Volume 16, Number 1, 2023. pp. 65-75

Jordan Journal of Physics

ARTICLE

Comparison of Models to Evaluate Daily Available Energy with Photovoltaic Array at Sirinka, Ethiopia

Tegenu Argaw Woldegiyorgis

Department of Physics, College of Natural Science, Wollo University, Dessie, P.O. Box 1145, Ethiopia.

Doi: **https://doi.org/10.47011/16.1.6**

Received on: 05/05/2021; Accepted on: 18/07/2021

Abstract:
Background: Energy utilization in Ethiopia is mainly based on traditional biomass, which causes indoor air pollution, especially for women and children (causing acute lower respiratory infection) living in rural areas.
Objective: This research was conducted to assess the performance of six empirical models for estimation of daily global solar radiation (DGSR) at Sirinka sites to evaluate daily available energy with photovoltaic (PV) array and energy available to the load (energy demand) and battery (energy-storage device).
Materials and Methods: In this study, sunshine hours, minimum and maximum temperatures were obtained from Kombolcha Meteorological Agency. Ms-Excel 2010 was employed as a descriptive statistics tool and MATLAB 2013a was used as software to plot the analyzed data.
Results: According to the statistical performance evaluation metrics, such as normalized mean bias error (NMBE) and normalized root mean square error (NRMSE), Angstrom Prescott model (AP), Louche model (LO) and Hargreaves model (H) performed best in order. The smallest daily mean power delivered to PV and the daily mean energy available to the load (energy demand) and battery (energy-storage device) were 288.11 W/m^2 and 248.92 W/m^2 sequenced and the largest mean power delivered to the PV and the mean energy available to the load and battery were 851.57 W/m^2 and 735.76 W/m^2 in order on April-10 for the study period of 2014–2018.
Conclusion The result of this work showed high solar energy potential and therefore, rural electrification using PV system is possible in the study area and can reduce health problems due to indoor pollution in the future.

Keywords: Daily global solar radiation, Empirical Model, environmentally friendly, Renewable Energy, Solar Power, Sunshine, Temperature, Photovoltaic.

1. Introduction

The sun is a staggering amount of free, environmentally friendly, quiet and reliable energy supply. The use of solar electricity to produce a real part of the required electrical power has been proposed since 1970 [1, 2]. Predicting as accurately as possible the future amounts of solar energy is of high importance in designing stand-alone or grid-connected solar plants [3]. Global solar radiation data in a particular region is essential for solar-energy applications and therefore, electricity generated from photovoltaic (PV) panels is directly affected by solar radiation [4, 5].

Ethiopia is located in the world's tropical zone, which has excellent solar availability. The daily average total solar radiation over Ethiopia ranges from 5 to 8 kWh/m^2/day [6, 7]. However, a large proportion of the population living in Ethiopia has no access to electricity. Among more than 110 million people living in Ethiopia, 46% only use electric energy for day-to-day activities, like food preparation and other tasks.

Corresponding Author: Tegenu Argaw Woldegiyorgis **Email**: argawtegenu3@gmail.com

In the rural area of the country, where 80% of the population live, people have no sustainable energy supply [8].

A few types of research have estimated global solar radiation in some selected locations in Ethiopia, such as [9] that revealed that the Dembel district, Somali has an abundant solar-energy potential (6.12 $KWh/m^2/day$). The global solar radiation was estimated in different seasons at Bale Robe, using Angstrom-Prescott and Hargreaves-Samani models, where both models were used successfully to estimate the seasonal value of global solar radiation [10]. Monthly average daily solar radiation using sunshine hours and measured temperature in Tepi, Ethiopia was estimated and the results revealed that the sunshine hours-based models Samuel and Newland models are appropriate for Tepi [11]. According to [12], daily global solar radiation using meteorological data at Lalibela was predicted and the maximum average daily global solar radiation (DGSR) was 5.86 KWh/m^2. [13] revealed that Hargreaves and Samani models were more suitable than Angstrom-Prescott's empirical equation at Kombolcha, South Wollo and an abundant average global solar radiation (7.09 $KWh/m^2/day$) was estimated. The result of (average) solar energy potential in Boke, rural villages of Nekemte area is 5.52 $KWh/m^2/day$. Electric load for a single household, school and clinic was estimated as 313, 2064 and 2040 Wh/day, respectively. The findings encourage the use of PV systems in remote sites as well as in rural areas [7].

A photovoltaic array consists of multiple solar panels electrically wired together to form a much larger PV system called an array. Solar panels are made up of individual photovoltaic cells connected together. The photovoltaic cell is a semiconductor device that converts light into electrical energy. After sunlight hits the solar panels, it's captured within photovoltaic cells and transported to an inverter where it's converted from direct-current (DC) electricity to usable alternating-current (AC) electricity.

