/m^2)
1	33	24	37.719	5.029
2	32	24	37.734	4.743
3	33	23	37.747	5.305
4	32	24	37.759	4.747
5	34	24	37.768	5.308
6	33	24	37.775	5.037
7	33	24	37.781	5.037
8	32	24	37.785	4.750
9	32	24	37.787	4.750
10	32	24	37.787	4.750
11	32	23	37.785	5.038
12	33	24	37.782	5.038
13	32	24	37.777	4.749
14	33	24	37.771	5.036
15	31	24	37.763	4.440
16	33	23	37.753	5.306
17	36	22	37.742	6.276
18	33	24	37.729	5.031
19	34	24	37.715	5.301
20	33	24	37.700	5.027
21	33	25	37.683	4.737
22	34	24	37.665	5.294

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23	32	24	37.646	4.732
24	31	24	37.625	4.424
25	31	24	37.603	4.422
26	33	24	37.581	5.011
27	32	24	37.557	4.721
28	32	23	37.532	5.004
29	32	23	37.507	5.001
30	33	24	37.480	4.997

Table 3: Maximum and minimum temperatures, Extraterrestrial solar radiation and global solar radiation of Ogaminana, (Lat 7.51, Long. 6.21, and Ks = 0.16).

S/N	Tmax (^{0}c)	Tmin (^{0}c)	Ra(Mj/m^{2}day)	Rs(kwhr/m^2)
1	33	24	37.724	5.030
2	34	20	37.736	6.275
3	34	21	37.747	6.049
4	35	20	37.756	6.499
5	33	22	37.763	5.566
6	36	20	37.768	6.714
7	35	22	37.772	6.053
8	32	24	37.773	4.748
9	34	21	37.773	6.053
10	35	18	37.771	6.921
11	34	22	37.767	5.815
12	34	24	37.762	5.307
13	33	24	37.755	5.034
14	33	24	37.746	5.033
15	33	24	37.736	5.031
16	33	24	37.724	5.030
17	39	25	37.711	6.271
18	35	24	37.696	5.557
19	37	25	37.680	5.801
20	34	25	37.663	5.022
21	38	25	37.644	6.032
22	37	25	37.624	5.793
23	32	24	37.602	4.727
24	32	24	37.580	4.724
25	31	24	37.556	4.416
26	33	24	37.532	5.004
27	31	24	37.506	4.410
28	32	23	37.480	4.997
29	32	24	37.452	4.708
30	34	24	37.424	5.260

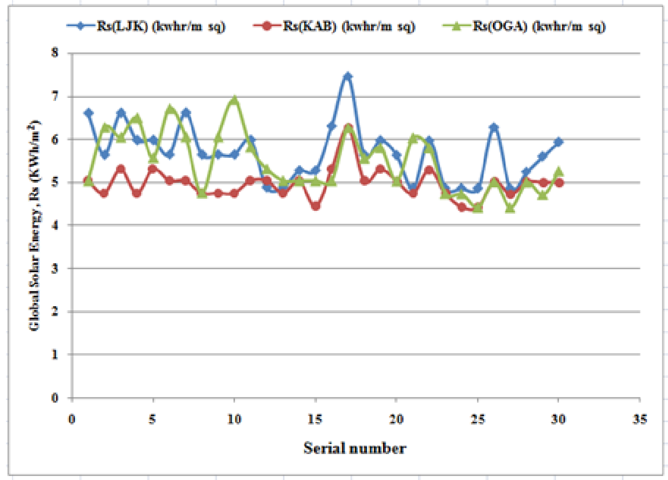

Fig. 1: Graph of Global solar energy of the study areas

(Where Rs (Ljk), Rs (Kab) and Rs (Oga), represent global solar energy potential of Lokoja, Kabba and Ogaminana respectively).

