WIND AND SOLAR ENERGY POTENTIALS AROUND SOUTHERN SINDH & SOUTHERN BALUCHISTAN PROVINCES, ESPECIALLY KARACHI OF PAKISTAN

Muhammad Shahid
Department of Electronic Engineering, Dawood University of Engineering & Technology. Karachi (Pakistan)
E–mail: engr_shahid82@yahoo.com

Sabir Ali Kalhoro
Department of Electronics Engineering NED University of Engineering and Technology. Karachi (Pakistan)
E–mail: sabir13es66@gmail.com

Darakhshan Ara
Department of Humanities, Mathematics and Basic Sciences, Dawood University of Engineering and Technology. Karachi (Pakistan)
E–mail: ara.chemistry@yahoo.com

Noor Bano
Indus University. Karachi (Pakistan)
E–mail: zarahassan497@gmail.com

Rubina Perween
Department of Chemistry, Federal Urdu University of Arts, Sciences and Technology. Karachi (Pakistan)
E–mail: rubinaperween@fuuast.edu.pk

Recepción: 05/03/2019 **Aceptación:** 05/04/2019 **Publicación:** 17/05/2019

Citación sugerida:
Shahid, M., Kalhoro, S. A., Ara, D., Bano, N. y Perween, R. (2019). Wind and solar energy potentials around Southern Sindh & Southern Baluchistan provinces, especially Karachi of Pakistan. *3C Tecnología. Glosas de innovación aplicadas a la pyme. Edición Especial, Mayo 2019*, pp. 116–141. doi: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116–141

Suggested citation:
Shahid, M., Kalhoro, S. A., Ara, D., Bano, N. & Perween, R. (2019). Wind and solar energy potentials around Southern Sindh & Southern Baluchistan provinces, especially Karachi of Pakistan. *3C Tecnología. Glosas de innovación aplicadas a la pyme. Special Issue, May 2019*, pp. 116–141. doi: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116–141

ABSTRACT

Electrical energy has a vital place as it amounts to being the basic necessity of sustainable life and necessitates itself for the development of human capital leading to the general economic uplift of a nation.

Pakistan has remained in the serious shortage of electric power leading to adverse effects on the state. Around 70 % of Pakistanis are living without stable electric supply. Those who are lucky enough to have access to electricity undergo around 12 to 14 hours of load– shedding. Pakistan is always in the lack of sufficient conventional sources of energy. Adding to this it is the fact that Pakistan has not made any significant steps to tap renewable energy resources like wind and solar energy. It seems very natural for Pakistan to employ the natural resources of energy which are yet to be tapped and are coming into the fulfilment of the shortage in the supply of energy.

In this paper, the existing potential of renewable energy resources is studied as a viable alternative to the current state in the energy supply and demand. Southern Pakistan is presented to hold key renewable resources such as wind and solar energy in order to address the energy shortfall.

Southern Pakistan, mainly coastal regions, possesses wind and solar potentials. The paper chooses selected areas in southern Pakistan containing an adequate level of wind power. The paper attempts to argue that renewable energy resources can meet the energy demand of the southern regions mainly coastal ones. The paper attempts to look at the current and future challenges in the transition to wind and solar power.

KEYWORDS

Renewable Energy, Energy Potential, Energy Shortfall, Coastal Regions Study.

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

1. INTRODUCTION

Comparing with other developing countries, Pakistan is facing serious energy crisis since the past several decades leading to an ever–increasing energy demand necessitating making it seriously dependent on import of pricy fossil fuels. In the villages of Pakistan, there is almost no electricity & cities are facing bitter load shedding problems (Ashfaq & Ianakiev, 2018). Load shedding is 14–18 hours in villages and 8–12 hours in cities. The customers located in residential, industrial and commercial sectors are badly affected making it an immense challenge for the government sector power infrastructure to ensure sustainable power. If we do not encounter these burning issues of electrical energy on a priority basis, then in future there will be the worst situations of electricity in Pakistan. A large number of research attempts is needed to explore the renewable energy (RE) resources to attend the gap between the supply and need. However, the renewable energy sector is yet to penetrate in the present conventional energy infrastructure predominantly located in northern and central regions (Kamran, 2018).

Pakistan has energy resources, renewable and non–renewable. Renewable energy is considered environment–friendly while the non–renewable energy is harsh for the environment. The sources of renewable energy are solar, wind, tidal, geothermal, biomass, hydro and thermal. Mostly the developed countries of the world depend on non–renewable energy resources to meet the energy demands. Also, the developing countries especially Pakistan still rely on the expensive fossil fuel based energy system which is expected to deplete shortly (Sher, Murtazs, Addoweesh & Chiaberge, 2015; Tahir & Asim, 2018). The non–conventional energy resources have been exploited to reduce fossil fuel–based local and commercial consumption bit by bit. As such, energy has earned the best quantity of attention globally than ever before. The energy crisis is already affecting the developing countries like Pakistan. Pakistan has 93.5% electricity rely on the oil, natural gas, hydropower, nuclear energy, coal and a little bit on the RE. Pakistan is mostly dependent on expensive fossil fuel. Pakistan utilizes 25.7% of natural gas, 37.2% of oil, 30.7% of hydropower, and 4.8% of nuclear energy (Index

Mundi, 2018). 0.1% of coal and only 0.8% of it is based on the RE to fulfil the energy demand of Pakistan up to 2015 as shown in Figure 1.

