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The Effect of Relative Humidity on the Solar Radiation Intensity in Port Harcourt, Nigeria

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Abstract

A study was conducted on the effects of relative humidity on the solar radiation intensity in Port Harcourt, *Nigeria. The data for this research work was obtained from the Nigerian Environmental Climatic Observatory Project Station (NECOP) situated at Rivers State University, Port Harcourt, Nigeria. The average solar radiation and relative humidity data from January to March 2018 were collated on daily, weekly and monthly intervals. The results obtained showed that average relative humidity is 61.20% for January, 71.89% for February and 74.18% for March 2018. While the average solar radiation intensity is 77.339 W/m² for January, 77.000 W/m² for February, and 71.297 W/m² for March 2018. The maximum average relative humidity occurred in the month of March, signifying a steady increase in the rainy season period. The increase in average relative humidity gives rise to a decrease in solar radiation and vice versa. This depicts an inverse relationship between humidity and solar radiation intensity.*

Key Words: Solar radiation intensity, Relative Humidity and Air temperature,

Introduction

The sun is the principal source of solar energy, and nearly all known elements are present in the sun. However, the main constituents are hydrogen and helium which constitute about 80% and 19% respectively. The sun mass is 1.9889 x 10^{30}kg, with a radius of 6.960 x 10^{8}m and mean distance of 150 million km from the earth. The volume and density are 1.412 x 10^{18}km^{3} and 1.622 x 10^{5}kgm^{-3} respectively. Its core temperature is about 2 x 10^{7}k, while the outermost layer has an equivalent black body temperature of 5760k. The electromagnetic energy radiated by the sun is derived from two types of nuclear fusion reaction that occurs in the sun; proton to proton chain and carbon-nitrogen cycle [1].

Solar energy is a free, unlimited and clean source of energy. Most recent research in energy field is focused on solar power systems. An increasing interest among developed and developing countries in photovoltaic (PV) technology has improved due to its advantages of converting solar energy into electricity. Energy radiated by the sun is the best alternative source of renewable energy available in vast capacity, to drive the industrialization and development of any community in the world. Electric power is largely responsible for the sustainable technological development of any nation. Therefore, increasing energy costs and growing concern about climate change has generated a rapid growth in the PV production industries in recent years. Research has revealed that the region with the most solar energy lies between latitude 15° N and 35° N [2]. The African continent is located in semi-arid region and Nigeria is located between coordinate (9.0820°N, 8.6753°E) with abundance of solar energy yet without adequate electricity. The daily incident solar energy in Nigeria is approximately 5.535 kWh/m^2/day and 1.804 x 10^{15}kwh every year with total area of 924 x10^3km^2. Therefore, if less than 0.2% of incident radiation on the country could be utilized for solar technology at a productivity rate of less than 0.2%, then it will have the ability to meet its total energy demand [3]. The solar radiation map of Rivers State, Nigeria with coordinate (4.8156°N, 7.0498°E) receives yearly mean solar radiation of approximately 4.0 kWh/m^2/day [4].

The total amount of solar radiation emitted to every part of the earth influences the weather conditions in our environment, and it is an integral aspect for the provision of food for mankind. Thus, having a good knowledge of solar radiation and the amount of solar energy incident on the earth's surface at various locations is vital [5]. The global solar radiation on any surface is influenced by the hours of sunshine, ambient air temperature and relative humidity of the location [6]. Meteorological global solar radiation data are generally measured on a horizontal surface [7]. The appropriate information on solar radiation is very vital in our contemporary world therefore; the use of solar energy has become an integral part of energy source. Solar radiation is partially absorbed, scattered and reflected by molecules, aerosols, water vapor and clouds as it passes through the atmosphere [8]. There are various measurements of solar radiations at several locations which are found to be vital in order to really evaluate the availability of solar energy arriving on the earth. The instruments which are used for measuring solar radiation are generally called solarimeter. A simple whole sky solarimeter which measures global solar radiation is known as pyranometer whereas pyrheliometer measures direct solar radiation. Alternatively, empirical models can be correlated with meteorological parameters at the location where the data is collected to obtain the global solar radiation. The results obtained may then be used for locations of similar meteorological characteristics [9].