Shortage of clean energy is a serious problem for rural households in Ethiopia that rely more on biomass fuels. These cause health problems due to indoor air pollution. Environmental degradation because of reliance on nature for collecting energy sources and inefficiency of energy-use technologies are well-known issues faced by rural households in Ethiopia. According to a WHO (2007) report, more than 50,000 deaths per year and 5% of the disease burden in the country were attributable to indoor air pollution [15]. Even when Ethiopia's grand renaissance national electrification program is completed, only 65% of the total population will have access to electricity by 2025. This means that the remaining 35% (>12 million households mainly in rural/off-grid areas) will still be living without electricity [16, 17]. With the rapid fall in the cost of solar panels and available solar irradiation of 5.5$KWh/m^2/day$ in Ethiopia, this makes stand-alone solar PV systems potentially viable and cost-effective solutions for providing access to affordable electricity supply and clean lighting energy in off-grid areas of Ethiopia and sub-Saharan Africa [18, 17]. There are no works that have been conducted before to predict daily power delivered by the PV array and the PV array energy available to the load and battery from estimated DGSR at the study sites. As a result, very important questions concerning the estimation of DGSR in Sirinka, Ethiopia are raised: Are all the models suitable to estimate DGSR in this study site? How is the potential of solar radiation in the study site? Is it the estimated DGSR feasibility that encourages to use the PV system? Can electricity from the PV system solve the health problems of women and children in the region in the future?

Therefore, the goal of this study was (i) to find the most accurate model for estimating DGSR on a horizontal surface in Sirinka. (ii) to estimate the daily mean power delivered to the PV and the daily mean energy available to the load & battery.

2. Materials and Methods

2.1 Study Site and Data Collection

Sirinka is a place in Amhara national regional state, Ethiopia. It is located at latitude 11.75 ^{o}N and longitude 39.6 ^{o}E with an elevation of 1850 meters above sea level. The data collected for the study site covered a period of 5 years (2014–2018). All daily values of meteorological data of sunshine hours, minimum temperature and maximum temperature were obtained from Kombolcha Meteorological Center covering the study site. The meteorological data of sunshine hours was measured by using Campbell Stock instrument and the temperature was measured using a thermometer apparatus. Ms-Excel 2010 was employed as a descriptive statistics tool and MATLAB 2013a software was used to plot the analyzed data.

2.2 Sunshine-based Model

The global solar radiation is mainly related to meteorological factors, such as duration of sunshine, extent of cloud cover, ambient temperature and so on [19]. For many developing countries, like Ethiopia, solar-radiation measurements are not easily available due to the high equipment cost and maintenance and calibration requirements of the measuring equipment. Therefore, there are very few meteorological stations that measure global solar radiation in Ethiopia [11]. In a sunshine duration fraction model in 1924, a linear equation relating the clearness index and the sunshine duration fraction proposed by Angstrom [20, 19] is as shown below:

$$\frac{R_s}{R_c} = a + b\left(\frac{n}{N}\right) \quad (1)$$

where $k_t = \frac{R_s}{R_a}$ is the clearness index, R_s is the daily global solar radiation, R_c is the clear-day global solar radiation, $\frac{n}{N}$ is the sunshine duration fraction, n is the daily sunshine duration, N is the maximum daily sunshine duration and a and b are empirical coefficients.

2.2.1 Model 1 (Angstrom-Prescott Model (AP))

Angstrom [21, 22] derived a simple linear relationship between the average daily sunshine duration and the ratio of average daily sunshine duration to the maximum possible sunshine duration. It is the most widely used correlation for estimating daily R_s [23]. Prescott [24] modified the method used and proposed the following equation:

$$R_s = \left[a + b\left(\frac{n}{N}\right)\right] * R_a \quad (2)$$

where R_s is the global solar radiation (MJ $m^{-2} d^{-1}$), R_a is the extraterrestrial radiation (MJ $m^{-2} d^{-1}$), h is the sunshine duration (h), N is the maximum possible sunshine duration (h) and a and b are empirical coefficients. The values of coefficients are evaluated as [25, 20]:

$$a = -0.11 + 0.235 * \cos(\varphi) + 0.323 * \left(\frac{n}{N}\right) \quad (3)$$

and

$$b = 1.449 - 0.553 * \cos(\varphi) - 0.694 * \left(\frac{n}{N}\right) \quad (4)$$

The estimation of R_a is also given as [26, 27]:

$$R_a = \left[\frac{24*60}{\pi}\right] G_{sc} dr \left[\cos(\phi)\cos(\delta)\sin(\omega_s) + \omega_s \sin(\omega_s)\sin(\delta)\right] \quad (5)$$

where G_{sc} is the solar constant (1367 W/m^2), d_r is the eccentricity correction factor of the earth's orbit, which can be calculated from:

$$d_r = 1.0 + 0.033 * \cos\left[2\pi\left(\frac{Julianday}{365}\right)\right]. \quad (6)$$

The other variables, φ- latitude of the site and δ- solar declination, can be calculated using:

$$\varphi = latitude * \left(\frac{\pi}{180}\right)$$

and

$$\delta = \left[\frac{23.45*\pi}{180}\right] * \sin\left[2\pi\left(\frac{284 + julianday}{365}\right)\right]. \quad (7)$$

Lastly, ω_s- mean sunrise hour angle and N- the maximum possible sunshine duration are also:

$$\omega_s = \cos^{-1}\left[-\tan(\varphi) * \tan(\delta)\right] \quad (8)$$

and

$$N = \frac{2\omega_s}{15} = \frac{2}{15} * \cos^{-1}\left[-\tan(\phi) * \tan(\delta)\right]. \quad (9)$$

2.2.2 Model 2 (Louche Model (LO))

Louche et al. [29, 30] have modified the Angstrom-Prescott model through the use of the ratio of (n/N_{nh}) instead of (n/N); the equation is presented as follows:

$$R_s = \left[a + b\left(\frac{n}{Nnh}\right)\right] * R_a$$

$$\frac{1}{N_{nh}} = \frac{0.8706}{N} + 0.0003 \quad (10)$$

where *a* and *b* are empirical coefficients.

