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Comparative analysis of direct, diffuse and global Irradiance at two different locations in Nepal

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Abstract

Analysis of solar radiation on different geographical location is important to understand their solar potential and possible energy harvest that can be turned to financial benefits for investors. Nepal has a huge solar potential but large scale solar installations are still minimal. In this regard, this study is an attempt to compare solar irradiances of two different geographical locations (Kathmandu & Nepalgunj) to observe the possible energy output. Real ground measurements of global and diffuse horizontal irradiances (GHI and DHI) along with direct normal irradiance (DNI) data are obtained for six months (Jan to June, 2019) from both sites. Analysis is presented based on comparison of daily and monthly average irradiances along with min by min plot of GHI for particular day of winter and summer season. Results suggest that average daily and monthly irradiance (GHI and DNI) for four out of six months (March toJune) are higher in Nepalgunj as compared to Kathmandu. The six month averages of GHI=350.38 W/m^2 and DNI=296.51 W/m^2 in Nepalgunj are found to be slightly higher than that of Kathmandu (GHI=321.9 W/m^2, DNI=292.25 W/m^2). Both locations have very good sunshine of 5 hours/day in winter and excellent sunshine of 8 hours/day in summer. Also during summer, the average GHI greater than 500 W/m^2 that would generate more energy output from the solar collector is higher for Nepalgunj (~71%) as compared to Kathmandu (~50%) whereas during winter, it is nearly 60% in Kathmandu and only about 39% in Nepalgunj.

Keywords*—DNI, DHI, GHI, Solar radiation*

1. INTRODUCTION

On an average, approximately 342 W/m^2 of solar energy falls on the earth's surface which is one quarter of the solar constant (~1367 W/m^2) and about 1715x10^{14} W of solar energy is received by the earth. Out of this 30% is reflected and only 30% of earth is above sea level hence, the useable solar energy on the earths' surface is only about 360x10^{14} W [1]. The solar installations will be done only at feasible geographical locations on earth and therefore, this energy will be further reduced. Thus, it is important that harvesting of solar energy to turn into solar electricity need installations of solar collectors with appropriate orientation and tilt angle so that maximum solar energy can be generated. For this, one has to understand different solar radiations that is utilized by the solar collector. Solar radiation entering the earth's atmosphere and falling onto the solar collector can be divided into direct, diffuse and reflected radiations as shown in Figure 1.

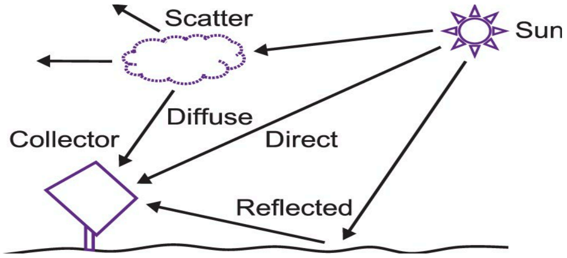


Figure 1: Different solar radiations falling on a collector. [2]

Different configurations of solar collectors like solar tracking, fixed tilted and horizontal installations can be done to generate solar electricity. In order to estimate the amount of energy that can be generated by the solar collector, one needs to measure watts per square meter (W/m^2) of different radiations that falls on the collector [3]. Solar collectors or modules utilizes much of direct and diffuse radiations to generate electricity whereas, the contribution of reflected radiation is minimal and often neglected unless the collector is steeply tilted and is installed at high reflective surroundings like snow [4]. Global solar radiation can be estimated using direct and diffuse solar radiation as,

$$GHI = DNI \times cos(\theta_z) + DHI \dots (1)$$

$Where,\ \theta_z\ is\ the\ solar\ zenith\ angle$

Special type of thermopile based sensors called pyranometer and pyrheliometer are available for the measurement of these different solar irradiance. Direct normal irradiance (DNI) is measured using pyrheliometer, global horizontal irradiance (GHI) using pyranometer and diffuse horizontal irradiance (DHI) is measured using pyranometer with shading ball that blocks the direct beam falling on the sensor [5].