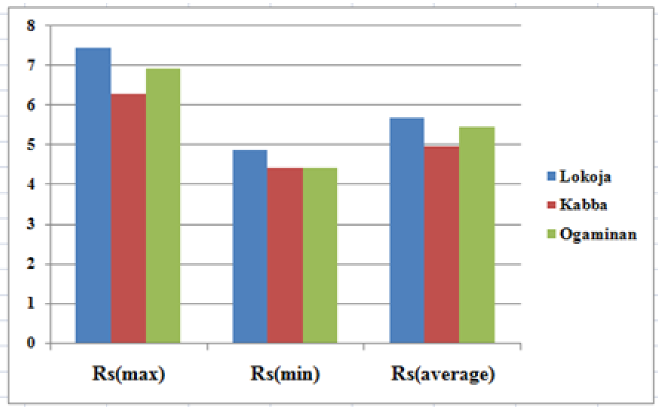

Fig. 2: Chart of the maximum, minimum and average global solar energy of the study locations.

4.2: DISCUSSION

Tables 1, 2, and 3 show the calculated parameters of the three locations- Lokoja, Kabba, and Ogaminana all in Kogi state. The global solar radiations of the locations were estimated using Hargreaves-Sammani's model. These parameters; solar radiation declination, inverse relative distance Earth-sun, sunset angle, extraterrestrial solar radiation, and Global Solar Radiation were gotten using their respective formulas, and the computations were done using Microsoft excel package worksheet. The global solar radiation gotten was further converted to global solar energy to give the actual amount of solar energy that can be generated in these locations. Hargreaves-Sammani's model is a model of global solar radiation prediction that makes use of only the minimum and maximum air temperature of the location. The data used for this work is for the month April, 2017, and the minimum and

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maximum temperature data used was obtained from the website of weather online limited.From the results, it is clear that, Lokoja has the highest global solar energy potential, followed by Ogaminana and the least is Kabba, as depicted in figure 2. As shown in Tables 1 and 3, the global solar energy of Lokoja and Ogaminana were equal at some points, with that of Ogaminana even higher than that of Lokoja at some points. However, the global solar energy of Kabba was never equal to or greater than that of Lokoja, except for just a day, as shown in Tables 1 and 2.Generally, the average global solar energy potentials of Lokoja, Ogaminana, and Kabba were 5.686 kwh/m2, 5.463 kwh/m2, and 4.968 kwh/m2/day respectively. This means that, with the present solar energy conversion efficiency of about 10%, (Markus et.al., 2006), the average global solar energy that can be generated in Lokoja, Ogaminana and Kabba per square meter of an exposed area of solar generating source, such as solar panel will be approximately 0.57 kwh, 0.55 kwh and 0.50 kwh respectively. Hassan & Onimisi (2013), studied the global solar energy potentials at the Nigeria Defense Academy Kaduna, for the month of March, April, and May, 2012, and found that, there was a monthly variation, with mean values of 20.11 ± 0.04, 20.14 ± 0.04, and 20.18 ± 0.04 MJ/m2/day respectively. The global climate and energy project (GCEP, 2006), reported that, the solar-to-electric efficiency of solar thermal technologies varies largely depending upon the solar flux concentration factor, the temperature of the thermal intermediary, and the efficiency of the thermal cycle for the production of mechanical work to electricity. The implication of the result is that, for the same capacity of installed solar power system in these three locations, the energy generated by the power system in Kabba will be less than that generated by the system in Ogaminana and Lokoja will generate the highest. Iziomon & Mayer (2002), studied the global solar radiation for a low land and mountain site and observed that, the monthly mean values of global solar radiation for a low land and mountain site were within 2.5% and 3.4% respectively. Thus, additional solar panels and batteries will be required in Kabba and Ogaminana to equate their capacity to that of Lokoja. The knowledge global solar energy radiation can bring about the efficiency of PV panel, that is, for the panels to receives the maximum amount of incident solar radiation (Seyed et.al, 2017).

