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Determination of Solar Energy Potentials Within Gombe State University, Gombe, Nigeria

***Dala, H. A., Bajoga, A. D., Abdulsalam, S. and Nafada, A. I.**

Department of Physics, Faculty of Science Gombe State University, Nigeria

*Corresponding author's email: dalaphysicist@gmail.com Phone: +2348034655891

ABSTRACT

This research work aimed to determine the solar energy potentials within Gombe State University campus between the period of 8th April and 8th May, 2010 using a Campbell Stokes sunshine recorder incorporated with cards and thermometers. The average bright sunshine per day was determined as seven hours, twenty-four minutes and the average daily temperature as 308.88K. The average amount of power obtained from the Sun within this period was found to be 525.22 W/m². The highest obtainable average temperature, average mean power and possible maximum power generated using 12% efficient solar panels per unit area is during the first week of the study and the minimum during the fourth week. Gombe State University, located in the northeastern region of Nigeria, experiences significant sunlight exposure due to its geographical position. The growing energy demands of the university, coupled with the rising costs and environmental concerns associated with conventional energy sources, necessitate the exploration of alternative and sustainable energy solutions. Solar energy, being abundant and renewable, presents a viable option for meeting the university's energy needs. This study was conducted to evaluate the solar energy potential within the campus, providing critical data and insights that could facilitate the adoption of solar technology for a more sustainable and cost-effective energy solution.

Keywords:
Solar energy,
Conversion,
Solar radiation,
Campbell Stokes sunshine recorder.

