Assessment of the Potential of Renewable Energy with Bias Correction Due to Climate Change Over South Asia Using Global Atlas Dataset

Muhammad Abid Khan and Koji Dairaku

Abstract

In order to meet the rising energy needs in South Asia as a result of population growth and societal development, the development of renewable energy is of paramount importance. With the hindcast data from the global atlas (GWA3 and Solargis) dataset, the aim of this study is to determine how climate change impacts wind power density (WPD) at 50 m above the ground level (AGL) through the power law method and photovoltaic (PV) potential over the subcontinent by using the climate change historical evaluation. The developing countries require the use of renewable energy, because of this, knowing the ideal location is important, and implementing wind and solar energy initiatives is crucial in this regard. The validation of GWA3 is based on the wind atlas methodology and the wind atlas analysis and application program (WAsP). Specifically, when analyzing threshold wind speed factors that influence wind energy production, according to the novelty of this research that applies the bias correction techniques quantile mapping based on Weibull distribution. Plus, global solar atlas uses Solargis PV modeling software and a high-resolution database of solar resources. The duration of data for wind energy and long-term reference data (ERA 5) is 2 and 12 years, respectively. In addition, overall subcontinent the average daily/yearly totals of solar PV plant that produces 1 kW-peak electricity, calculated for the period of 20 recent years. For WAsP modeling, the mean wind speeds of the predicted wind climates have an estimated ~ 6.5% standard uncertainty in the region of Pakistan and Maldives, and Bangladesh, respectively. For GWA3 modeling, the mean wind speeds of the predicted wind climates have an estimated mean absolute bias of 17% ± 8% and ± 2% standard deviation (assuming no bias or uncertainty on the WAsP modeling) in the region of Pakistan and Maldives, respectively. Moreover, for Bangladesh 1% ± 0 percent standard deviation is. Furthermore, in the simulation, losses due to dirt and soiling were estimated at 3.5%, while the total loss from all conversion losses was estimated at 7.5%. Another point worth mentioning was to estimate the energy density based on the data results on wind speed (m/s) at the hub height of 50 m AGL over the subcontinent. For instance, maximum and minimum energy density regions are Afghanistan and Maldives, respectively. Meanwhile, the PV system consists of crystalline silicon PV modules mounted at a fixed position, tilted to maximize yearly energy production. Consequently, understanding long-term WPD and PV power potential for micro-scale energy yields is crucial for understanding subcontinental variations. Additionally, the RE system reduces GHGs and limits global climate change. The CO_2 can be switched to low with this method.

Keywords

Renewable energy · Subcontinent · Simulations · Bias correction · Weibull distribution

1 Introduction

A growing number of greenhouse gas (GHG) emissions from burning fossil fuels make climate change the biggest environmental issue today (Burton, 2014). As a result, scientists are trying to come up with a source of energy that doesn't harm the environment and generates enough energy (Khan, 2018). Renewable energy sources such as wind and solar can generate electricity cleanly and at a relatively low cost. Using a photovoltaic (PV) module and a wind

M. A. Khan (✉) · K. Dairaku
Department of Engineering Mechanics and Energy,
Graduate School of Science and Technology,
University of Tsukuba, Tsukuba 305-8577, Ibaraki, Japan
e-mail: s2130195@u.tsukuba.ac.jp

H. Chenchouni et al. (eds.), *Recent Advancements from Aquifers to Skies in Hydrogeology, Geoecology, and Atmospheric Sciences*,
Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-031-47079-0_67

turbine, wind and solar energy can be converted into electricity (Khan, 2020). Several countries have met their electricity needs with wind and solar power. Wind and solar atlases generated from weather forecast models could assist address "grand challenges" in the wind and photovoltaic energy science of them. To model the interaction between microscales and mesoscales of atmospheric motion, wind atlases have been used in the past.

There have been a lot of scientific studies on using wind and solar energy to generate electricity. Zhou et al. (2011) studied the potential for onshore wind energy in China using meteorological data from 1979 to 2008. About 146,336 GWh can be produced by onshore wind farms in the study region. Additionally, Rehman et al. (2017) examined whether a grid-connected photovoltaic (PV) system of 10 MW could be feasible in 44 locations in Saudi Arabia. A future PV plant should be installed at Bisha, they concluded. Based on the Paris Agreement and the International renewable energy agency (IRENA), it should limit global warming, decrease the temperature and explore switching from high carbon to low carbon energy by wind yield to limit climate change for the next generation, respectively. In addition, based on the IPCC fourth and fifth reports global warming is caused by human action and needs to decrease greenhouse gas (GHG) emissions to stop climate change, sequentially.

