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Article

Evaluation of Solar Energy Potentials in Minna, Niger State

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Abstract: This research work presents the analysis of Solar Energy in Minna and feasible utilization for power generation. Daily sun duration and minimum and maximum temperature was taken for two months, solar radiation varies according to season of the year. The extraterrestrial and solar radiation were computed for month of July and August as $R_a = 8.133 MJm^{-2}day^{-2}$ and $R_s = 1.108 MJm^{-2}\ day^{-1}$ and $R_a = 9.256 MJm^{-2}day^{-1}$, $R_s = 1.212 mJm^{-2}\ day^{-1}$ respectively. Considering present socio-economic environmental factors of conventional power generation, this study has shown a consistent and adequate solar radiation during seasons of intermittent solar radiation thus makes Minna a suitable location for adequate solar energy harvesting systems.

Keywords: Renewable Energy, Solar Radiation, Daily Temperature

1. Introduction

Renewable energy takes complete forms of energy produced from natural resources such as sunlight, wind, hydro power, biomas, biofuels, geothermal heat and tide. They are gotten from natural processes that are constantly replaced and each of the renewable sources has features that determine place and exactly how renewable energy are used (Oghogho, *et al* 2014).

The exhaustion of fossil fuels and harmful to the environment has caused universal worry in migrating to the exploitation of sun base energy. It could be one of the challenging form of renewable

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energies in term of cost presently that only some countries really shows serious concerned and the concern is of increase (Hasnainn et al 1995)

The way out of electrical energy shortage and over reliance on the exhausting non-renewable energy bases is to upsurge the use of renewable energy bases. The model of renewable energy was presented to tackle this problem and it was totally recognized as right model to cushion the effect of energy shortage (Azarpour et al 2012).

All the energy on earth comes primarily from solar energy. It is renewable, unlimited and environmental friendly. The main sources of power generation today are fossil fuels and nuclear reaction. The expected yearly daily average of overall solar radiation differs around 12.6 MJ/m^2/day (3.5 kWh/m^2/day) in the seaside region to about 25.2 MJ/m^2/day (7.0 kWh/m^2/day) close to that of desert, therefore the expected solar radiation is about 17,459,215.2 million MJ/day (17.439 TJ/day) of solar energy reaching the earth surface 923,768 km^2 land area. Provided there is an estimated average of 18.9 MJ/m^2/day (5.3 kWh/m^2/day) over the entire year, an average of 6,372,613 PJ/year (E1770 thousand TWh/year) of solar energy is estimated to reach the entire land space. Upon all this prospect by solar energy it does not gain ground in Minna, Niger state, the over energy combination even though the region has good and feasible prospect for solar applications ranging from stand-alone micro units to large scale grid linked applications. (Ohunakin *et al* 2014). However, solar street light is used in some areas in Niger state.

Though they are some challenge confronting the several ways of applications of solar energy, these includes, inconsistency and fluctuation of radiation; Sunlight based energy is a variable asset and its accessibility as a fuel source changes. Daylight length in Nigeria goes from a base 4 h in the South to 9 h/day in the Northern area of the nation (ECN-UNDP 2005). Secondly, the beginning investment cost, an essential hindrance to the improvement of sun powered energy innovation in Nigeria as a growing nation lies in the high beginning expenses, including high establishment costs with long recompense times (Karekezi and Kithyoma 2003). Thirdly, the running and maintenance costs, the nation needs alternating source of energy production like solar energy especially in the villages. The challenge with solar technologies at this time is the running and maintenance costs are significantly not affordable as result of technical know-how.

Therefore, the intended subscribers of these technologies which are people in the villages may be great affected and prevented from embracing by solar energy conversion system in the country due to uncertainties in the lack of technical backings. Lastly, insecurity of solar structure, the security situation in the country is major concern in every region, the most suitable areas like the northern part of the country where solar energy potential exploitation are in abundant is where the occupant and

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technical structures are being attacked on daily bases by insurgency in the last years and at the moment. This will discourage potential futures investor in solar energy installation in this region.