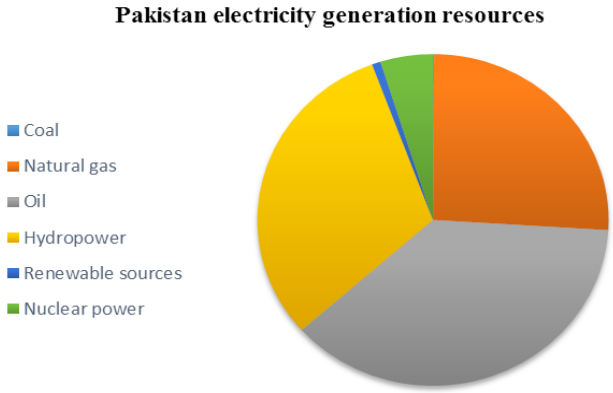

Figure 1. Electricity Sources percentage use in Pakistan. **Source:** Index Mundi.

The past and the present attempts aimed at curtailing the existing energy crisis rendering the most of the urban areas suffering from power outages for 12 hours on a regular basis. According to the International Energy Agency, Pakistan has a vast proportion of its population which does not have access to energy. The most population of the country is even not connected to the national electricity grid. The population with access to on–grid electricity is enduring load shedding on a daily basis. This illustration is shocking which requires immediate attention. The policymakers are required to feature such type of energy resources that overcome the current demand of the country (Best & Burke, 2018; Wakeel, Chen & Jahangir, 2016; Asif, 2009; Harijan, Uqaili, Memon & Mirza, 2009).

The geography of Pakistan is blessed with a lot of solar and wind energy throughout the year. In normal days Pakistan gets 7.5 hours of sunlight each day having 6 kWh/m2 average solar radiations along with most of the territory of the country. In earlier days, Pakistan never utilizes the energy potential but later 1991 the government acquires an interest in the technologies. Then different departments, boards, companies & corporates are working in developing technologies.

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

Pakistan is highly relying on foreign expensive fuels. It is, therefore, time to utilize the available rich potential of the renewable energy resources within Pakistan. The solar, wind and biomass are excessively available in Pakistan. These renewable energy resources are economical and environmentally friendly and highly careful regarding sustainability. The renewable energy resources are very much encouraged able at the position of the expensive fossil fuel–based resources. The available unchecked renewable resources can meet the current energy demands that facilitate to conserve the standard of current resources that are early decreasing. This paper provides a detailed description of the unchecked areas in Pakistan where there is a high potential for renewable energy. The proposed research aims to explore the RE potential. The southern Sindh and southern Baluchistan provinces especially Karachi have a lot of opportunities in wind & solar energies. In this paper, these potentials will be explored with the help of real–time analysis of solar & wind measurements (Halacy, 1980; Kumar, 2017; Usman, Hussain, Ahmad. & Javed, 2015; Baloch, Kaloi & Memon, 2016).

There is square measure virtually no grid interconnection of the alternative energy at the established stage. The dynamic circumstances are significantly changing from the conventional power resources to the non–conventional energy resources. Solar and wind are the best resources to contribute to the national grid in the current situation. Pakistan government constructs the three wind farms interconnection network and lots of others in the pipeline. The federal policy on wind energy system has recently modified for the future task. The continued schemes of the wind park have gotten slow because of low maintenance. The planned analysis paper gives detail developments within the wind energy sectors of the country. Additionally, the suggestions which will contribute to boosting the penetration of wind energy within the national sector are highlighted in Pakistan (Shahzada, Nawaz &Alvi, 2018; Farooq & Kumar, 2013).

The wind and solar energy are the cost–effective non–conventional sources of energy. Pakistan has a high potential for renewable energy due to its geographical

location. Pakistan has unlimited potential of RE, e.g., 2,900,000MW of solar, 346000 MW of wind, 3000MW of biogas, 2000MW of tiny hydropower and 1000MW from waste. Pakistan has high RE potential but still relies on expensive fossil fuel. Pakistan has so much noted area like southern Sindh and southern Balochistan where there is the great potential of renewable energy to alleviate the current increasing demand. Pakistan is still unable to use these noted sites of the two provinces of the country. The Sindh and Baluchistan have the potential to fulfil the current demand of the country. The proposed study is based upon the potentials of wind and solar energy around southern Sindh and southern Baluchistan Provinces of Pakistan (Mirjat, *et al.*, 2017; Wakeel, *et al.*, 2016; Sadiqa, *et al.*, 2018; Yuan, *et al.*, 2018). This ly among 250 Km of the southeastern and 800 Km of the southwestern regions of Asian nation. The annual wind speed information is reported for variable heights of those predictable sites. The wind energy around these areas that represent to possess an associate degree. The annual average wind speed of 6.63 m/s and 5.33 m/s correspondingly. The facility of yearly generation from these noted locations of two provinces is 7.653 GWh, and 5.456 GWh. This study conjointly elaborates the benefits and side effects. The generation of electricity from the wind and solar within the selected remote zones areas will offer the economical and relatively best implementation to the national off–grid system. The findings of this research can facilitate the government, local and industrial sector. The proposed acceptable research will attract the investment for the wind and solar energy to eradicate the on–going electricity crisis within the country (Moretto, Branca & Colla, 2018; Ishaque, 2016; Ashfaq & Ianakiev, 2018).

In the past, there were no such real–time data of solar and wind measurements in Pakistan. The planner has worked on solar and wind energies in Pakistan. The real–time measurements of solar and wind energies are highly good from all orientation. The Karachi is the biggest city of Pakistan, has great potentials of solar and wind energies. Previously, there is no data available for wind and solar measurements of the megacity. The proposed research sources are depending on the World Bank (WB) data. In Pakistan, WB has

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

started to gather data of solar measurements of different cities from April 2015 & wind measurements from September 2016. But in Pakistan, there is no coordination with these real–time data (Ashfaq & Ianakiev, 2018; Shoaib, *et al.*, 2017).