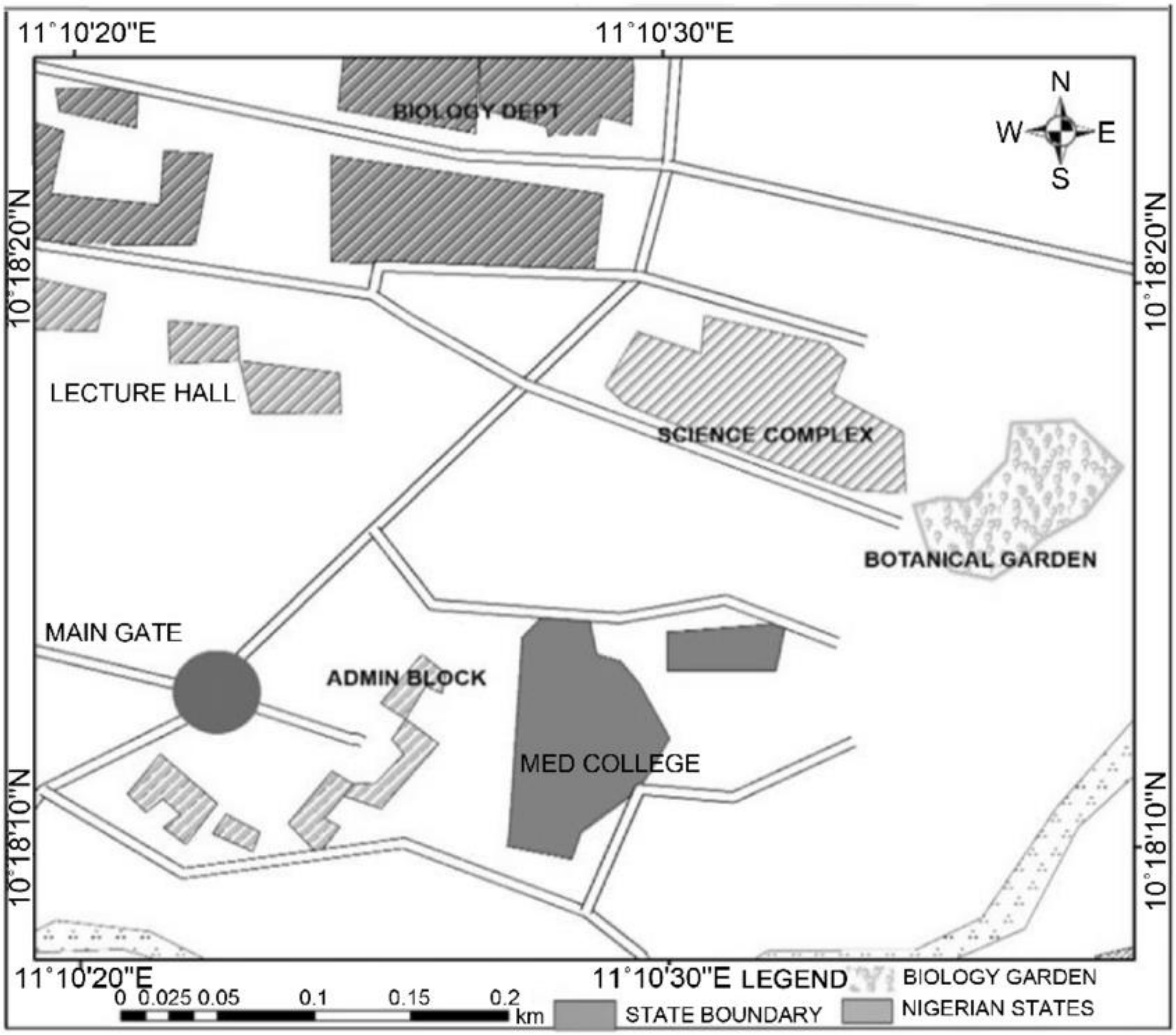
INTRODUCTION

Solar energy as an abundant and sustainable resource, has garnered significant attention due to the increasing global energy demands and the environmental impact of fossil fuels. Solar power harnesses the energy from the sun, converting it into electricity or heat through various technologies, primarily photovoltaics (PV) and solar thermal systems. Gombe State University, located in a region with substantial solar exposure, offers a promising site for solar energy exploitation. This study aims to evaluate the availability and intensity of solar radiation, to identify the most suitable locations within the university for solar energy harvesting and quantify the solar energy potentials at Gombe State University by examining solar radiation and temperature data collected over a 30-day period.

The importance of solar energy cannot be over emphasized. It is a renewable energy source and is critical in addressing global warming and reducing greenhouse gas emissions. Unlike fossil fuels, solar energy is mostly available, sustainable and inexhaustible on a human timescale and has minimal environmental impact. Harnessing solar energy can significantly reduce energy costs and provide a reliable source of power, especially in regions with high solar insolation like Gombe, North-east Nigeria (Quaschning, 2003).

Solar energy has been used for centuries for various purposes, including heating, cooking, and drying. In recent decades, technological advancements have enabled the efficient conversion of solar energy into electricity. Photovoltaic cells, commonly known as solar panels, convert sunlight directly into electricity using semiconducting materials. Solar thermal systems, on the other hand, use sunlight to heat a fluid, which then generates steam to drive a turbine and produce electricity (Goswami *et al.*, 2000). It is an alternative viable source of energy and one of the important source of green energy.

Gombe State is located in northeastern Nigeria and is characterized by a semi-arid climate with high levels of solar radiation. The region experiences abundant sunshine throughout the year, making it an ideal location for solar energy projects. The university campus, with its open spaces and rooftops, presents an excellent opportunity to harness solar power for educational and operation



MATERIALS AND METHODS

The study was conducted between 8th April and 8th May, 2010, at Gombe State University. A Campbell Stokes sunshine recorder, complemented by cards and thermometers, was employed to measure solar radiation and ambient temperatures. The recorder provided daily data on bright sunshine hours, while thermometers recorded temperatures at 10 am and 4 pm daily.

Equipment and Setup

Campbell Stokes Sunshine Recorder

This device is a widely used instrument for measuring the duration of sunshine. It consists of a glass sphere that focuses sunlight onto a calibrated paper card, which records the intensity and duration of sunlight. The instrument is simple yet effective for long-term sunshine duration measurements (Duffie & Beckman, 2013).

Figure 1: Campbell Stokes sunshine recorder

Thermometers: Used for recording temperatures at specified times (10 am and 4 pm). The readings were used to calculate the average daily temperatures and analyze the variations throughout the study period.

Data Collection Procedure

Daily temperatures were as specified time in the morning and afternoon i.e. between 10 am and 4 pm daily for one month. The readings were used to calculate the average daily temperatures, which are later used to analyze the variations throughout the period of study. The average bright sunshine duration was noted, and the corresponding solar power was calculated using established solar energy conversion principles (Stine & Geyer, 2001).

Table 1 shows the daily temperature measured and recorded for 30 days. The readings were taken in the morning and afternoon for one month. These were used to calculate the average daily temperatures and analyze the variations throughout the period of study. It also shows the mean temperature for each day for the duration of the study. Figure 2 also shows a variation of daily temperature both for morning and afternoon measurements over the study period. From the result, it can be seen that a relatively higher temperature was experienced in the afternoon than in the morning. This may not be unconnected with the amount of solar insolation reaching the earth's surface at afternoon hours at the study area. The mean temperature determined for some days were observed to be constant. For example, constant temperatures were observed on the following days: 307 ^{0}K on the 11th, 12th, 21st and 22nd, while 309 ^{0}K was on the 13th, 14th, 15th, 23rd, 24th and 25th day.