However, the ways out of those barriers, promising government strategy, ideal strategies are essential to long haul supportability of sun based energy advancement. Guaranteeing that laws are steady and authorized is imperative as potential financial supporters will require sensible conviction that key administrative arrangements set up for solar oriented exercises will stay steady, unambiguous and implemented, along these lines permitting the congruity of interest into what is to come. Furthermore, the current power levy is low; the duty is not market intelligent for productive interest in power age even with the current petroleum derivative fuel sources and henceforth will not energize any exchanges into sunlight based applications by any expected financial backer. Nonetheless, expanding the tariff system might be counter-gainful considering the way that bigger segment of the populace have a place with the low-pay level.

In the 1980s, selenium photovoltaic cells were developed that could convert sunlight into electricity with 1-2% efficiency but how the conversion was done was not understood then. Solar power therefore remained a curiosity for some time. In 1901, larger focusing collector in the form of truncated cone generated steam for a 4.5hp engine. Between 1907 and 1911, solar steam engine of several hp that were used for pumping water were built. According Liebowitz and Hanseth (1982) that by the middle of 1950s the efficacy of 45 and advanced 11% had been attained with silicon photovoltaic cells. Since that time, the awareness in solar power deepened. Throughout the late 1950s and 1960, the space program played important part in the progress of photovoltaic. The faultless sources of electric power used cells for satellite because they were better, lightweight and this may be potential energy requests dependably. Inappropriately, the cells were not applied globally because of the high cost of making them effective and easy to carry. (Jack, 1991).

Hoff and Cheney (2000) submitted that time scale and topographical place played a major rule on accessibility amount of solar energy. The duration of sun hours and therefore the radiations in diverse zones vary. The amount of sun power getting to the earth is about 1000W/m^2. The entire amount of energy that the earth receives daily is 1353W/m^2.

Solar radiation being plentifully present in Minna and other areas of Minna state, is one area of focus among the renewable energy resources. Minna north central Nigeria receives an average solar radiation of about 7.0kWh/m^2-day (25.2MJ/m^2/day) in the far North West and about 3.5kWh/m^2/day (12.6MJ/m^2/day) in the coastal latitudes (Ileoje, 1997). The various energy centers are making giant strides in production of solar energy technologies for direct harnessing of solar energy since the country is situated in the high solar radiation belt of the world. According to (Onyebuchi 1989) that approximate prospect of solar energy in the Country with 5% device transformation effectiveness is 5.0 x 1014 kJ of

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consumed energy yearly. The amount of oil produced yearly is equal 258.62 million barrels and around 4.2 x 105GWh of electrical power generated yearly in the country (Akinbami, 2001). Most persons in north central Nigeria dwell in remote villages where there are difficult topographies, no good roads, electricity grids and no easy access to fossil fuel energy resources. Actual harnessing of solar radiation using solar energy technologies to improve energy amount from fossil fuel energy resources would augment accessibility of energy for socio-economic actions and to enhance the living standard of the populist in the communities (Ilenikhena 2010). .

Minna is situated at latitude 9º36`N degree north suffers from lack of in sufficient electrical power supply, go through the same malaise as many rural villages in developing satellite town of the cities in the north central Nigeria. This has cause a number of able self-employ youth and some private companies to exceeds the metropolis to urban area where is there average power supply. This has negative effect on the economy of the city. The reason for this paper is to highlight how plenteous and availabilities and suggest solution of harnessing this energy source for power supply.

2. Materials and Methods

The maximum and minimum thermometer, dry and wet thermometer bulb and sunshine recorder, and sunshine cards where the instrument used in the research work. A minimum-maximum thermometer measured the minimum and maximum temperature over a desired time period.

Minimum and maximum thermometer was used to take daily temperature. The thermometer was positioned five feet above the ground, to avoid picking up excess heat from ground and if placed too high will likely have too cool temperature due to normal cool. Complete exposure to direct sunlight was avoided in order not to have excess higher temperature. It was positioned in the shade.

At the point when the temperature of air rises, the mercury in the thermometer extends and powers its way into the stem past it throat. When the bulb cooled none of the mercury over the throat would get once more into the bulb and afterward the length of the mercury stays as before. The finish of the mercury string farthest from the bulb enlists the Maximum temperature came to in a day.

In least the thermometer, when the temperature falls, the liquor section hauls the file towards the bulb end however when the temperature rises the liquor segment extends and runs past the record without upsetting it. Consequently the finish of the file farthest from the bulb gives the most minimal temperature accomplished in the day. The base temperature was perused and recorded at 0600GMT that is 7am local time, at this point it would have recorded minimal temperature during the evening. The instrument were set up as shown blow.