5.0 CONCLUSION

Hargreaves-Samanni's model has been used to estimate the global solar energy of the three locations; Lokoja, Ogaminana and Kabba, using the data of maximum and minimum temperatures for the month of April, 2017.From the result, it was observed that, Lokoja has highest global solar energy potentials, followed by Ogaminana, and Kabba having the least. Although, the global solar energy potential of Ogaminana was higher than that of Lokoja on some days, but the average global solar energy of Lokoja, Ogaminana and Kabba were; 5.686 kwh/m2 /day, 5.463 kwh/m2 /day, and 4.968 kwh/m2/ day respectively. The maximum and minimum global solar energy for the three study areas followed this same trend as Lokoja has the highest, followed by Ogaminana and Kabba being the least, as shown in figure 2.This study serves as a guide on a solar power system installation and the optimization of a PV panels efficiency for maximum energy generation in the study locations.

6.0 RECOMMENDATION

Although, April is supposed to be one of the months for rainy season, but the amount of rain experienced in the study areas during this period was very scanty. Therefore, I suggest that, similar work be carried out in these areas for the months of June, July and August, when the amount of rainfall is expected to be higher.

7.0 REFERENCES

1.Adedoja,O.S; Ayatunji, B.G.; Saleh U.A.; & Jatto,S.S.(2015). Diurnal and seasonal variation of global solar radiation at Anyigba, North-central Nigeria. International Journal of Engineering science and innovative technology (IJESIT) volume 4, issue 4. ISSN: 2319 – 5967.

2.Anderson Lorraine & Palkovic Rick (1994). Cooking with sunshine. Marlowe and company.

3.C. O. Osueke, P. Uzendu & I. D. Ogbonna (2013). Study and Evaluation of Solar Energy Variation in Nigeria. International Journal of Emerging Technology and Advanced Engineering.

4.GCEP (2006). An assessment of solar energy conversion Technologiesandresearchopportunities.http://www.sandia.gov.

/pv.

5.Hargreaves, G. and Samani, Z.(1982). Estimating potential evapotranspiration. Journal of Irrigation and Drainage Engineering.

6.Hassan I. & Onimisi M.Y.(2013). Assessment of the global solar energy potentials at the Nigeria Defense Academy (NDA) permanent site, Afaka Kaduna, Nigeria. American Chemical Science Journal 3(3); 232 -246. Science domain International. www.sciencedomain.org

7.I.U. Chiemeka & T. C. Chineke (2009). Evaluating the global solar energy potential at Uturu, Nigeria. International Journal of Physical Sciences.

7.K.H. Solangi; M.R.Islam; R.Saidur; N.A. Rahim & H.Fayaz (2011). A Review on global solar energy policy. Renewable and sustainable energy review 15, 2149 – 2163. www.elsevier.com/locate/rser.

8.Markus C.S.; David M.; Markus K.; Patrick D.; Christoph W.; Alan J.H. & Christoph J.B. (2006). Design Rule for Donors in Bulk-Heterojunction solar cells- Towards 10% Energy-conversion efficiency. Advanced materials, 18, 789 – 794. www.advmat.de.

9.Mathias Aarre Maehlum (2013). What is the potential of solar Energy?. Energyinformative.org/

10.M.G. Iziomon & H.Mayer (2002). Assessment of some global solar energy parameterization. Journal of atmospheric and solar Terrestrial physics, 64, 1631 – 1643. www.Elsevier.com/locate/jastp.

11.Moriarty, P., & Honnery, D. (2012). What is the global potential for renewable energy?. Renewable and Sustainable Energy Reviews, 16(1), 244-252

12.S. A. Ayegba N. O. Sampson Ibileke J. O Akintulerewa O. S L. S. Owa W. Desmond Fonyuy David-Ndahi A (2016). “Assessment Of Global Solar Radiation: A Case Study Of Abuja, Nigeria ”. International Journal of Innovative Research and Advanced Studies, 3 (13), 342-346.

13.Seyed Abbas M.M.; H.Hizam; & Chandima G. (2017). Estimation of hourly, daily and monthly global solar radiation on inclined surfaces. www.mdpi.com/journal/energies.

14.Saeed D. Foroudastan & Olivia Dees (2006). Solar power and sustainability in developing countries. Proceeding of the Internatiomal conference on renewable energy for developing countries.

15.http://www.weatheronline.co.uk

ISSN:-2349-3585 |www.ijrdt.org