Table 1: Temperature readings during the study period

Day	Temperature (^{0}K)		
	Morning	Afternoon	Daily mean
1	306	308	307
2	307	310	309
3	305	309	307
4	308	311	310
5	306	312	309
6	307	308	308
7	308	311	310
8	306	309	308
9	307	310	309
10	308	312	310
11	305	309	307
12	306	308	307
13	307	311	309
14	308	310	309
15	306	312	309
16	307	308	308

17	308	311	310
18	306	309	308
19	307	310	309
20	308	312	310
21	305	309	307
22	306	308	307
23	307	311	309
24	308	310	309
25	306	312	309
26	307	308	308
27	308	311	310
28	306	309	308
29	307	310	309
30	309	311	310
Total mean	**307**	**310**	**308**

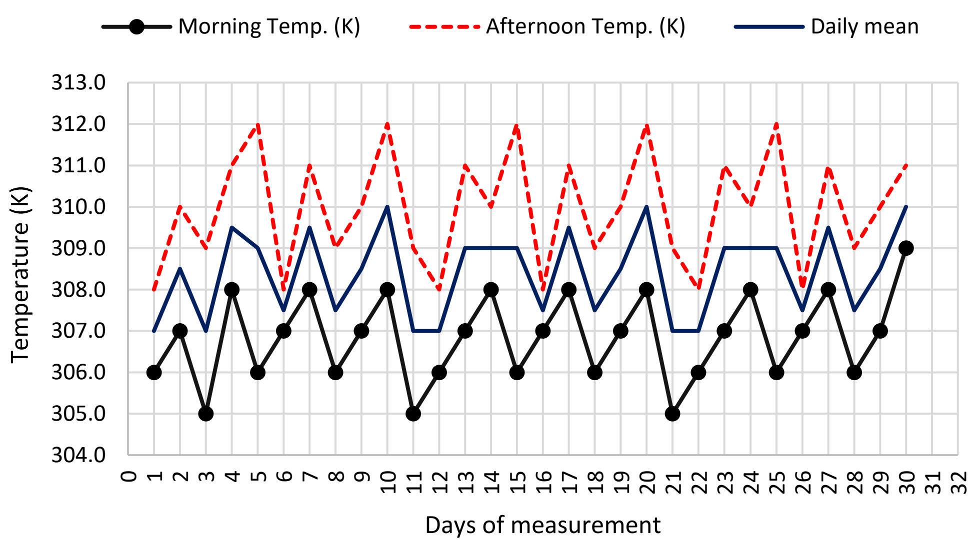


Figure 2: Daily temperature readings over the 30-day study period

Table 2 gives the average morning and afternoon temperatures calculated for each week of the study. These averages help in understanding the weekly temperature trends and their potential impact on solar energy availability.

Table 2: Weekly average morning and afternoon temperatures over the study period

Week	Average morning temperature (K)	Average afternoon temperature (K)
1	306.6	309.8
2	307.2	310.4
3	306.4	310.8
4	307.4	310.4

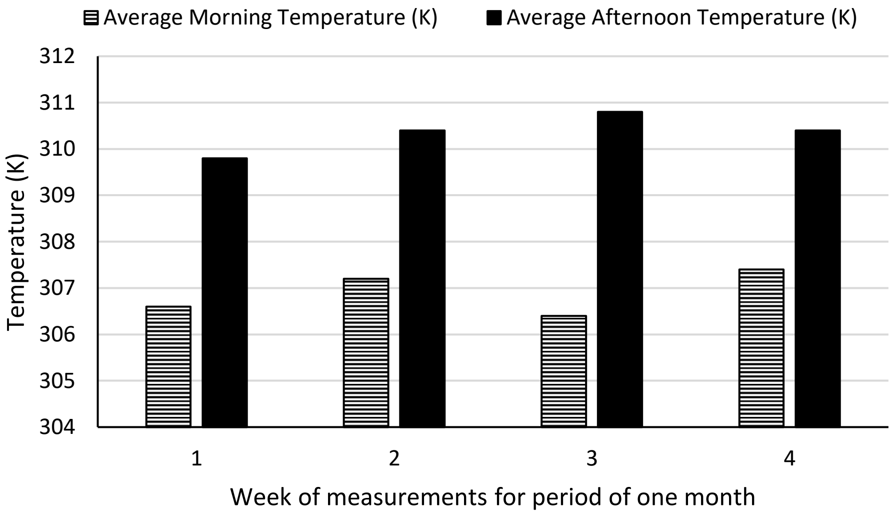


Figure 3: Average morning and afternoon temperatures

Figure 3 shows the average morning and afternoon temperatures calculated for each week of the study. These averages help in understanding the weekly temperature trends and their potential impact on solar energy availability.