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Figure 1: Minimum thermometer setup

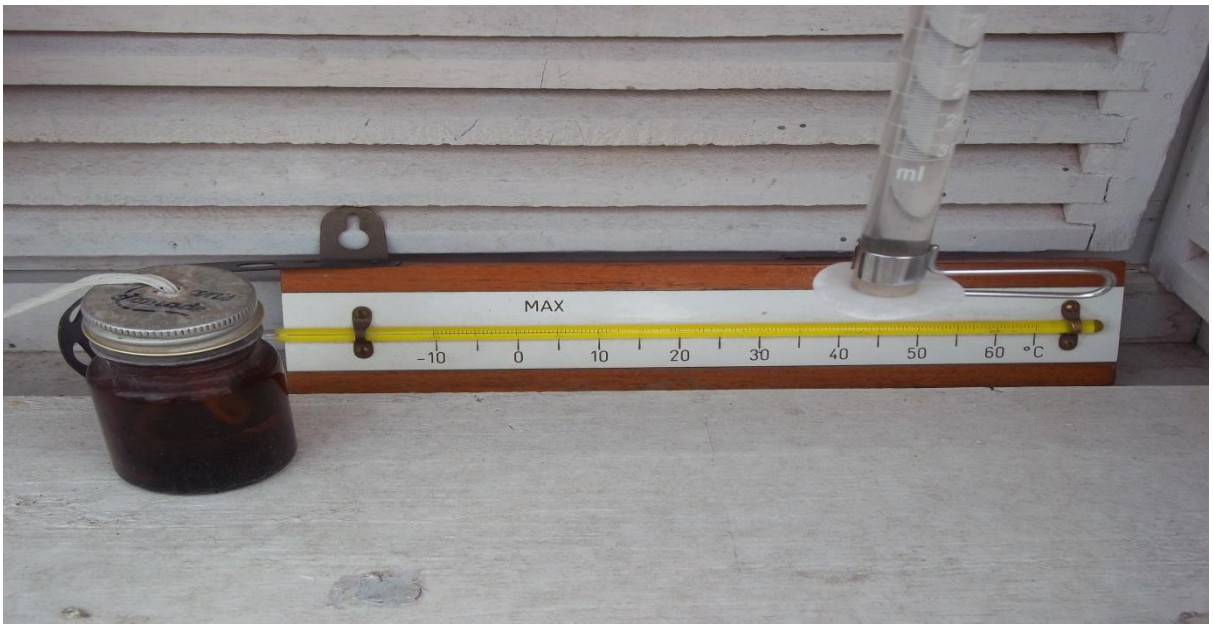

Figure 2: Maximum mercury-in-glass thermometer setup

2.1. Daily Light Hours Measurement

Campbell stokes sunshine recorder was used. It was mounted on a convenient height so it would be easy to measure and change card from sunshine recorder machine. It has three slot, the southern hemisphere, northern hemisphere and the position of equator. It is calibrated in degrees of different latitudes. It was positioned on east west direction because the sunrises on east and sunset on west. In each of the day the sunshine recorder was used, it will be position by 18:30GMT (Nigeria Time) in the evening the previous day with the sunshine cards. As the sun arise from east the rays of the sun stroked the convex lens of the sunshine recorder and the sun rays projected to the western side of the paper and burnt trace along graduated area and it continued till at noon where the center will being to burnt traced

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the center and as the sun goes down away from the center to the east the western side of the paper left burn trace till the sun set, the burn left trace marked on the paper for easy analysis of sunshine hours of the day. Care was taken when measuring the length of the sunshine recorder burnt card. The cards are graduated in hours. This was carried on daily bases from 1 July to August 31, 2019 the data obtained are shown on table 1.