The wind characteristics at turbine hub height over the region under changing climate for micro-scale energy yield have been investigated in only a few studies. Renewable energy (RE) resources are abundant in South Asian countries, which can produce a great deal of electricity in a short period of time. The paper followed a method based on subcontinental results for fast-cycle correction of windspeed forecast biases. Hence, a novel perspective is presented on the new method for windspeed forecast corrections. In this regard, it is appropriate to determine how RE should be utilized as well as to implement appropriate technologies to maximize its potential.

2 Methods

The validation of GWA3 is based on the wind atlas methodology and the wind atlas analysis and application program (WAsP). Specifically, when analyzing threshold wind speed factors that influence wind energy production, according to the novelty of this research that applies the bias correction techniques quantile mapping based on Weibull distribution. For bias correction of variables are applied quantile mapping with Weibull distribution (QWD), expressed in the following Eqs. 1 and 2 (Haas, 2014). Further, the power law method was used for extrapolation. Moreover, global solar atlas uses Solargis PV modeling software and a high-resolution database of solar resources. The duration of data for wind energy and long-term reference data (ERA-5) is 2 and 12 years, respectively. In addition, overall subcontinent the average daily/yearly totals of solar PV plant that produces 1 kW-peak electricity, calculated for the period of 20 recent years.

$$W_{\text{cor. m/s}} = F_{\text{ref}}^{-1}\left(F_{\text{atlas}}(W_{\text{atlas}})\right) \tag{1}$$

$$W_{\text{cor. m/s}} = \alpha_{\text{ref}}\left[-\ln\left(1-\left(1-\exp^{-\left(\frac{W_{\text{atlas}}}{\alpha_{\text{atlas}}}\right)^{\beta_{\text{atlas}}}}\right)\right)\right]^{\frac{1}{\beta_{\text{ref}}}} \tag{2}$$

Weibull parameters scale (α) and shape (β) are calculated by the method of moments.

3 Results

3.1 Energy Potential Calculations

Afterward, the correction of the climate variable based on QWD, the author investigated the energy protentional based on the global atlas sources for the wind yield in the first part of the research. Meanwhile, the second part of the research is solar yield by global solar atlas through Solargis did the work.

3.2 Wind Energy Yield

Figure 1 illustrated the wind energy density at 50 m above the ground level for the subcontinent on average at 6.02 m/s velocity. In this research, the area shows the maximum energy level in Afghanistan, followed by Nepal, and the minimum comes out in the Maldives, followed by the second last minimum yield in Bangladesh. This data is for 10% of the windiest areas in this research. Therefore, on mean value is 370.5 w/m^2 for the energy density, based on the average wind speed is 6.02 m/s. In the case of validation sites for GWA3 modeling 12 meteorology stations were examined in Pakistan, 1 and 2 for Bangladesh and Maldives, respectively.

For WAsP modeling, the mean wind speeds of the predicted wind climates have an estimated ~ 6.5% standard uncertainty in the region of Pakistan and Maldives, and Bangladesh, respectively. For GWA3 modeling, the mean wind speeds of the predicted wind climates have an estimated mean absolute bias of 17% ± 8% and ± 2% standard deviation (assuming no bias or uncertainty on the WAsP modeling) in the region of Pakistan and Maldives, respectively. Moreover, for Bangladesh 1% ± 0% standard deviation is.

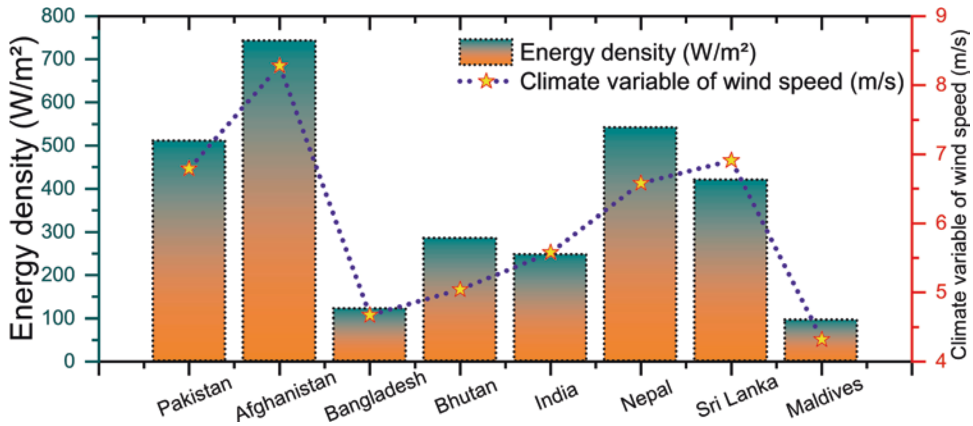

Fig. 1 Wind energy density at 50 m above the ground level (AGL) presenting for the subcontinent countries at an average of 6 m/s

3.3 Photovoltaic Power Potential Yield

In the second part of the research simulation for PV power potential, losses due to dirt and soiling were estimated at 3.5%, while the total loss from all conversion losses was estimated at 7.5%. There's no downtime on the power plant. Based upon a 30-min time step analyzed by satellite and atmospheric data, the solar resource database is determined with a spatial tenacity of 1000 m and is computed from meteorological and satellite data. PV system consists of crystalline silicon PV modules mounted at a fixed position, tilted to maximize yearly energy production presented in an overview in Fig. 2.