The average solar radiation in Nepal is about 4.7 kWh/m^2/day with average sunshine hours of 6.8 hours/day for approximately 300 days in a year [6]. Based on geographical locations different amount of solar radiation is intercepted at every instant and it is essential to compare the measurements so that it gives an idea for the investors where to locate their solar plant to get best energy output and maximum cost benefits. The earlier work from the literature for the analysis of solar radiation in Nepal involves the use of daily average GHI data obtained from department of hydrology and meteorology (DHM) of the year 2018 to estimate the annual average global solar radiation at four different locations in Nepal [7]. This study tries to analyze all three different solar irradiances (GHI, DNI and DHI) at two different geographical locations in Nepal. One location is Kathmandu (27.6816°N,85.3187°E) that lies in the hilly region at an elevation of 1320m and the another location is Nepalgunj (27.6816 °N, 85.3187) that lies in the terai region at an elevation of 150m.

2. METHODOLOGY

The solar measurement systems are identical for both location as shown in Figure 2. It consists of a 2D-Solsys2 type solar tracker mounted on a metal structure at a height of 2m. The tracker consists of three thermopile based sensors for measuring different solar irradiances. Pyrheliometer (Class A, CHP 1) for measuring DNI, two pyranometers (class A, CMP 21) for measuring GHI and DHI. Pyranometer with a shading ball setup will measure DHI. All sensors and sun tracker are well calibrated before use and per minute average data measured by the sensors are recorded on a data logger. The site was well maintained and the sensors were cleaned almost on a daily basis. The installation was a part of Renewable Energy Resource Mapping and Geo Spatial Planning Project (ID: P150328), supported by Energy Sector Management Assistant Program (ESMAP), administered by the World Bank.

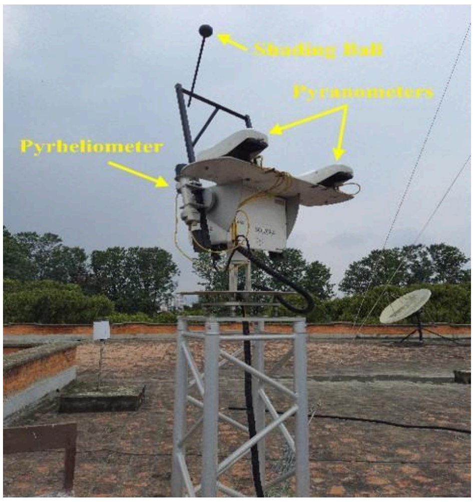


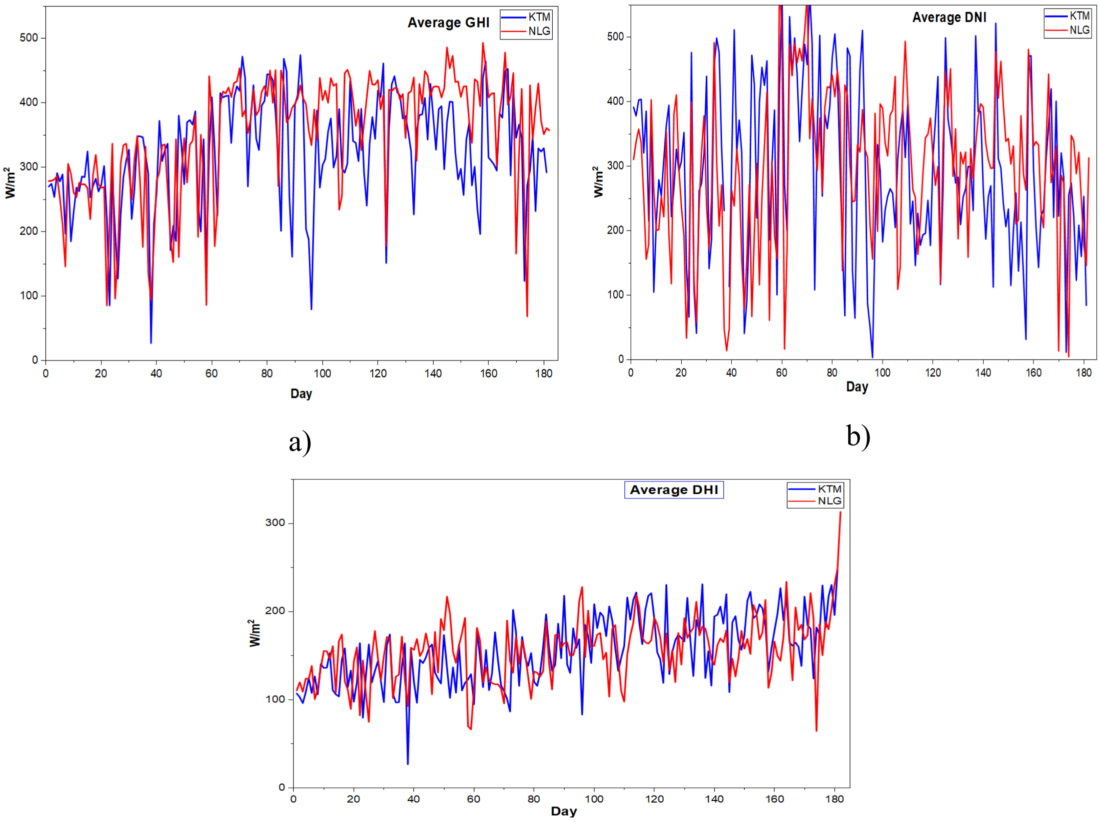
Figure 2: 2D-Solar tracker with sensors at measurement site.