One weather parameter which influences the amount of solar radiation on an area is the relative humidity. Relative humidity can be defined as the ratio of water vapor essentially in the air to the maximum water vapor the air can hold at a given temperature [10]. Since the capacity of air to hold water vapor is primarily a function of temperature, then warmer air has a greater capacity for holding water vapor than cooler air [11]. Out of 100% energy coming from the sun approximately 30% of the energy is either reflected back or absorbed by clouds, oceans, and land masses. As per the fact that the earth's crust mainly consists of 70% of water, the energy which strikes the earth is indirectly striking the water/oceans which helps in increasing of humidity level on the overall basis. The humidity doesn't only create hurdles for the energy actually received at the top of the atmosphere but also effects the device consumptions by many aspects. Solar radiation reduces with increasing relative humidity, increasing air-water content, increases solar radiation scattering and reduces the received solar intensity. In Port Harcourt, Nigeria the relative humidity often peaks at 50% due to the area's low elevation.

Study Area

The research was carried out in Port Harcourt, Nigeria situated along the southern part of Nigeria on the gulf of Guinea on the West Coast of Africa within latitudes

4.7958° N and Longitudes 7.0244° E. The study area has two major seasons namely the Rainy Season and the Dry Season. During the months of April to November is the rainy season when there is plenty of rainfall, December to April is the dry season and the warmest period is from February to April [12].

Materials and Methods

The data for this research works was obtained from Nigeria Environmental Climatic Observatory Project station (NECOP) in Rivers State University Port Harcourt, Nigeria. The station is automated with a real time data analysis system with very low level of uncertainty. The solar radiation and humidity data were taken from the month of January to March, 2018 at 5 minutes intervals. Basically, data were collected and analyzed in order to enable the researchers predict or make inferences about some relationships existing between the variables. Daily, weekly and monthly averages of solar radiation intensity (W/m2), relative humidity (%) data collated were estimated using excels spreadsheet. The analyzed results were presented in tables and graphs.