2. MODELS

2.1.SOLAR MODELS

The photovoltaic model provides long–term averages of solar radiation such as global, diffuse and direct normal. The given models are signifying solar efficiency. The solar thermal energy technologies, on the other hand, for example, the Concentrated Solar Power (CSP) and Concentrated Photovoltaic (CPV) rely on Direct Normal Irradiation (DNI). Terrain elevation determines the best site and concert for the solar PV as described in Eq.1.

$$Cos\,\theta = \sin\delta \sin\varphi + Cos\,\delta\, Cos\,\varphi \cos\omega$$
$$Cos\,\theta = \sin\delta \sin\varphi + Cos\,\delta\, Cos\,\varphi \cos\omega$$

Eq.1

DNI is the relevant photovoltaic concentrating technologies as Eq. 2.

$$\mathrm{DNI} = \mathrm{A}.\exp(-\mathrm{B}/\mathrm{Cos}\,\theta)\mathrm{DNI} = \mathrm{A}.\exp(-\mathrm{B}/\mathrm{Cos}\,\theta)$$

Eq. 2

DHI is the solar irradiation component as given below in Eq. 3.

$$\mathrm{DHI} = \mathrm{C}.\mathrm{DNIDHI} = \mathrm{C}.\mathrm{DNI}$$

Eq. 3

GHI is considered as a climate reference as it enables comparing individual sites or regions as referring to Eq. 4.

$$GHI = DHI + DNI \cdot \cos(\theta)GHI = DHI + DNI \cdot \cos(\theta)$$

Eq.4

Air temperature is taken at 2 meters above the ground. Air temperature, in °C or °F, determines the temperature of PV cells and modules. The air temperature and also some other meteorological parameters are an important part of each solar energy project calculation as they define the functional circumstances and working proficiency of the solar PV as given in Eq.5.

$$\eta = \eta Tref[1 - \beta ref(Tc - Tref)]\eta = \eta Tref[1 - \beta ref(Tc - Tref)]$$

Eq. 5

Photovoltaic, generally, is the most applied and versatile technology. The Atlas continually indicates the estimation of yearly average values of power generation for PV systems that enormously use the World Bank parameter for installation of the solar power plant. The PV electricity simulation program, based on an algorithm, is combined within the atlas which always provides a secondary approximation of the potential electrical occurrence energy, which may be made at any location ruled by the interactive map as given below in Eq. 6.

$$T_c = T_a + \left(\frac{NOCT - 20}{800}\right) G_t T_c = T_a + \left(\frac{NOCT - 20}{800}\right) G_t$$

Eq. 6

2.2. IMPORTANT PARAMETERS

A Apparent extraterrestrial irradiance (W/m^2)

B Atmospheric attenuation coefficient (W/m^2)

C A dimensionless constant

Cn Cloud cover index DHI (Diffuse horizontal irradiance) (W/m^2)

DHIcs Diffuse horizontal irradiance under a clear sky

DNI Direct normal irradiance (W/m^2)

DNIcs Direct normal irradiance under a clear sky

DNIcs Maximum direct normal radiation under clear sky during the day (W/m^2)

DNIcn Maximum direct normal radiation under cloudy sky during the day (W/m^2)

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

GHI Global horizontal irradiance (W/m^2)

–z solar zenith angle rain Probability of precipitations

RMSE% Root Mean Square Error

2.3. WIND MODELS

Pakistan is the country in the world where there are great wind energy potentials. Electricity, in large quantities, can be produced by taking advantage of the available renewable energies.

$$P_w = \frac{1}{2} C_p(\lambda,\beta)AV^3 P_w = \frac{1}{2} C_p(\lambda,\beta)AV^3$$

Eq. 12

The wind energies of southern Sindh and southern Baluchistan of Pakistan especially Karachi have been investigated with the help of available World Bank data.

The wind energies of the selected regions give the commendable measurement which can be exploited to generate the great amount of wind energy.

$$Q_\omega = P \times Time\,[KWh] Q_\omega = P \times Time\,[KWh]$$

Eq. 13

$$T_t = \frac{1}{2} C_p(\lambda,\beta)A\left(\frac{R}{\lambda}\right) T_t = \frac{1}{2} C_p(\lambda,\beta)A\left(\frac{R}{\lambda}\right)$$

Eq. 14

The required parameters like turbulence intensity, min. wind speed, max, wind speed, mean wind speed & wind speed standard deviation have been studied to extract the wind energy. According to the analysis of the World Bank data, these parameters are based upon the World Bank wind calculations. The parameters are used to show the data of the provinces especially Karachi. The World Bank chooses these parameters to calculate the wind potential of Pakistan as shown in Eq. 12 to Eq. 14.

3. RESULTS

3.1. SOLAR RESULTS FOR SOUTHERN SINDH

In solar energy, some parameters like global horizontal irradiance (ghi), DNI (direct normal irradiance, DHI (diffuse horizontal irradiance), air temperature and relative humidity have been analyzed. According to the analysis, these two provinces including Karachi have the great solar energy potentials as shown in Figure 2. The solar panels in large quantities can be installed in these noted areas to get the maximum amount of electrical energy. Also, the solar potential of the Hyderabad shown the great potential as refer Figure 3.