2.2.3 Model 3 (Glover-McCulloch Model (GM))

Glover and McCulloch [22, 32] suggested the following model, which took into account the effect of latitude of the site as an extra input and was valid for φ< 60°:

$$R_s = \left[a * \cos(\varphi) + b\left(\frac{n}{N}\right) \right] * R_a \quad (11)$$

where *a* and *b* are empirical coefficients.

2.3 Temperature-based Models

2.3.1 Hargreaves Model (H)

Estimation of solar radiation (R_S) was first proposed by Hargreaves and Samani by using data from the difference in the maximum and minimum air temperature [29, 32, 26, 33].

. The proposed equation for estimating the solar radiation is:

$$R_s = a * R_a \left[T_{\max} - T_{\min}\right]^{0.5} \quad (12)$$

where R_S is the solar radiation (MJ/m^2.day), T_{max} and T_{min} are the daily maximum and minimum air temperature (^{0}C). R_a is the extraterrestrial radiation (MJ.m^{-2}.d^{-1}) which is a function of latitude and day of the year. a is an empirical coefficient, where the value of a is 0.16 for interior regions and 0.19 for coastal regions. The value of R_a depends on Julian day and the value of R_s is proportional to the difference between the maximum and minimum air temperatures (T_d = T_{max} - T_{min}). If the value of T_d increases, the value of R_s will increase as well.

2.3.2 Annandale Model (A)

Solar radiation estimated by the model of Annandale [30, 32], modified by Hargreaves and Samani, is corrected for altitude. Annandale model is written as follows:

$$R_S = R_a * A_{mod}\left(1 + 2.7 * 10^5 * Z\right) * \left(T_{max} - T_{min}\right)^{0.5} \quad (13)$$

where R_a is the extraterrestrial radiation (MJ/m^{2}day), A_{mod} is the coefficient of the model used (A_{mod} is 0.263) and Z is the average altitude above sea level. T_{max} and T_{min} are the maximum and minimum temperatures, respectively (^{0}C). R_s in the form of a linear equation can be written as follows:

$$R_S = d * R_a \left[T_{\max} - T_{\min}\right]^{0.5} \quad (14)$$

where d is a constant which can be expressed as: $A_{mod}(1+2.7*10^{-5}Z)$.

2.3.3. Garcia Model (G)

Garcia proposed a single-parameter model for estimating global solar radiation in 1994. Garcia model is an adaptation of the AP model with a slight modification that makes it of temperature-based type. The Garcia model is expressed in the form:

$$\frac{R_s}{R_a} = a + b * \left(\frac{\Delta T}{N}\right) \quad (15)$$

where (a, b) are regression constants to be determined and ΔT is the difference between maximum and minimum temperature values [34, 35].

3. Energy on the PV Array

The power delivered by the PV array (E_P) is calculated by [36, 7]:

$$E_P = A_P \eta_P H \quad (16)$$

where A_P is the module area (1m^2) and η_P is the efficiency of PV module (for this study 12%). The array energy available to the load and the battery (Ea) is obtained by the following equation:

$$E_a = E_P\left(1 - \lambda_P\right) * \left(1 - \lambda_C\right) \quad (17)$$

where λ_P is the total loss as a result of dust cover on the PV array (assumed at 4%) and λ_c is power conditioning losses commonly taken as 10%.

4. Performance Evaluation of Models

There are many studies in the literature that addressed the assessment and comparison of DGSR estimation models. The most popular statistical parameters are the NMBE and the NRMSE. Therefore, in this study, some statistical tests, such as NMBE and NRMSE tests, are used to verify the accuracy of linear relationship between the predicted and measured values. For better data modeling, such statistics should be close to zero [34, 37, 38, 39, 35].

4.1 The Normalized Mean Bias Error (NMBE)

$$NMBE(\%) = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(R_{i,cal} - R_{i,mea}\right)}{\frac{1}{n}\sum_{i=1}^{n} R_{i,mea}} * 100. \quad (18)$$

This test, as given above, provides information on long-term performance. A low NMBE value is desirable. A negative value gives the average amount of underestimation in the calculated value.

4.2 The Normalised Root Mean Square Error (NRMSE)

$$NRMSE = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(R_{i,cal} - R_{i,mea}\right)^2}{\frac{1}{n}\sum_{i=1}^{n} R_{i,mea}} . \quad (19)$$

The NRMSE, as given above, provides information on the short-term performance of the correlations by allowing a term-by-term comparison of the real deviation between the predicted and measured values. The smaller the value is, the better is the performance of the model.

Ethiopia is characterized by three distinct seasons. These are locally known as Bega/winter (October to January), Belg /autumn (February to May) and Kiremt/summer (June to September). Bega is the dry season and is mostly associated with hot dry days and cool nights. It is frosty in early mornings accompanied by occasional frost over most of the highland areas. Belg is the small rainy period for most parts of Ethiopia except southern and southeastern low lands. During this season, rainfall is highly variable in time and space and maximum temperatures are common. From Belg season, March, April and May months are the warmest months. Kiremt or Meher (summer) is the main rainy season in which about 85% to 95% of the food crops of the country are produced. It covers the period from June to September after the Belg rains and is associated with frequent rains and homogeneous temperatures mainly in July and August. The size of rainfall is higher as compared to rain fall in the other seasons for many parts of the country [40, 41].