Table 1: Mean weekly Daily daylight hours at Latitude 9º36 in Minna, Niger state for month of July and August 2019

Months	**Week 1**	**Week 2**	**Week3**	**Week 4**
July	50.4	49.7	51.2	51.6
August	52.8	51.3	51.7	52.6

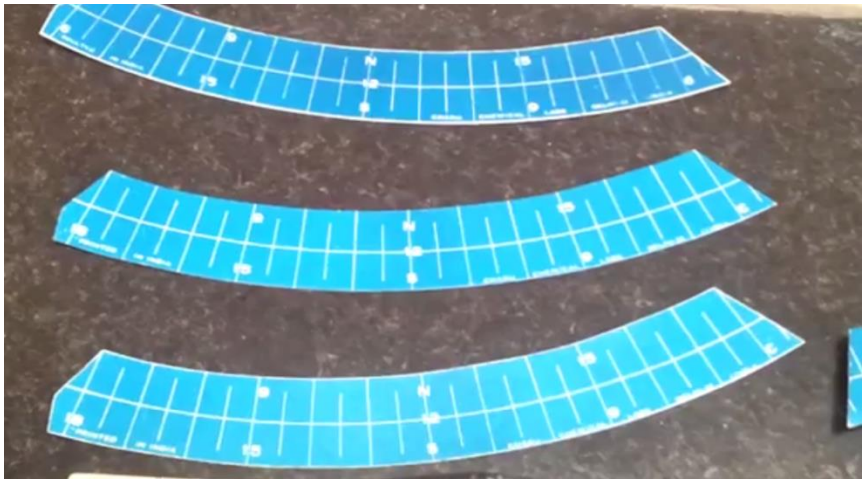

Figure 2. Sunshine recorder cards

2.2. Methods of Data Collection

The data of sunshine duration and temperature was collected on daily bases for period of two months using Campbell stokes sunshine hour's record and maximum and minimum thermometer respectively, however, data of daily temperature and sunshine duration was collected from NIMET Centre Minna for the year 2018.

2.3. Estimation of Solar Radiation

To determine the solar radiation from the temperature data of July in various local government areas of Niger state at latitude of 9º36`N and at 2m above sea level, the solar radiation for the month of July and August 2019 were actual reading taken on daily bases. The mean monthly maximum and minimum air temperature were readings obtained from Campbell Stoke.

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The extraterrestrial radiation was calculated using equation 1(Duffie and Bechman 2006).

$$R_a = \frac{24(60)}{\pi} G_{sc} d_r [\omega_s \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega_s)] \quad (1)$$

Where

R_a = extraterrestrial radiation [MJ m^{-2} day^{-1}]

d_r = inverse relative earth-sun

G_{sc} = solar constant = 0.0820 MJ $m^{-2}min^{-1'}$

ω_s = sunset hour angle [rad]

φ = latitude [rad] of Minna

δ = solar decimation [rad]

The solar decimation, sunset hour angle and inverse relative earth-sun were computed using equation 2, 3 and 4 respectively

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

$$\omega_s = \cos^{-1}[-\tan(\varphi)\tan(\delta)] \quad (3)$$

$$d_r = 1 + 0.033\cos\left(\frac{2\pi}{365}J\right) \quad (4)$$

Where J is the number of the days in the month of the year

The latitude, (φ) expressed in radians is positive for the northern hemisphere and negative for the southern hemisphere. The conversion from decimal degrees to radians is given in equation 5

Latitude = 9º36`N (degree, minute)

$$\frac{\pi}{180}x\left(\frac{36}{60} + 9\right) = 0.168 \text{ rad} \quad (5)$$

The Solar Radiation was the estimated using equation 6

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

where

R_s = solar radiation (MJ m^{-2} day^{-1})

R_a = extraterrestrial radiation [MJ $m^{-2}d^{-1}$]

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T_{max} = maximum air temperature [^oC]

T_{min} = minimum air temperature [^oC]

K_{RS} = adjustment coefficient (0.16, 0.19) [$^oC^{-0.5}$]

The adjustment coefficient K_{RS} is empirical and differs for interior or coastal regions. In this study, K_{RS} of 0.16 was used, since the region of study is interior.

3. Results and Discussions

The result of maximum and minimum daily temperature for the month of July and August 2018 and 2019 are presented in Table 2 and 3. It could be seen that daily temperature variation are not significantly different ($P<0.05$) and temperature variance between the two month in both years are also insignificantly different ($P<0.05$), however, the obvious decrease in mean temperature (Table 6) during the months of July and August could be due increasing cloud cover and increasing amount of rainfall in the month of July and August (Ohunakin et al., 2015). The results obtained are comparable to the data obtained from NIMET (Table 4) thus placed it at competitive advantage as less expensive approach for short time climate data collection.