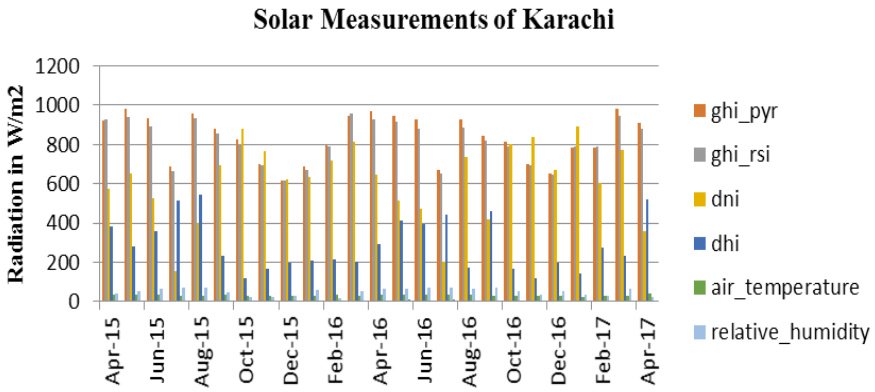

Figure 2. Solar Measurements of Karachi, Sindh. **Source:** The World Bank.

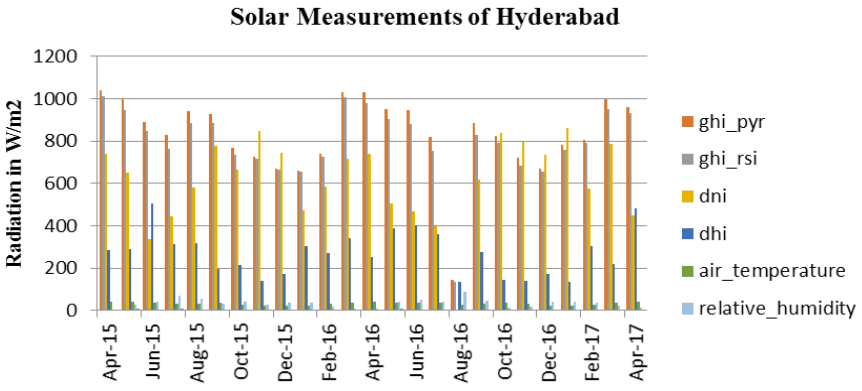

Figure 3. Solar Measurements of Hyderabad, Sindh. **Source:** The World Bank.

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

3.2. SOLAR RESULTS FOR SOUTHERN BALOCHISTAN

In solar energy, some parameters like global horizontal irradiance (GHI), DNI (direct normal irradiance, DHI (diffuse horizontal irradiance), air temperature and relative humidity have been analyzed. According to the analysis, these regions including southern Sindh and southern Balochistan have great solar energy potentials. This is proved to form the result of the World Bank group. The solar potential of the southern Balochistan is shown in the Figures 4–5. The solar panels in large quantities can be installed in these noted areas to get the maximum amount of electrical energies.

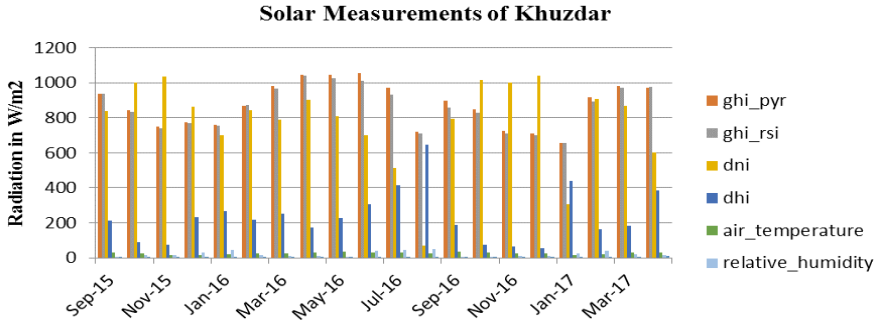

Figure 4. Solar Measurements of Khuzdar, Baluchistan. **Source:** The World Bank.

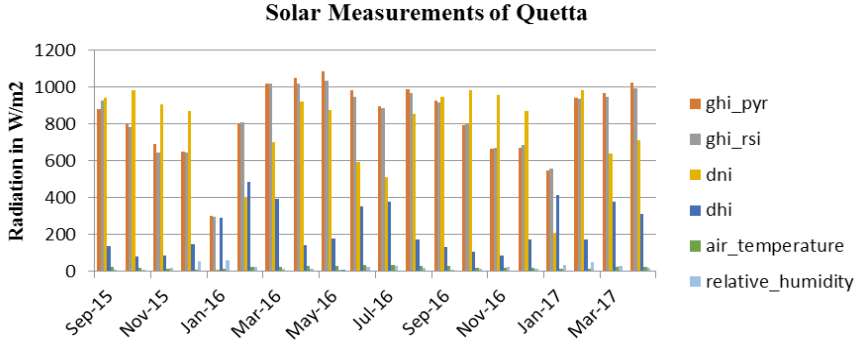

Figure 5. Solar Measurements of Quetta, Baluchistan. **Source:** The World Bank.

3.3. WIND RESULTS FOR SOUTHERN BALOCHISTAN AND SOUTHERN SINDH

Pakistan is one of the countries in the world where there are great wind energy potentials. Electricity, in large quantities, can be produced with the help of these renewable energies.