5. Results and Discussion

In this study, three sunshine and three temperature-based empirical models are evaluated using daily meteorological data (sunshine hours and temperatures) for estimating DGSR at Sirinka, North Wollo administrative zone, Amhara national regional state of Ethiopia. Performances of the models were evaluated and compared using (NMBE %) and NRMSE (KWh/m^2). A closer agreement was observed between the estimated and NASA values of the mean DGSR for AP, LO and H models than Glover-McCulloch model (GM) and Annandale Model (A), as illustrated in Fig. 1 and Table 1. Using the best results of the models, the daily power delivered by the PV array and the PV array energy available to the load and the battery are calculated and indicated in Fig 1.

TABLE 1. Model performance evaluation from 2014-2018 for three sunshine-based models and three temperature-based models.

Month	Performance	AP	LO	GM	H	G	A
Jan.	NMBE(%)	-13.49	-18.93	-25.34	-16.44	31.47	44.21
	NRMSE	0.17	0.21	0.27	0.17	0.32	0.45
Feb.	NMBE(%)	-9.21	-14.25	-21.59	-13.06	37.82	50.04
	NRMSE	0.10	0.17	0.23	0.12	0.39	1.48
Mar.	NMBE(%)	-0.66	-6.48	-13.91	-10.66	39.80	54.18
	NRMSE	0.05	0.08	0.14	0.11	0.40	0.54
April	NMBE(%)	7.50	0.56	-6.85	-6.65	39.89	61.11
	NRMSE	0.10	0.06	0.09	0.08	1.07	0.61
May	NMBE(%)	12.50	6.02	-2.28	0.426	51.54	73.32
	NRMSE	0.14	0.08	0.06	0.05	0.53	0.73
June	NMBE(%)	7.01	0.19	-6.76	13.19	85.17	95.35
	NRMSE	0.13	0.10	0.11	0.16	0.88	0.96
July	NMBE(%)	8.80	1.71	-4.54	21.15	103.65	109.09
	NRMSE	0.14	0.10	0.10	0.22	5.55	1.09
Aug.	NMBE(%)	6.15	-0.49	-6.92	11.05	79.30	91.66
	NRMSE	0.12	0.10	0.12	0.14	0.81	0.92
Sept.	NMBE(%)	7.94	1.42	-5.48	1.153	68.85	74.57
	NRMSE	0.11	0.07	0.08	0.05	0.70	0.75
Oct.	NMBE(%)	1.10	-5.35	-12.16	-7.24	1.39	60.09
	NRMSE	0.05	0.07	0.13	0.09	0.49	0.60
Nov.	NMBE(%)	-7.18	-12.60	-19.65	-13.23	39.73	49.75
	NRMSE	0.10	0.14	0.20	0.92	0.98	0.50
Dec.	NMBE(%)	-4.79	-9.35	-17.86	-17.25	37.59	42.81
	NRMSE	0.09	0.12	0.19	0.17	0.855	0.43