Results

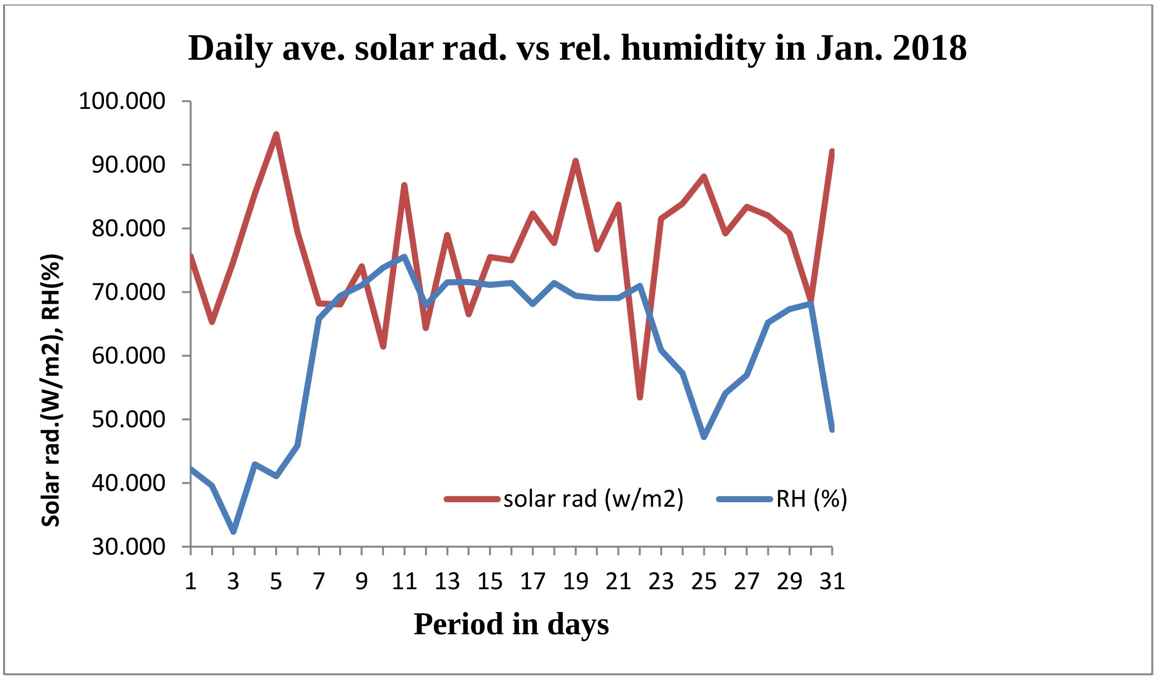

Fig 1: Daily average of solar radiation and relative humidity in January 2018

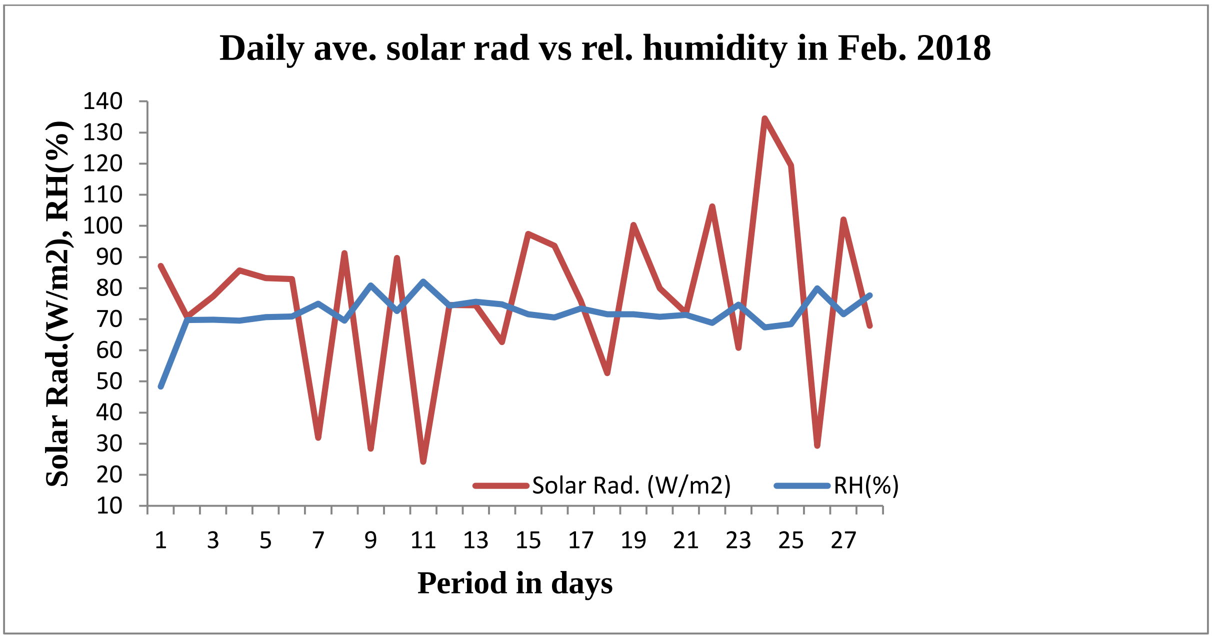

Fig 2: Daily average of solar radiation and relative humidity in February 2018

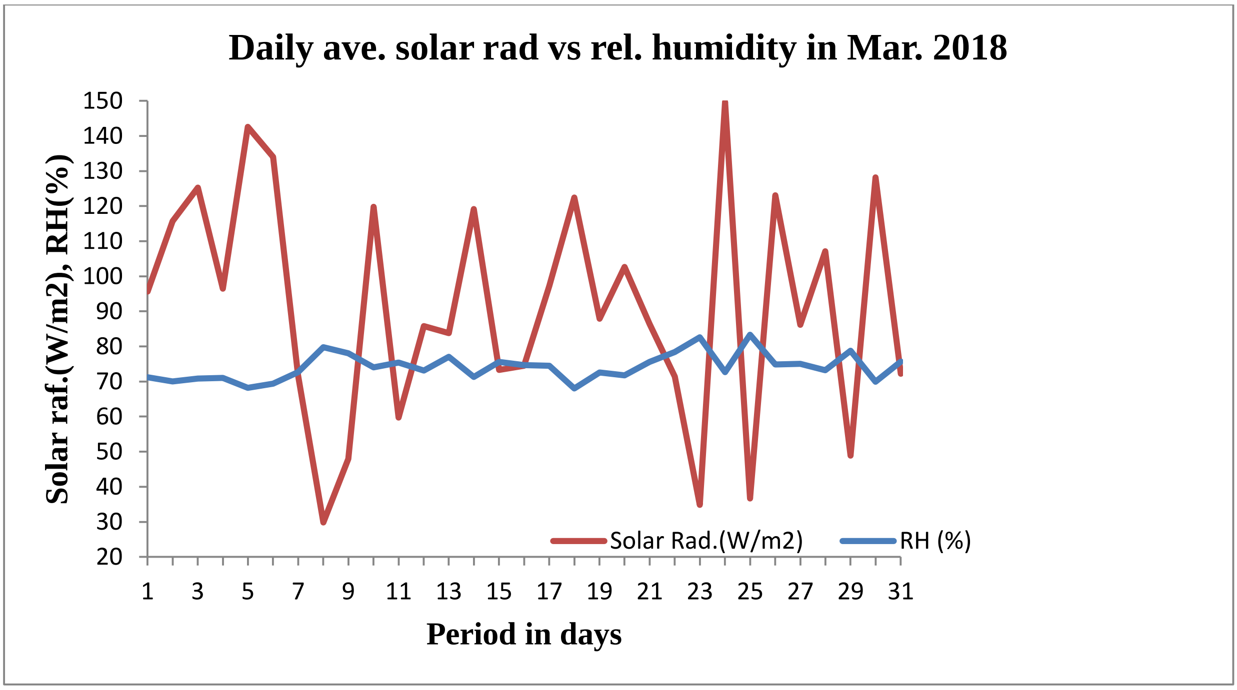

Fig 3: Daily average of solar radiation and relative humidity in March 2018

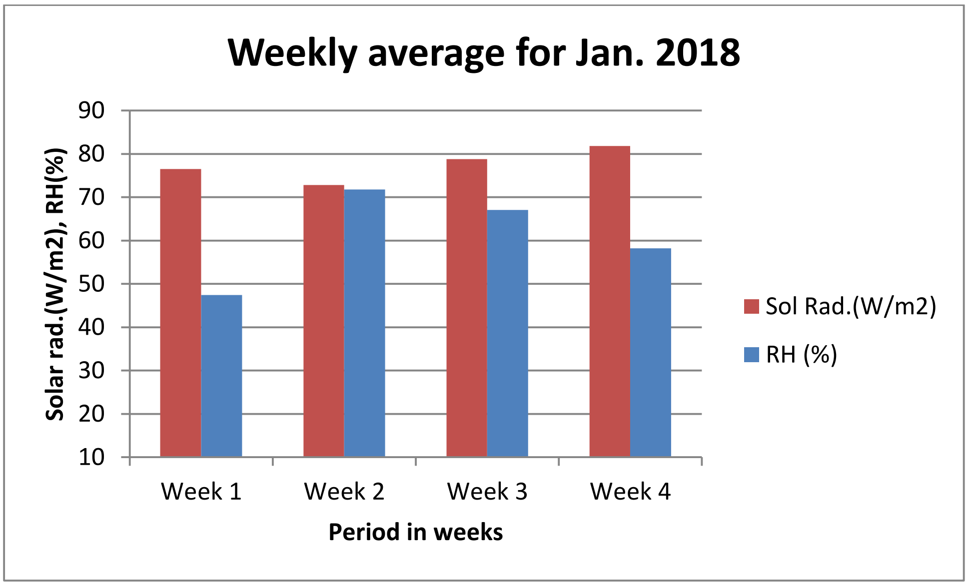

Fig 4: Weekly average of solar radiation and relative humidity in January

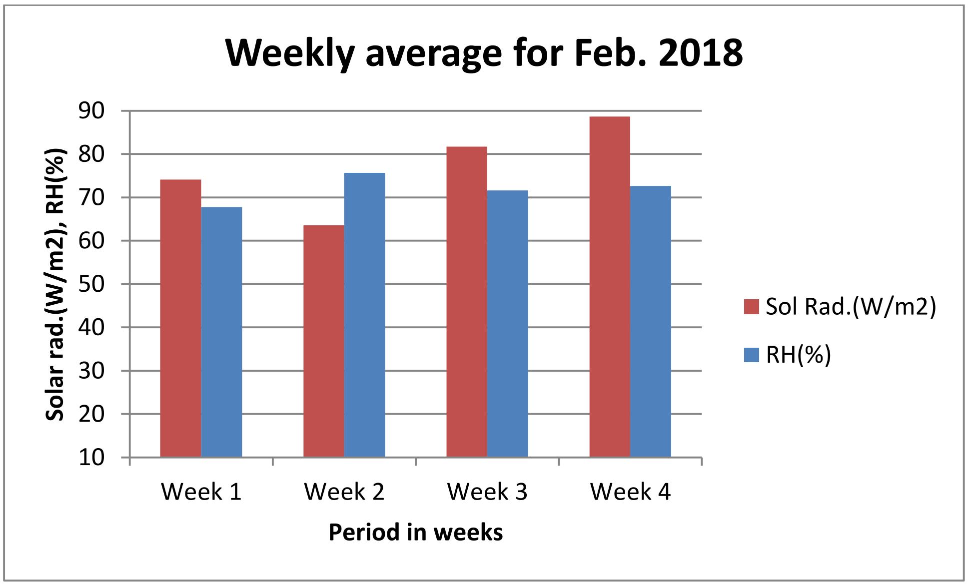

Fig 5: Weekly average of solar radiation and relative humidity in February 2018

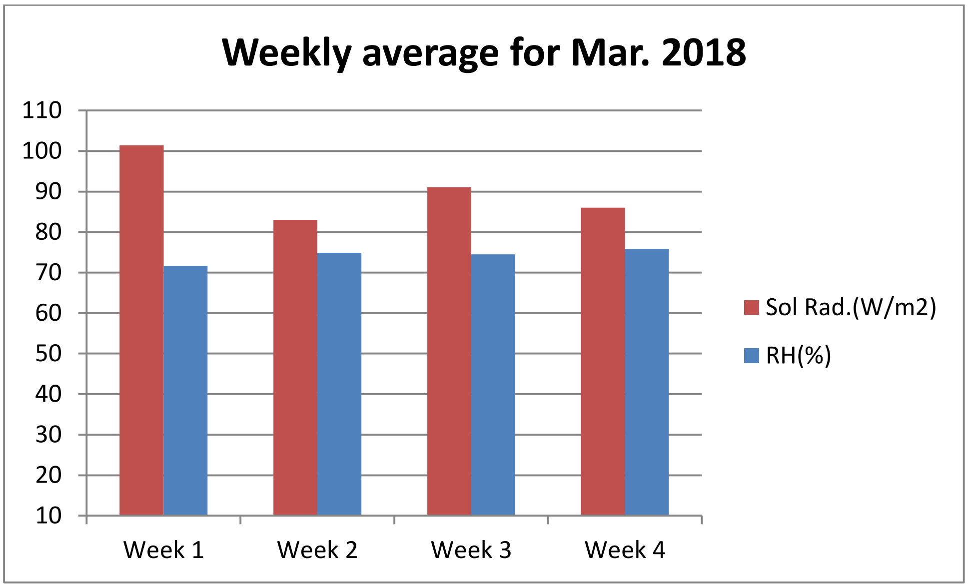

Fig 6: Weekly average of solar radiation and relative humidity in March

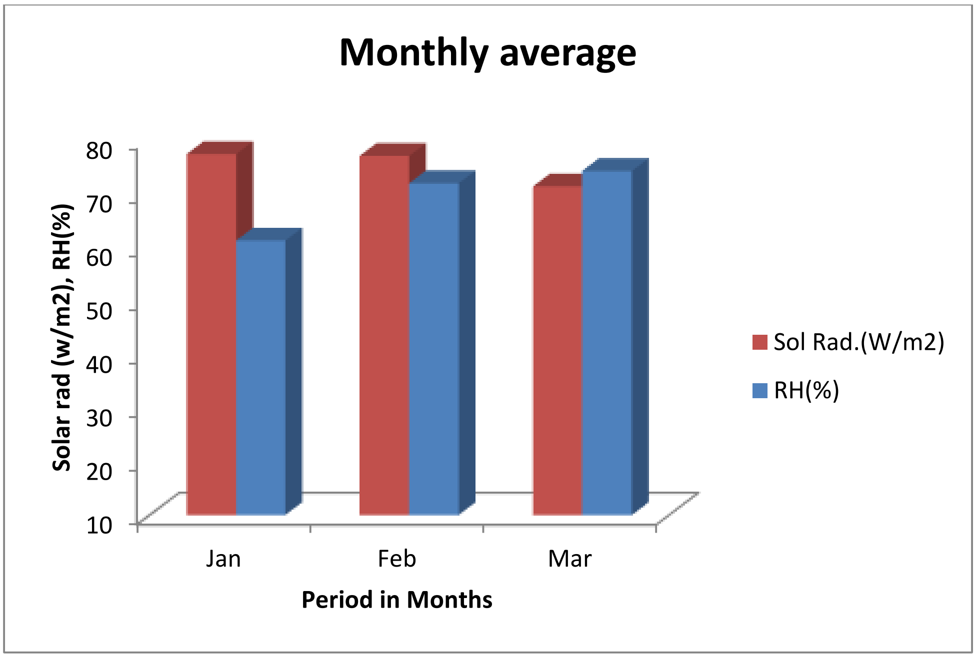

Fig 7: Monthly average of solar radiation and relative humidity in January to March

Discussion

Daily average solar radiation and relative humidity

The graph of figures 1 to 3 shows the daily average solar radiation and relative humidity for the months of January to March 2018. From the graph the daily average solar radiation keeps changing with average relative humidity making it difficult maintaining ideal matching at all radiation levels. However, the graph indicates that the average relative humidity for each day together with other weather factors like temperature, rainfall, wind speed etc. affects