In this study, the potentials of wind energies of southern Sindh and southern Baluchistan especially Karachi have been analyzed. The real–time data measurements of wind energies of the regions have been examined as shown in Figures 6–9. In wind energy, some parameters like turbulence intensity, min. wind speed, max, wind speed, mean wind speed, and wind speed standard deviation have been investigated. According to the analysis, these provinces especially Karachi have abundant wind potentials. It is proved from the Figures 8–9 that the wind potential of the southern Sindh provinces is more than the southern Balochistan. Wind turbines can be installed in these areas to get a lot of electrical energies. The parameters for the wind installation are the following:

- T_I = a20_turbulence_intensity
- ws_max = a20_wind_speed_max
- ws_min = a20_wind_speed_min
- ws_mean = a20_wind_speed_mean
- ws_sd = a20_wind_speed_stddev

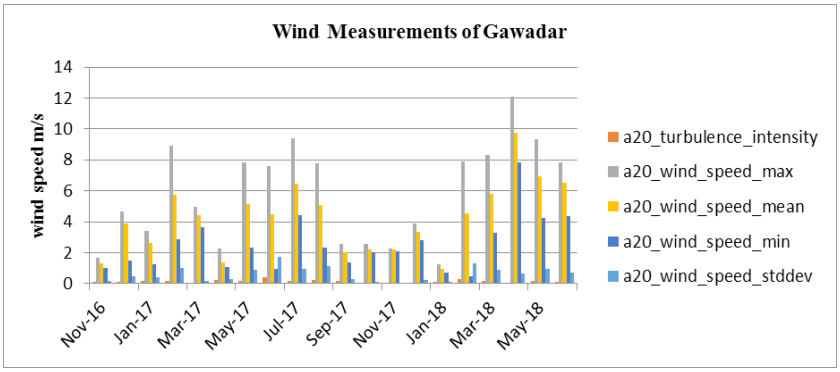

Figure 6. Wind Measurements of Gawadar, Baluchistan. **Source:** The World Bank.

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

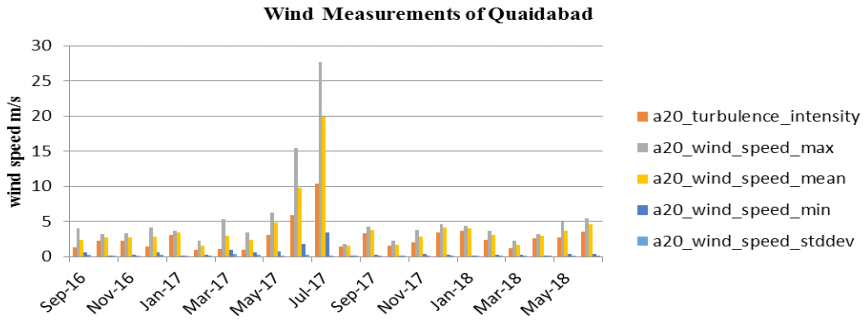

Figure 7. Wind Measurements of Quaidabad, Karachi, Sindh. **Source:** The World Bank.

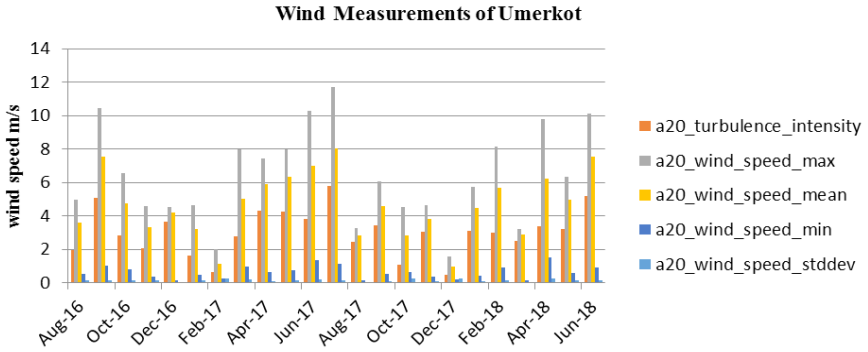

Figure 8. Wind Measurements of Umerkot, Sindh. **Source:** The World Bank.

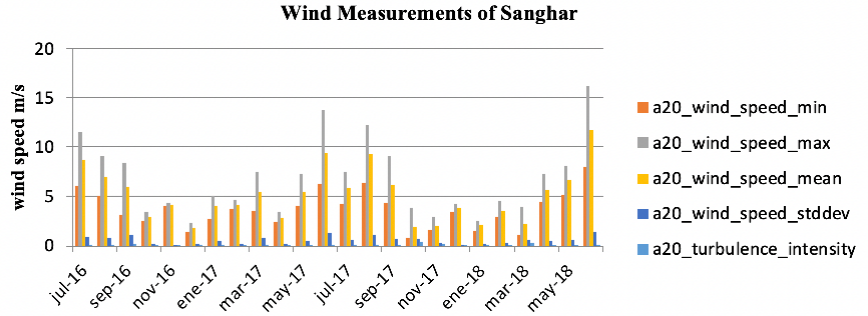

Figure 9. Wind Measurement of Sanghar, Sindh. **Source:** The World Bank.

4. ANALYSIS

4.1. SOLAR POTENTIAL ANALYSIS

In solar energy, some parameters like global horizontal irradiance (GHI), DNI (direct normal irradiance, DHI (diffuse horizontal irradiance), air temperature and relative humidity have been studied. The analysis of southern Sindh and southern Baluchistan provinces has been observed. The selected areas have great solar energy potentials due to the rich amount of irradiation observation. The observed ghi for the Karachi is in the range of minimum 652 in December to maximum 979.3 in the month of March. The observed ghi for the Hyderabad is minimum 670.9 in December to maximum1041 in April. Also, the observation of ghi for the Khuzdar is minimum 712.3 in December to maximum 1056.7 in June. The observation of ghi for the Quetta is minimum 672.3 in the December to maximum 1084.2 in May. The observation of the ghi is the best for the installation of the solar panels. Hence the large quantities of the solar PV can be installed in the noted areas to get the maximum amount of electrical energies. Similarly, DNI, DHI are observed in the selected areas. The observed irradiation is highly abundant in the selected areas of the southern Sindh and southern Balochistan.