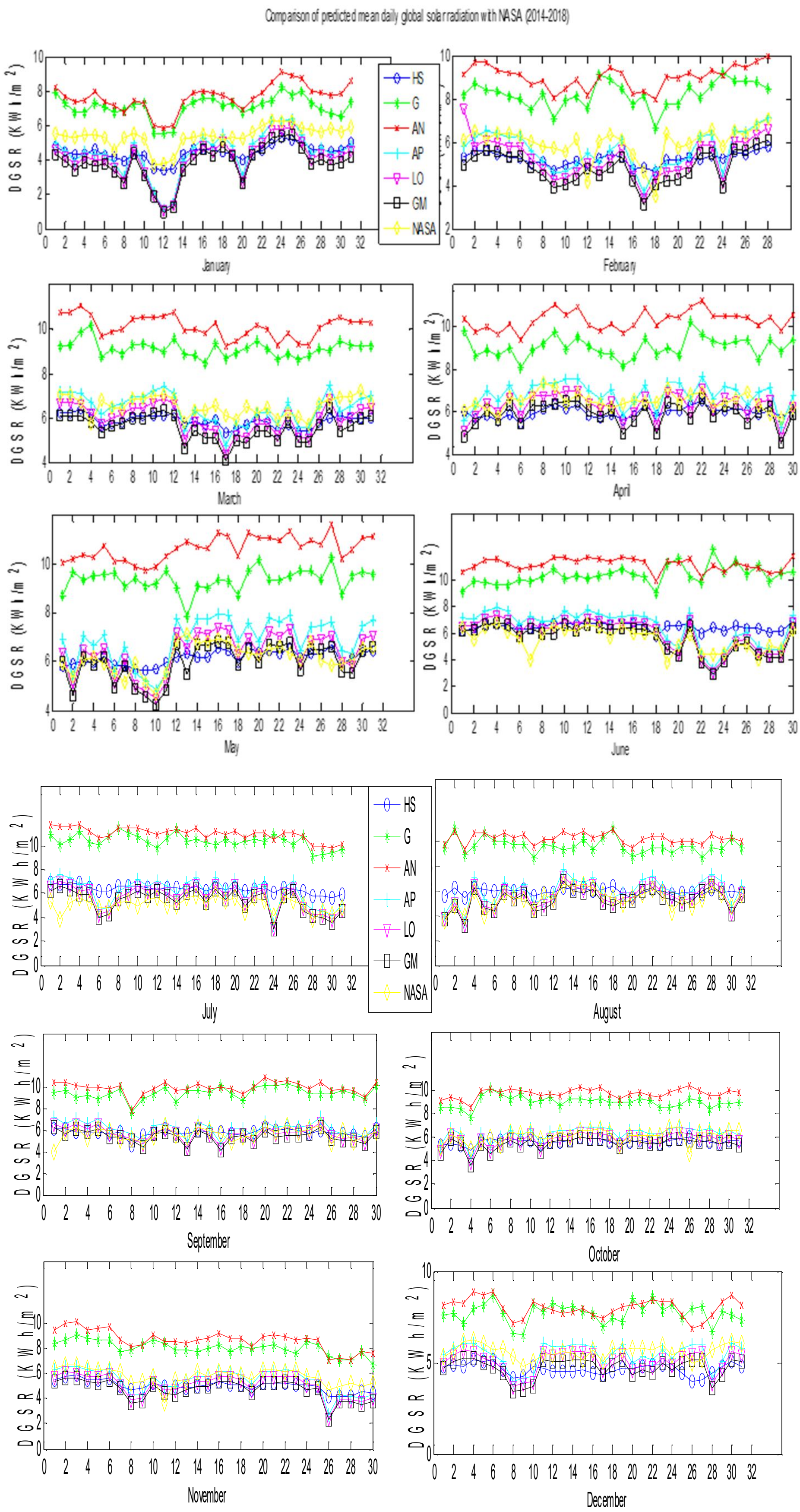

FIG. 1. Comparison of predicted mean DGSR using sunshine and temperature-based models with NASA values from (2014-2018).

The result in Fig. 1 exhibited the predicted mean DGSR values on the horizontal surface based on six models, with the values from NASA for the study place. As shown in this figure, the least mean DGSR at Sirink occurred on January-12, January-13, January-11 and February-17 with values of 2.40 kWh/m^2, 2.69 kWh/m^2, 3.14 kWh/m^2 and 3.15 kWh/m^2, sequentially, in the period of 2014-2018. The largest mean DGSR was found on April-10, April-11, April-20, April-9 and April-24 with the corresponding values of 7.10 kWh/m^2, 7.07 kWh/m^2, 6.97 kWh/m^2, 6.95 kWh/m^2 and 6.94 kWh/m^2, in order, in this paper. During this month, the maximum temperature is common, since this month is one of the warmer months.

From the proposed six models, AP model, LO model and H model were the best models according to statistical test evaluation (a smaller value is an indicator of a better performance of the model) for Sirinka, North Wollo administrative zone, Amhara national regional state of Ethiopia, in order. The AP model was the best model from January to March and from October to December to estimate the mean DGSR in the study period of 2014-2018. Next to this model, LO model was the best model for the months April, June, July and August to predict the mean DGSR of the study site. Lastly, the best model was the H model to estimate the mean DGSR for the months of May and September.

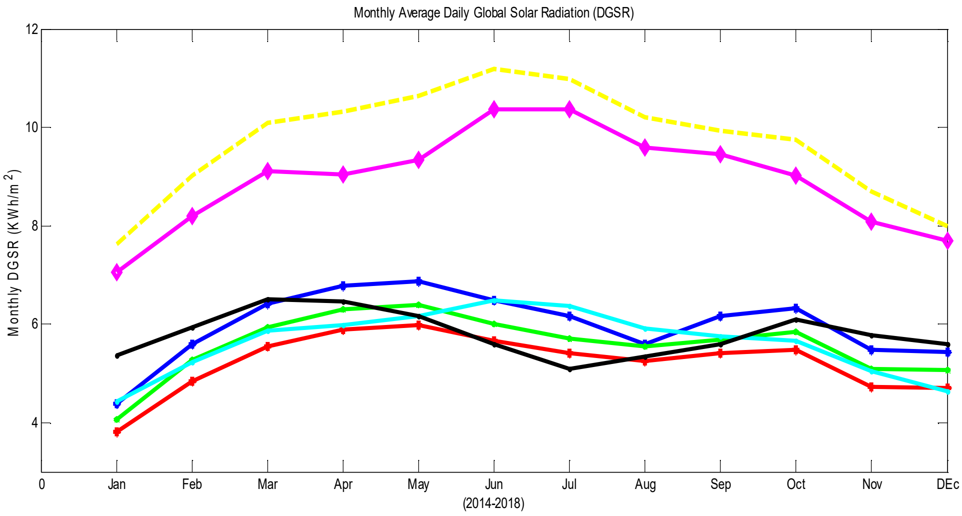

FIG. 2. Monthly averages of DGSR using three sunshine and three temperature-based empirical models at Sirinka from 2014-2018.