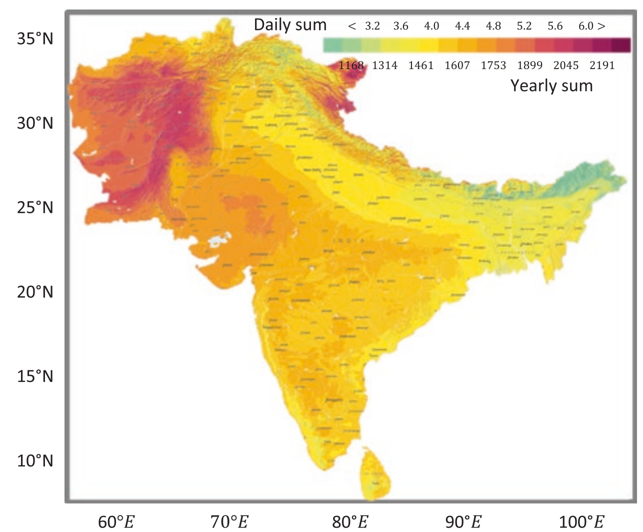

Fig. 2 Photovoltaic power yield consists of crystalline silicon PV modules mounted at a fixed position, tilted to maximize yearly energy production over the subcontinental countries

4 Discussion

An additional point worth mentioning was to estimate the energy density based on the data results on wind speed (m/s) at the hub height of 50 m above the ground level over the subcontinent. For instance, maximum and minimum energy density regions are Afghanistan and Maldives, respectively. Meanwhile, the PV system consists of crystalline silicon PV modules mounted at a fixed position, tilted to maximize yearly energy production. Tilting the telescope toward the equator at least 0.0° but not more than 39.0° is optimal. Inverters that are high-efficient are assumed to be used.

As in previous research such as (Haas, 2014), modeling uncertainties arising from model choice affect methodology when assessing climate change's impact on renewable energy yield. According to Khan (2020), Rehman et al. (2017), the studies applied RETScreen models for photovoltaic power yield which raise the uncertainties in the collection and analysis of the dataset without bias correction. Consequently, in the present research to decrease the uncertainties in the investigation of renewable energy such as wind and solar yield by the bias correction techniques quantile mapping based on Weibull distribution applied.

For the future, it should be calculated at 100 m above the ground level to know the performance of QWD, but the data availability level is limited. However, most of the studies applied the power law method to extrapolate to the desired height without validation. Undoubtedly PV systems should consider the dual position tilted to maximize yearly energy yield after applying the QWD method.

5 Conclusion

This research examines the wind power density, photovoltaic power, and static atmospheric stability of two state-of-the-art wind and solar atlases. Consequently, firstly, long-term WPD and PV power potential for micro-scale energy yield assist understand the variations in regions that has be highly susceptible in the subcontinent. Secondly in the additional research, applying the RE system can reduce GHG and limit global climate change and break the temperature. So, this method can switch to low CO_2. Estimated the energy density at the hub height of 50 m AGL for the subcontinental region renewable energy yield was maximum and minimum energy density regions are Afghanistan and Maldives, respectively. Besides, there is no downtime on the PV power plant. Based upon a 30-min time step analyzed by satellite and atmospheric data.

References

Burton, L. (2014). *Agriscience: Fundamentals and applications*. Cengage.

Haas, R., Pinto, J. G., & Born, K. (2014). Can dynamically downscaled windstorm footprints be improved by observations through a probabilistic approach? *Journal of Geophysical Research: Atmospheres*, 119, 713–725.

Khan, M. A., Çamur, H., & Kassem, Y. (2018). Modeling predictive assessment of wind energy potential as a power generation sources at some selected locations in Pakistan. *Modeling Earth Systems and Environment*, *5*, 555–569. https://doi.org/10.1007/s40808-018-0546-6

Khan, M. N. K. A. R. (2020). Power generation development based on solar potential at urban and rural regions selected locations in Pakistan. *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, 2601–2618.

Rehman, S., Ahmed, M., Mohamed, M., & Al-Sulaiman, F. (2017). Feasibility study of the grid connected 10 MW installed capacity PV power plants in Saudi Arabia. *Renewable and Sustainable Energy Reviews*, *80*, 319–329. https://doi.org/10.1016/j.rser.2017.05.218

Zhou, Y., Wu, W., & Liu, G. (2011). Assessment of onshore wind energy resource and wind—Generated electricity potential in Jiangsu, China. *Energy Procedia*, *5*, 418–422. https://doi.org/10.1016/j.egypro.2011.03.072