The map describes the photovoltaic electricity output (PVOUT) potential in selected areas. It is clear from the World Bank atlas based map that there are a lot of PVOUT potentials as shown in the Figure 10.

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

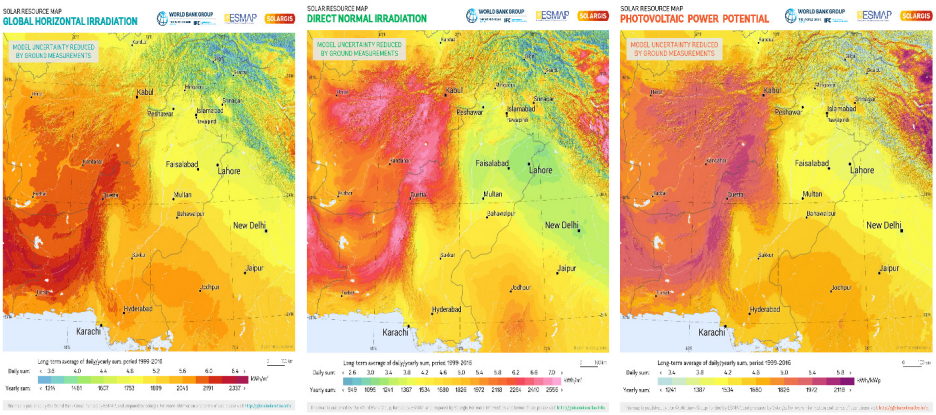

Figure 10. Solar Map Resources Expressing the ghi, dni and PVOUT potential. **Source:** World Bank Group, Solar Resources Map, Solargis.

The below map as shown in the Figure 11 describes the ghi for the Karachi. It is clear from the map that there is very good ghi condition in the selected areas especially Karachi. The map defines the huge amount of irradiation as 1967 KWh/m2 per year which will play a significant role for the power generation.

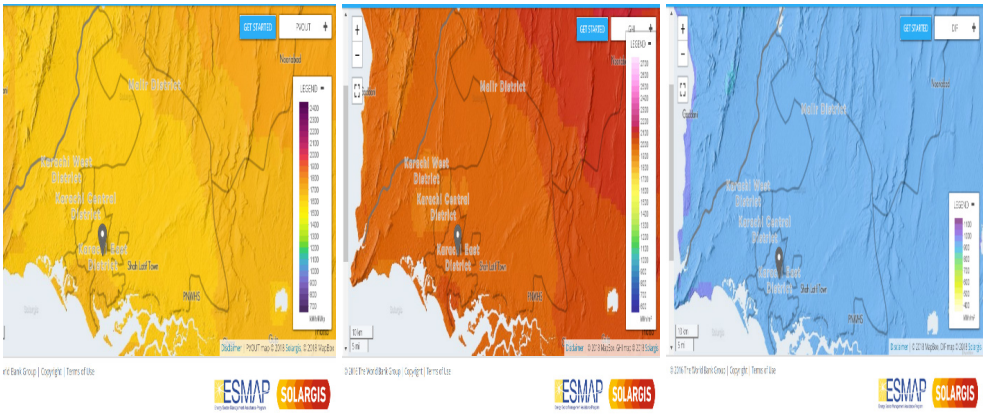

Figure 11. Solar Map Resources Expressing the ghi, dni and PVOUT potential for the Karachi. **Source:** World Bank Group, Solar Resources Map, Solargis.

This map also refers to the DHI of the selected areas, especially for the Karachi. The observation of the irradiation is 917 KWh/m2 per year. The DNI of Karachi is 1564 KWh/m2 per year. The available map is the normal map of the Karachi. The temperature of Karachi is average 26.8oC as shown in the Figure 12.

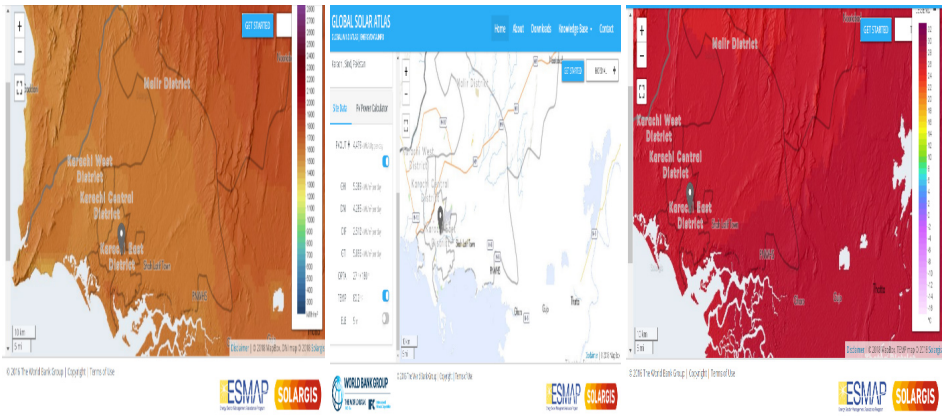

Figure 12. the Solargis Map describes the solar power and temperature of the areas especially Karachi. Sources: World Bank Group, Solar Resources Map, Solargis.