The monthly average minimum daily global solar radiation was found in the months of January (4.85kWh/m^2), July (5.30 kWh/m^2), August (5.31kWh/m^2) and November (5.39 kWh/m^2), sequentially. In Ethiopia, January and November represent the dry season with cold weather in the morning, especially in January, while July and August are summer, where the largest rainfall is found. Due to this, the mentioned months have the least DGSR. The monthly average maximum DGSR was found in the months of April (6.46 kWh/m^2), March (6.43kWh/m^2), May (6.17 kWh/m^2) and October (6.08 kWh/m^2), as indicated in Fig. 3. In Ethiopia, March, April and May are autumn, while October is the beginning of winter. March, April and May are the warmest months. In this study, the month of April is the month in which the largest DGSR occurred. The least mean daily power delivered by the PV array and the energy available to the load and battery from the PV array occurred on January-12, January-13, January-11 and February-17, with estimated values of 288.11 W/m^2 and 248.92 W/m^2, 323.31 W/m^2 and 279.34 W/m^2, 376.51 W/m^2 and 325.30 W/m^2 and 378.18 W/m^2 and 326.75 W/m^2 for the period of 2014-2018 at the study area of Sirinka, Ethiopia. The largest mean daily power delivered by the PV array and energy available to the load and the battery from the PV array occurred on April-10, April-11, April-20, April-9 and April-24 with estimated values of 851.57 W/m^2 and 735.76 W/m^2, 848.97 W/m^2 and 733. 51W/m^2, 836.37 W/m^2 and 722.62 W/ m^2, 833.65 W/ m^2 and 720.28 W/ m^2 and 831.74 W/ m^2 and 718.62 W/ m^2, in order. The month of April is the month in which the maximum temperature is found.

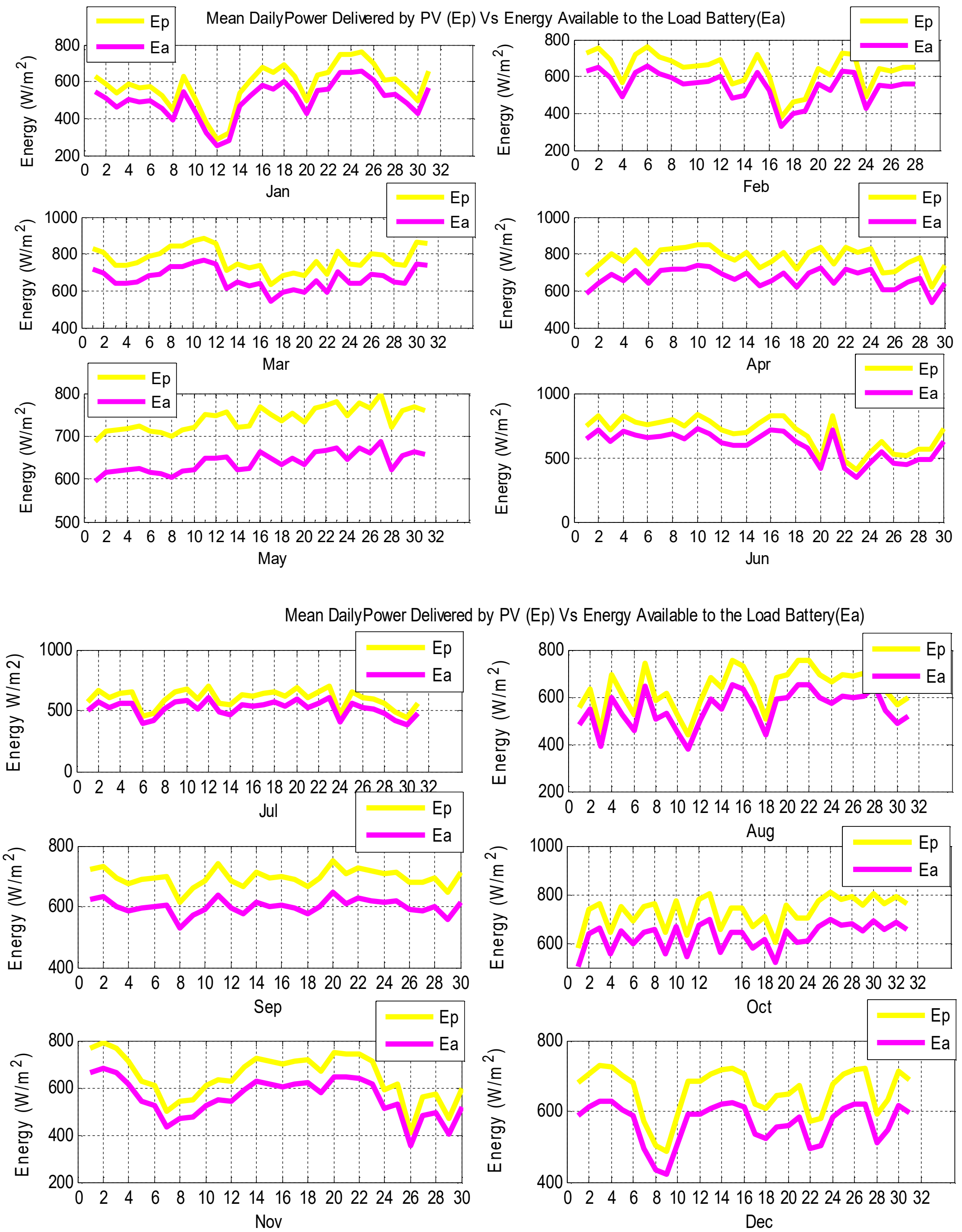

FIG. 3. Mean daily power delivered by the PV array (Ep) and energy available to the load and the battery (Ea).