The data of GHI, DNI and DHI for a period of six months from Jan to June, 2019 are extracted, analyzed and presented for comparative study. Comparison is done based on daily and monthly averages of all three irradiances along with min by min plot of GHI for a particular day of winter and summer (21st Jan and June) for both locations. Data from the data logger were obtained in .csv format and the analysis has been done on excel sheet. Some minor error in the data has been noted due to the misalignment of the solar tracker resulting from heavy wind. For example on April 6, the daily average of DHI is found to be higher than GHI which violates eqn-1. The result presented here is as per the recorded data and no altercation of data has been done. However, once the misalignment was noticed the tracker was aligned at the earliest possible time or the next day.

3. RESULTS & DISCUSSIONS

A. Comparison of daily average irradiance

Comparison of daily averages of all three irradiances for a period of six months (Jan to Jun 30, 2019) for both locations, Kathmandu (Blue) and Nepalgunj (Red) is shown in Figure 3 a), b) and c).



a)

b)

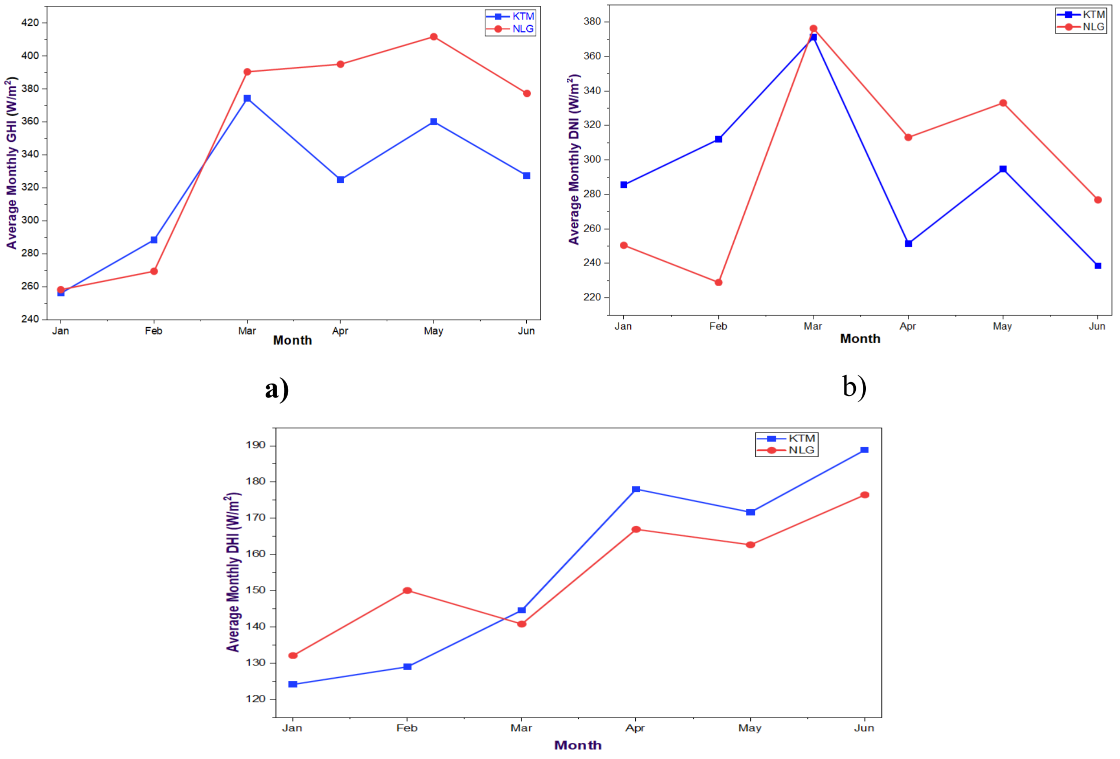
c)