The estimated extraterrestrial radiation and solar radiation for August 2019 are 9.256 and 1.212 $MJm^{-2}day^{-1}$ respectively, these values are beyond the minimum threshold value, thus, intermittent seasons of solar radiation do not pose a significant challenge to solar availability.

Table 2: Maximum and minimum daily temperature for the month of July 2019

Days	Maximum temperature (^oC)	Minimum temperature (^oC)
1	28.6	21.6
2	28.5	22.5
3	26.7	21.7
4	29.5	22.8
5	29.4	22.3
6	28.6	21.5
7	27.2	23.2
8	28.3	22.2
9	27.3	22.1
10	26.7	21.5
11	25.9	22.1
12	27.4	23.2
13	27.7	22.3

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14	28.4	21.5
15	29.2	22.5
16	28.3	21.8
17	29.5	23.5
18	28.5	22.7
19	29.2	22.8
20	28.6	21.9
21	29.0	23.7
22	28.4	21.6
23	27.6	22.6
24	28.9	21.9
25	25.6	21.3
26	27.4	22.4
27	29.3	22.9
28	28.5	23.6
29	29.1	22.6
30	28.7	21.6
31	28.2	22.3
Mean temperature	**28.2**	**22.3**

Table 3: Maximum and minimum daily temperature for the month of August 2019

Days	Maximum temperature (ºC)	Minimum temperature (ºC)
1	28.2	22.6
2	27.9	22.2
3	29.5	22.8
4	28.7	21.6
5	27.8	22.4
6	29.6	22.9
7	28.8	22.6
8	27.7	21.1
9	28.7	21.5
10	27.4	21.8
11	28.1	22.2
12	28.5	22.6
13	27.3	22.5
14	28.7	22.3
15	30.0	22.6
16	28.0	22.7
17	26.9	21.5

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18	28.2	22.4
19	27.7	21.7
20	29.0	22.4
21	28.5	21.7
22	29.1	22.8
23	27.4	22.4
24	28.4	22.5
25	27.2	21.7
26	26.3	21.2
27	28.6	22.6
28	29.8	22.6
29	30.3	22.3
30	29.7	21.1
31	28.5	22.5
Mean temp.	**28.4**	**22.2**

Monthly Mean of Maximum and Minimum Temperature collected from Minna Nigeria Meteorological Niger State north central are tabulated below. (Niment Minna 2018).

Table 4: The monthly mean maximum and minimum temperature for 2018

Months	Maximum temperature (ºC)	Minimum temperature (ºC)
January	34.8	19.8
February	36.1	22.2
March	38.9	24.6
April	36.3	24.4
May	33.7	24.2
June	30.9	21.9
July	29.2	21.9
August	28.3	21.7
September	29.5	20.9
October	33.0	21.1
November	36.0	19.4
December	36.4	20.0

Source: ((NIMET, 2018)

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Table 6: Average monthly sunshine hours for Minna, Niger state

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	6.5	7.7	9.20	7.6	8.0	6.6	5.8	5.5	5.9	8.4	7.9	5.6

Source: (NIMET, 2018)

Table 7: Estimated solar energy parameters of July and August 2019 in Minna, Niger state

S/N	Estimated parameters	Values for July	Values for August	Unit
1	G_{sc}	0.0820	0.0820	MJ $m^{-2}day^{-1}$
2	d_r	7,956	9.017	rad
3	ω_s	1.627	1.573	rad
4	φ	0.168	0.168	rad
5	δ	0.320	0.139	rad
6	R_a	8.133	9.256	$MJm^{-2}day^{-1}$
7	R_s	1.108	1.212	$MJm^{-2}day^{-1}$

4. Conclusions

This study accesses the potentials of solar energy for different energy applications in Minna, Niger state during months of intermittent solar radiations, the work draws the following conclusions.

- The methods used gave comparable results to data obtained from Metrological Centre in Minna, Niger state and could be used for short term study of solar radiations with limited capital.
- The extraterrestrial and solar radiation of the months of July and August 2019 are beyond the accepted threshold value of 1.366 MJ/m^2, this makes Minna a promising location for siting solar energy farm.

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