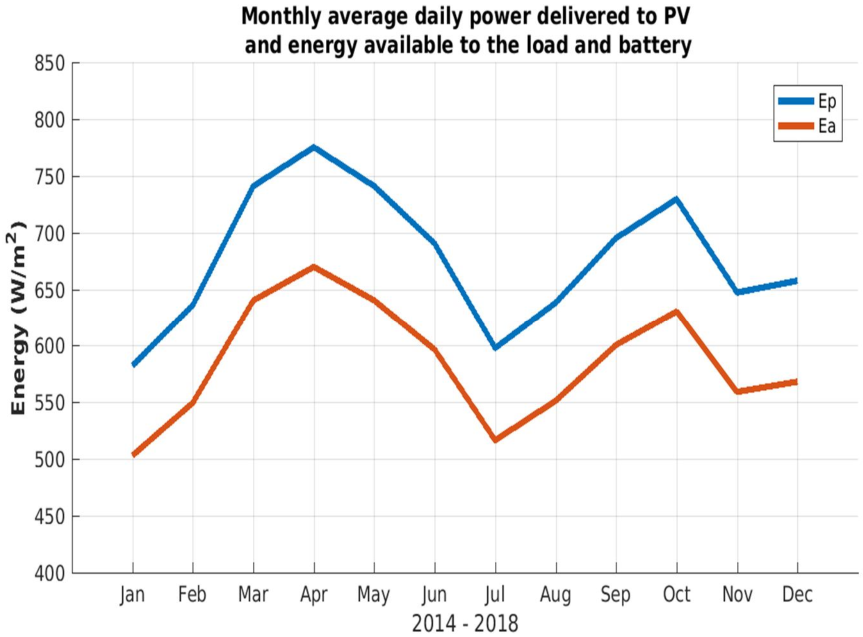

FIG. 4. Monthly average daily power delivered to the PV array and the energy available to the load and the battery from 2014-2018.

The monthly minimum daily power delivered by the PV array and the energy available to the load and the battery were found in the months of January (595.2 W/m^2 and 514.25 W/m^2), February (636.0 W/m^2 and 549.50 W/m^2) and December (657.6 W/m^2 and 568.17 W/m^2), sequentially. The monthly maximum daily power delivered by the PV array and the energy available to the load and the battery were found in the months of May (830.4 W/m^2 and 717.46 W/m^2), April (828.0 W/m^2 and 715.39 W/m^2) and March (771.6 W/m^2 and 666.6 W/m^2), as indicted in Fig. 4. The month of May is the hottest month in Ethiopia among the months of the year.

6. Conclusion

In the present paper, DGSR is predicted to analyze the daily available energy on the PV array in the period of (2014 – 2018). The predicted DGSR was evaluated and compared against the values of NASA. Performance and accuracy of the three sunshine and three temperature-based models were evaluated at Sirinka site, Ethiopia for the estimation of DGSR. The data was analyzed using the latest MATLAB software and Excel sheets.

The results showed that AP, LO and H models in order were the most accurate and best performing models for the study site compared to the GM and A models according to their lowest values of normalized root mean squared error (NRMSE) and normalized mean bias error (NMBE). These best performing solar radiation models could be considered for estimating DGSR to predict the power delivered by the PV array and the energy available to the load and the battery from the PV array at the study area.

The monthly minimum daily power delivered by PV array and the energy available to the load and the battery were found in the month of January (595.25W/m^2 and 514.25 W/m^2, respectively) while the maximum values were found in the month of May (830.4 W/m^2 and 717.46 W/m^2). The results revealed that the site has a high potential of global solar radiation. According to [42], in Ethiopia, eighty percent of rural women cooked indoors using biomass fuel with no ventilation. In the same rural population, the level of reported respiratory diseases is two to three times higher than in urban traditional or middle-class groups. Based on the results of [43], acute respiratory infection among under-five years' children remains high in Ethiopia. Therefore, installing PV systems will be essential to reduce the usage of traditional biomass as well as to reduce the death of children and women due to indoor air pollution. Moreover, increasing the accuracy of DGSR prediction improves the performance and power of intermittent PV systems. The results of this study will be helpful to researchers and engineers to understand the variation in DGSR to install PV devices and solar thermal systems in the study site.

Acknowledgements

The author acknowledges Mr. Eninges Asmare, Mr. Ashenafi Admasu, Mr. Ashenafi Abebe and Dr. Natei Ermias for valuable discussions and for their contributions to the edition of the manuscript. Special thanks to Kombolcha Meteorological Agency, Ethiopia, for providing the sunshine duration, minimum temperature and maximum temperature data used in this study.

Conflict of Interest

The author declares no conflict of interest.

References

[1] Hegedus, S. and Luque, A., “Achievements and Challenges of Solar Electricity from Photovoltaics”. Handbook of Photovoltaic Science and Engineering, (2011), pp.1-38.

[2] Sojoudi, M., Madatov, R., Sojoudi, T. and Farhadi, P., Engineering, Technology & Applied Science Research, 1 (6) (2011) 151.

[3] Boubaker, S., Kamel, S. and Kchaou, M., Engineering, Technology & Applied Science Research, 10 (1) (2020) 5228.