Figure 3: Daily average irradiances (GHI, DNI, DHI) of Kathmandu and Nepalgunj

For Kathmandu, the maximum daily average of GHI and DNI are found to be 471.92 W/m^2 and 570.6 W/m^2 respectively (March 12) whereas, maximum daily average of DHI is 247.15 W/m^2 (June 30). Similarly, the minimum daily averages of GHI, DNI and DHI are found to be 79.73 W/m^2, 3.81 W/m^2 and 83. 27 W/m^2 respectively on April 6. Under the clear sky, GHI should always be greater than DHI (eqn-1) thus, this recorded measurement is an error which may be due to the misalignment of pyranometer on the solar tracker [8].

In the case of Nepalgunj, the maximum daily averages of GHI, DNI and DHI are found to be 493.41 W/m^2 (June 7), 595.42 W/m^2 (Feb 28) and 249.02 W/m^2 (Jun 30) respectively. Similarly, the minimum daily averages of GHI, DNI and DHI are found to be 68.86, 5.1 and 64.49 W/m^2 respectively on Jun 23. The daily minimum average DNI less than 10 W/m^2 in both location suggest that those days had the highest attenuation of sunlight which may be due to presence of thick cloud or high aerosol contents of dust and smoke in the atmosphere [9]. On a clear sky and sunny day, the maximum daily average value of DNI reach greater than 570W/m^2 in both locations suggesting that both locations have tremendous solar potential.

B. Comparison of monthly average irradiance



a)

b)

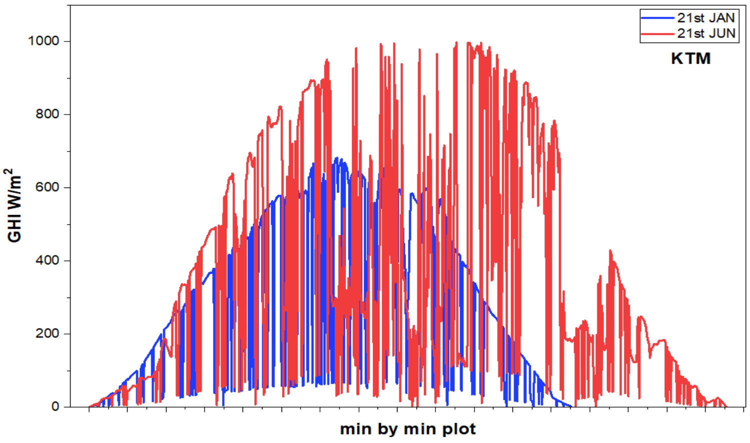
c)

Figure 4: Monthly average irradiances (GHI, DNI and DHI) for both locations

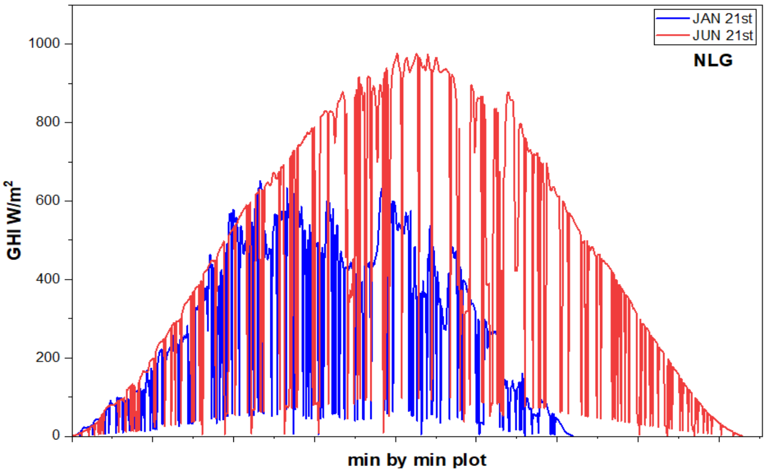
It is found that monthly average of GHI and DNI (Mar to Jun) are higher for Nepalgunj with maximum value on May (GHI=360.19 W/m^2) and March (DNI=376.36 W/m^2) as comparison to Kathmandu (GHI=374.56 W/m^2 and DNI=371.14 W/m^2) but, monthly average DHI is found to be higher in Kathmandu during those months with maximum on June (DHI=188.85 W/m^2). Similarly, the monthly average DNI for the months of Jan and Feb is lower in Nepalgunj as compared to Kathmandu with lowest on Feb (DNI=228.95 W/m^2) and the monthly average GHI is lower in Nepalgunj for the month of Feb but almost similar for Jan as compared to Kathmandu with lowest on Jan (GHI=256.02 W/m^2). At the same time, DHI is lower for the months of Jan and Feb in Kathmandu as compared to that in Nepalgunj with lowest on Jan (DHI=124.16 W/m^2). Out of six months, four months (Mar to Jun) has higher monthly averages of GHI and DNI suggesting that clearer and sunnier days occur more in Nepalgunj than Kathmandu. Also, higher monthly average DHI suggest that aerosol concentration like smoke and pollution along with presence of clouds is higher in Kathmandu than Nepalgunj [10].