Wien's Displacement Law

Wien's Displacement Law relates the temperature of a blackbody to the peak wavelength of its emission. The formula is:

$$\lambda_{max} = \frac{b}{T} \quad (1)$$

where λ_{max} is the peak wavelength, b is Wien's constant (2.898×10^{-3} m/K), and T is the temperature in Kelvin (Green, 2005).

Calculation of Peak Wavelengths

For the weekly average temperatures:

λ_{max} (morning) = $2.898{\times}10^{-3}T_{morning}$

λ_{max} (afternoon) = $2.898{\times}10^{-3}T_{afternoon}$

Table 3 shows the peak wavelengths corresponding to the average morning and afternoon temperatures for each week. The wavelengths were calculated using Wien's Displacement Law. The values fall within the infrared region, which is typical for terrestrial temperatures.

Table 3: Peak wavelengths for morning and afternoon temperatures

Week	Morning Temperature (K)	Morning Wavelength (m)	Afternoon Temperature (K)	Afternoon Wavelength (m)
1	306.6	9.456×10^{-6}	309.8	9.358×10^{-6}
2	307.2	9.438×10^{-6}	310.4	9.337×10^{-6}
3	306.4	9.463×10^{-6}	310.8	9.324×10^{-6}
4	307.4	9.433×10^{-6}	310.4	9.337×10^{-6}

Solar Intensity and Power Calculations

The solar intensity (I) was calculated using the Stefan-Boltzmann Law:

$$I = \sigma T^4 \quad (2)$$

where σ is the Stefan-Boltzmann constant (5.67×10^{-8} $Wm^{-2}K^{-4}$) and $T$is the temperature in Kelvin (Kalogirou, 2009).

To find the power (P) generated by a 12% efficient solar panel, the following equation (3) is used:

$$P = 0.12 \times I \quad (3)$$

Table 4 presents the calculated solar intensities and corresponding power outputs for the average morning and afternoon temperatures. The solar intensities were computed using the Stefan-Boltzmann Law, and the power outputs were derived considering a 12% efficient solar panel. These calculations help in understanding the potential solar energy that can be harnessed and converted into usable power.

Table 4: Solar intensity and power generated

Week	Morning Temperature (K)	Solar Intensity (W/m^2)	Power (W/m^2)	Afternoon Temperature (K)	Solar Intensity (W/m^2)	Power (W/m^2)
1	306.6	517.03	62.04	309.8	531.15	63.74
2	307.2	519.28	62.31	310.4	533.20	63.98
3	306.4	516.28	61.95	310.8	534.76	64.17
4	307.4	519.84	62.38	310.4	533.20	63.98

RESULTS AND DISCUSSION

The results from this study reveal that Gombe State University experiences significant solar radiation, making it an ideal location for solar energy projects. The average bright sunshine duration of 7 hours and 24 minutes provides ample opportunity for solar energy harvesting.

The recorded temperatures ranged from 306.4K to 307.4K in the mornings and 309.8K to 310.8K in the afternoons. These temperatures were used to calculate the peak wavelengths of the emitted radiation using Wien's Displacement Law. The peak wavelengths fell within the infrared range, which is typical for terrestrial temperatures.

The solar intensity was calculated based on the temperature data and the corresponding peak wavelengths. The average solar intensity was found to be 525.22 W/m^2, with slight variations observed throughout the study period. The power output for a 12% efficient solar panel was also calculated, showing an average power of approximately 63.07 W/m^2.

The highest average temperatures and solar intensities were recorded during the first week, while the lowest were observed during the fourth week. This variation can be attributed to changes in atmospheric conditions such as cloud cover and humidity. These factors influence the amount of solar radiation reaching the Earth's surface and, consequently, the solar power available (Reddy, 2006).

The study's findings indicate significant potential for solar energy utilization at Gombe State University. With an average solar power availability of 525.22 W/m^2, the university can consider investing in solar energy systems to meet its energy needs. The use of solar panels can provide a sustainable and cost-effective energy solution, reducing dependence on non-renewable energy sources (Tiwari & Ghosal, 2005).

CONCLUSION

This study has successfully determined the solar energy potentials within Gombe State University. The findings highlight the region's suitability for solar energy exploitation, with an average daily solar power availability of 525.22 W/m^2. The application of Wien's Displacement Law provided valuable insights into the peak wavelengths of solar radiation, further validating the potential for solar energy conversion. Conduct detailed feasibility studies to determine the optimal placement and size of solar panels, invest in high-efficiency solar panels and related infrastructure to maximize energy conversion and promote awareness about the benefits of solar energy and provide training for maintenance and operation of solar systems.

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