If work is planned to install the solar power project in these noted areas, then the country will never be more dependent on the existing expensive fossil fuel. The southern Sindh and southern Baluchistan have high potential to generate the abundant economy for the country. It is clear from the Solargis model that Pakistan is a geographically rich country and it is the need to fulfil the existing demand by utilizing the proposed study.

4.2. WIND POTENTIAL ANALYSIS

Pakistan is one of the countries in the world where there are great wind energy potentials. The potentials of wind energies of southern Sindh & southern Baluchistan of Pakistan especially Karachi have been analyzed with the help of available World Bank data. The wind energies of the selected regions have been analyzed. The southern Sindh and southern Balochistan have a respectable amount of the wind that can be utilized to generate valuable electricity for the country.

The analysis of proposed study rediscovers the energy potentials of two provinces especially Karachi of Pakistan. The southern Sindh and southern Balochistan have great wind energy potentials as shown in the Figure 13. There is a need to plan to install the wind turbines in these areas to get a lot of electrical energies.

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

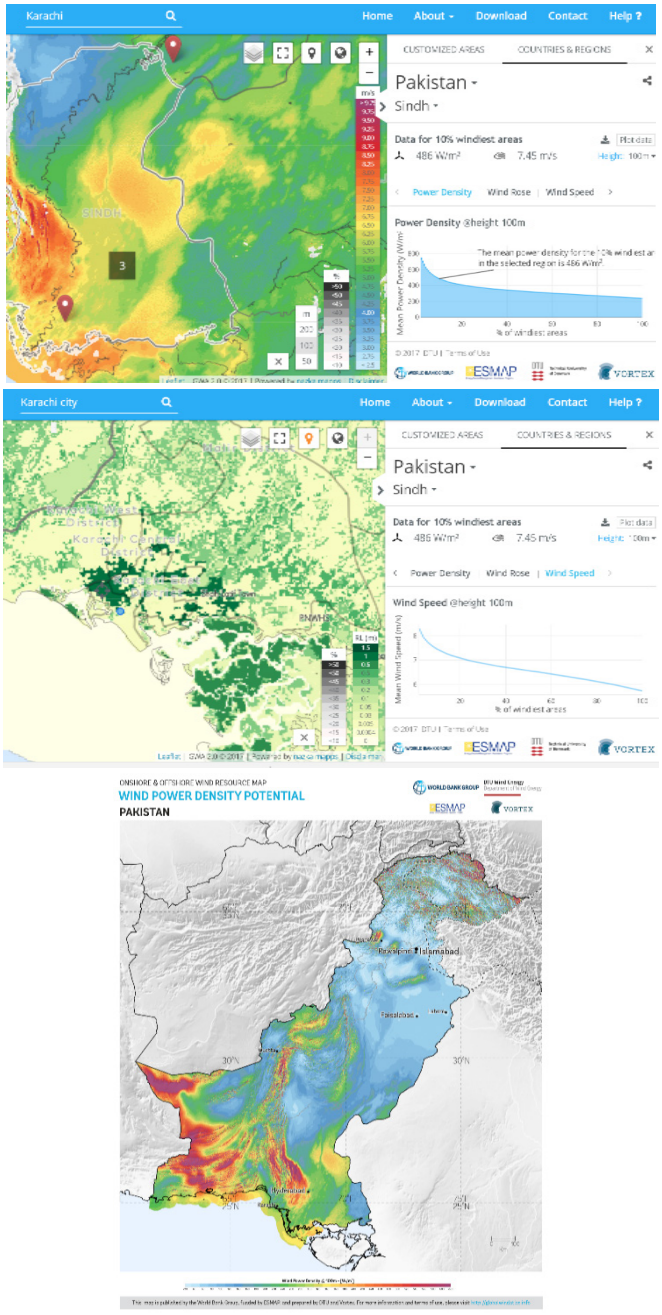

Figure 13. The Wind Map resources describe the wind potentials+ in the selected areas. **Source:** World Bank Group, Wind Resources Map, Wind Measurement.

The wind speed in the coastal area of southern Sindh and southern Baluchistan describes the more availability of the wind energy in these areas as shown in the Figure 13. The below map describes the power density at height 100m for wind measurements in the Sindh province of Pakistan. Also, the map defines the wind power density potential in Pakistan. It is clear from World Bank data that there are a lot of wind energy potentials and overall good wind speed condition in noted areas of Pakistan as shown in the Figure 14.

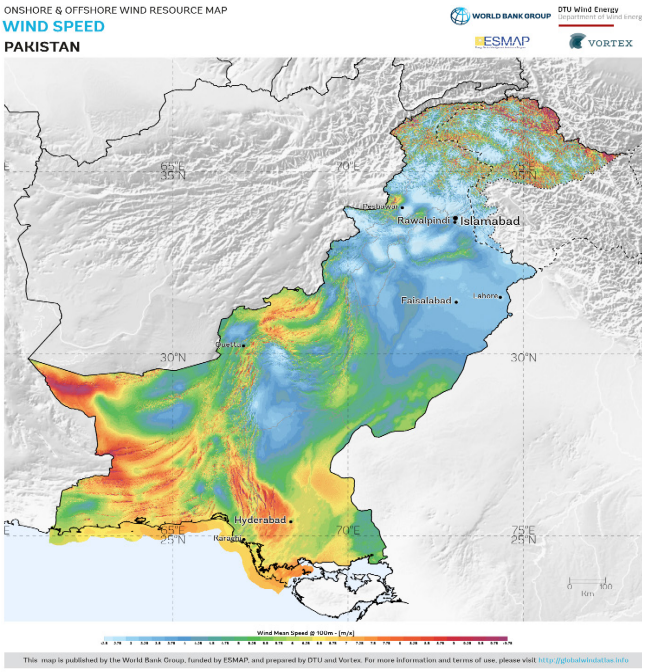

Figure 14. The Onshore and Offshore Wind Map resources show the wind potentials of southern Sindh and southern Baluchistan. **Source:** World Bank Group, Wind Resources Map, Wind Measurement.