The six month averages of GHI, DNI and DHI are found to be 321.9, 292.25 and 156.06 W/m^2 respectively for Kathmandu whereas, it is 350.38, 296.51 and 154.86 W/m^2 respectively for Nepalgunj. This suggest that Nepalgunj has slightly better solar radiation compared to Kathmandu.

C. Comparison of min by min plot



a)



b)

Figure 5. Min by min plot for 21st day of Jan and Jun

In order to see a clear picture on the length of the day and good sunshine duration with higher GHI values, a min by min plot of both locations for 21st day of Jan (winter) and June (summer) is obtained as shown in Figure 5 a) & b). The result show that, the length of day in winter is nearly 10.5 hours while the length of day reaches almost 13.5 hours during summer which is a similar value as in the literature [11].

During winter in Kathmandu, the recorded GHI value is from 7:01 am in the morning till 5:26 pm in the evening with almost 60% of the data greater than 500 W/m^2 between 10:00 am till 3:00 pm. Similarly, the recorded GHI value in Nepalgunj is from 7:18 am in the morning till 5:37 pm in the evening with nearly 39% of the data greater than 500 W/m^2 from 10:00am till 3:00 pm. This suggest that both locations have very good sunshine window of 5 hours per day during the winter. Considering the 1000W/m^2 STC for solar modules, the yield from the solar collectors will be nearly half of the peak output power generating slightly higher yield in Kathmandu as compared to Nepalgunj during winter [12, 13].

In case of summer in Kathmandu, the recorded GHI values is from 5:20 am till 7:06 pm in the evening with nearly 50% of the data greater than 500 W/m^2 between 8:00am to 4:00 pm. Similarly, the GHI values in Nepalgunj is from morning 5:25 am till 7:13 pm in the evening with about 71% of the data greater than 500 W/m^2 between 8:00 am to 4:00 pm. This result suggest that, Nepalgunj would generate more output power from the solar collector as compared to that of Kathmandu and both locations have excellent sunshine window of 8 hours per day.

4. CONCLUSION

This study has presented a comparative solar radiation measurement analysis of data from Jan to June, 2019 obtained from the two locations of Nepal (Kathmandu & Nepalgunj). Both location uses identical solar measurement setups with pyranomerters and pyrheliometers for measuring GHI, DNI and DHI mounted on a solar tracker. The daily and monthly average irradiances for both location has been compared. The results suggest that out of six months, Nepalgunj has better daily and monthly average values of GHI and DNI for almost four months (March to Jun). The min by min plots of both location suggest that, the length of day during summer reaches to almost 13.5 hours while, during winter it is about 10.5 hours. Considering the availability of GHI greater than 500 W/m^2, results suggest that a very good sunshine of 5 hours/day in winter and an excellent sunshine of 8 hours/day during the summer is available in both location. Hence, both location are suitable for longer usable sun hours to obtain better energy output from solar collector. However, the energy yield for solar collector will be obtained more in Nepalgunj than in Kathmandu since, nearly 71% of GHI higher than 500 W/m^2 are recorded in Nepalgunj during summer as compared to only 50% in Kathmandu. Hence, Nepalgunj is more suitable for solar investors in terms of obtaining better energy output as compared to Kathmandu.

5. LIMITATION

In this study, the analysis of data over the period of six months between Jan to June, 2019 has been presented as the data after this time frame were not available. This definitely lowers the accuracy of the predicted result and will differ from the annual energy projection. Hence, the authors suggest the possibility of further work for annual energy projection if data for the whole year is available.

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