[4] Tijjani, B.I., Bayero Journal of Pure and Applied Sciences, 4 (2) (2011) 24.

[5] Timilsina, G.R., Kurdgelashvili, L. and Narbel, P.A., Renewable and Sustainable Energy Reviews, 16 (1) (2012) 449.

[6] Drake, F. and Mulugetta, Y., Solar Energy, 57 (3) (1996) 205.

[7] Woldegiyorgis, T.A., Journal of Modern Materials, 6(1) (2019) 13.

[8] Getie, E.M., Journal of Electrical and Computer Engineering, 2020 (2020) 7502583.

[9] Benti, N.E., American Journal of Modern Energy, 3 (4) (2017) 73.

[10] Chala, A.A. and Gemeda B.A., Journal of Energy Technologies and Policy, 8 (8) (2018) 14.

[11] Nage, G.D., International Journal of Energy and Environmental Science, 3 (1) (2018) 19.

[12] Woldegiyorgis, T.A., Applied Journal of Environmental Engineering Science, 6 (3) (2020) 6.

[13] Woldegiyorgis, T.A., Journal of Energy, Environmental & Chemical Engineering, 4 (3) (2019) 39.

[14] WHO, Indoor Air Pollution: National Burden of Disease Estimates, (WHO, France, 2007).

[15] Bersisa, M., Heshmati, A. and Mekonnen, A., Environmental Science and Pollution Research, 28 (2021) 58701.

[16] Lakew, H., Tesfaye, G. and Yirgu, A., “Low-carbon Africa: Ethiopia”, (Christian Aid Ethiopia, 2011).

[17] Wassie, Y.T. and Adaramola, M.S., Energy for Sustainable Development, 60 (2021) 52.

[18] Grimm, M. and Peters, J., The Journal of Field Actions, 15 (2016) 160.

[19] Xue, J., Lin, J., Briseghella, B., Tabatabai, H. and Chen, B., Applied Sciences, 8 (4) (2018) 627.

[20] Amou, K.A., Sagna, K., Lare, Y. and Napo, K., Science, 5 (3) (2017) 58.

[21] Zhang, Q., Cui, N., Feng, Y., Jia, Y., Li, Z. and Gong, D., Advances in Meteorology, 2018 (2018) 3894831.

[22] Angstrom, A., Quarterly Journal of the Royal Meteorological Society, 50 (210) (1924) 121.

[23] Liu, X., Mei, X., Li, Y., Wang, Q., Zhang, Y. and Porter, J.R., Agricultural Water Management, 96 (7) (2009) 1137.

[24] Prescott, J.A., Trans. Roy. Soc. S. Aust., 46 (1940) 114.

[25] Hassan, G.E., Youssef, M.E., Mohamed, Z.E., Ali, M.A. and Hanafy, A.A., Applied Energy, 179 (2016) 437.

[26] Chineke, T.C., Renewable Energy, 33 (4) (2008) 827.

[27] Suwarn, R., Indonesian Journal of Electrical Engineering and Computer Science, 6 (2) (2017) 286.

[28] Louche, A., Notton, G., Poggi, P. and Simonnot, G., Solar Energy, 46 (4, (1991) 261.

[29] Almorox, J.Y. and Hontoria, C., Energy Conversion and Management, 45 (9-10) (2004) 1529.

[30] Annandale, J., Jovanovic, N., Benade, N. and Allen, R., Irrigation Science, 21 (2) (2002) 57.

[31] Glover, J. and McCulloch, J.S.G., Quarterly Journal of the Royal Meteorological Society, 84 (360) (1958) 172.

[32] Bandyopadhyay, A., Bhadra, A., Raghuwanshi, N.S. and Singh, R., Agricultural and Forest Meteorology, 148 (11) (2008) 1707.

[33] Shahidian, S., Serralheiro, R., Serrano, J., Teixeira, J., Haie, N. and Santos, F., "Hargreaves and Other Reduced-set Methods for Calculating Evapotranspiration", In: "Evapotranspiration", (2012) pp. 59-80.

[34] Gueymard, C., Solar Energy, 68 (3) (2000) 285.

[35] Muzathik, A.M., Nik, W.M.N.W., Samo, K. and Ibrahim, M.Z., Journal of Physical Science, 21 (2) (2010) 51.

[36] Chandler, W.S., Whitlock, C.H. and Stackhouse Jr, P.W., J. Sol. Energy Eng., 126 (3) (2004) 945.

[37] Bulut, H. and Büyükalaca, O., Applied Energy, 84 (5) (2007) 477.

[38] Koussa, M., Malek, A. and Haddadi, M., Energy Conversion and Management, 50 (5) (2009) 1227.

[39] Şenkal, O. and Kuleli, T., Applied Energy, 86 (7-8) (2009) 1222.

[40] Legese, W., Koricha, D. and Ture, K., J. Earth Sci. Clim. Change, 9 (443) (2018) 2.

[41] Jima, W.L., Korecha, D. and Ture, K., International Journal of Environmental Chemistry, 3 (2) (2020) 84.

[42] Edelstein, M., Pitchforth, E., Asres, G., Silverman, M. and Kulkarni, N., BMC International Health and Human Rights, 8 (1) (2008) 1.

[43] Enyew, H.D., Mereta, S.T. and Hailu, A.B., Public Health, 193 (2021) 29.