the average solar intensity of the location, such that any increase in the relative humidity at a particular period will decrease the amount of solar intensity being experienced at the location. This is in agreement with [13] that daily solar radiation of a location keeps changing with changing temperature making it difficult to attain ideal matching for all radiation level.

Weekly average solar radiation and relative humidity

The graph of figures 4 to 6 depicts the weekly average solar radiation and relative humidity for the months of January to March 2018. The graph of Fig. 3 indicates that relative humidity increase from 47.418% to 71.772% while the solar radiation increased from 72.833 W/m^2 to 81.834W/m^2 for the month of January 2018. It can be observed that the percentage increase for the average relative humidity increase was about 34 percent, whereas the solar radiation increased was about 11 percent. This clearly shows that the average relative humidity is maximal for the second and third week while the first and last week experience less humidity. The relative humidity for all the weeks in February is almost the same, and this is clearly shown in Fig. 5. This indicates that all the weeks in the month of February 2018 experienced more average relative humidity at the location of study. This same scenario was also observed in Fig. 6 for the month of March 2018 where the average relative humidity is almost identical all throughout the weeks increasing from the first week to the fourth week.

Monthly average solar radiation and relative humidity

The average monthly solar radiation and relative humidity is represented in Figure 7. It is clear from the graph that the month of March experiences the maximum increase in average solar radiation. This confirms that solar radiation reduces with increasing relative humidity as clearly investigated. Since increasing air water content increases solar radiation and reduces the received solar radiation intensity. As a result, the solar radiation incident on the atmosphere suffers from dispersion and high loss in the incoming energy. The average relative humidity is 61.20% for January, 71.89% for February and 74.18% for March 2018. While the average solar radiation intensity is 77.339 W/m^2 for January, 77.000 W/m^2 for February, and 71.297 W/m^2 March 2018. The maximum average relative humidity occurred in the month of March, 2018 signify as steady increase cumulating to the rainy season period. The results obtained from the analysis shows that an increase in average relative humidity gives rise to a decrease in solar radiation and vice versa.

This depicts an inverse relationship between average relative humidity and solar radiation intensity. This result is in agreement with [13] that increased relative humidity will give rise to low solar radiation intensity and low temperature. Also in agreement with [11] that increased solar flux is attained when relative humidity is low.

Conclusion

The average relative humidity/solar radiation intensity is (61.20% / 77.339W/m^2) for January, (71.894% / 77.000W/m^2) for February and (74.18% / 71.297W/m^2) for March 2018. The maximum average relative humidity occurred in the month of March, 2018 signifying a steady increase cumulating to the rainy season period. The increase in average relative humidity gives rise to a decrease in solar radiation and vice versa. This depicts an inverse relationship between average relative humidity and solar radiation intensity.

Recommendation

The meteorological parameter used in this project is limited to relative humidity and solar radiation data which indicates that not all the weather variable were used such as temperature, wind, sunlight, etc. therefore the duration of the research work should be increased further to at least a year or more. This will assist industrialist, researchers, government and non- governmental organization to effectively plan and proffer solutions to natural disaster associated with weather or global climatic change for technological innovation.

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