5. CONCLUSION

The solar and wind energy potentials have been observed in southern Baluchistan and southern Sindh especially in Karachi region of Pakistan. However, southern Pakistan, mainly coastal region possesses great wind and solar potentials. Also, it has an adequate level of wind as well as solar power generation due to its geographical status. The wind resources can meet the energy demand of the southern regions mainly coastal areas. The southern Sindh and southern

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

Baluchistan regions can generate valuable energy by the installation of small and large renewable power plants. The generated renewable energies can be added to the main grid stations to overcome the shortage of electrical energies. The planners need to focus on the proposed areas for renewable energy generations.

ACKNOWLEDGEMENTS

The efforts of the Department of Electronic Engineering, NED University of Engineering & Technology, Karachi, are acknowledged for its support for research efforts. Also, the efforts of the World Bank are acknowledged for making the data available for Pakistan.

REFERENCES

Ashfaq, A. & Ianakiev, A. (2018). Features of fully integrated renewable energy atlas for Pakistan; wind, solar and cooling. *Renewable and Sustainable Energy Reviews, 97*(C), pp. 14–27. doi: http://dx.doi.org/10.1016/j.rser.2018.08.011

Asif, M. (2009). Sustainable energy options for Pakistan. *Renewable Sustainable Energy Review, 13*, pp. 903–909. doi: http://dx.doi.org/10.1016/j.rser.2008.04.001

Baloch, M. H., Kaloi, G. S., & Memon, Z. A. (2016). Current Scenario of the Wind Energy in Pakistan Challenges, Future Perspectives: A Case Study, *Energy reports, 2*, pp. 201–210. doi: http://dx.doi.org/10.1016/j.egyr.2016.08.002

Best, R. & Burke, P. J. (2018). Adoption of solar and wind energy: The roles of carbon pricing and aggregate policy support. *Energy Policy,* 118, pp. 404–417. doi: http://dx.doi.org/10.1016/j.enpol.2018.03.050

Energy Info Data. Retrieved from https://energydata.info/dataset/peshawar–annexes

Farooq, M. K. & Kumar, S. (2013). An assessment of renewable energy potential for electricity generation in Pakistan. *Renewable Sustainable Energy Review, 20*, pp. 240–54. doi: http://dx.doi.org/10.1016/j.rser.2012.09.042

Halacy, J. D. S. (1980). *Solar energy and the biosphere.* Solar Energy Technology Handbook, Part A: Engineering Fundamentals. New York: ed. W. C. and PN. Marcel, pp. 1–8.

Index Mundi. Retrieved from https://www.indexmundi.com/pakistan/

Ishaque, H. (2017). Is it wise to compromise renewable energy future for the sake of expediency? An analysis of Pakistan's long–term electricity generation pathways. *Energy Strategy Reviews, 17,* pp. 6–18. doi: http://dx.doi.org/10.1016/j.esr.2017.05.002

Harijan, K., Uqaili, M. A., Memon, M. & Mirza, U. K. (2009). Assessment of centralized grid connected wind power cost in the coastal area of Pakistan. *Renewable Energy, 34*(2), pp. 369–373. doi: http://dx.doi.org/10.1016/j.renene.2008.05.001

Kamran, M. (2018). Current status and future success of renewable energy in Pakistan. *Renewable and Sustainable Energy Reviews, 82*(1), pp. 609–617. doi: http://dx.doi.org/10.1016/j.rser.2017.09.049

Kumar, M. M. (2017). On Electricity Generation from Wind Corridors of Pakistan (Two Provinces): A Technical Proposal for Remote Zones. *Sustainability, 9*(9), p. 1611. doi: http://dx.doi.org/10.3390/su9091611

Mirjat, N. H., Uqaili, M. A., Harijanb, K., Valasaib, G. D. & Shaikh, M. F. (2017). A review of energy and power planning and policies of Pakistan. *Renewable and Sustainable Energy Reviews, 79*(C), pp. 110–127. doi: http://dx.doi.org/10.1016/j.rser.2017.05.040

Moretto, D. D., Branca, T. A. & Colla, V. (2018). Energy efficiency and reduction of CO2 emissions from campsites management in a protected area. *Journal of Environmental Management, 222*, pp. 368–377. doi: http://dx.doi.org/10.1016/j.jenvman.2018.05.084

Rafique, M. M. & Rehman, S. (2017). National energy scenario of Pakistan – Current status, future alternatives, and institutional infrastructure: An overview. *Renewable and Sustainable Energy Reviews, 69*(C), pp. 156–167. doi: http://dx.doi.org/10.1016/j.rser.2016.11.057

Sadiqa, A., Gulagi, A. & Breyer, C. (2018). Energy transition roadmap towards 100% renewable energy and role of storage technologies for Pakistan by 2050. *Energy, 147*(C), pp. 518–533**.** doi: http://dx.doi.org/10.1016/j.energy.2018.01.027

Shahzada, M., Nawaz, N. & Alvi, S. (2018). Energy security for socioeconomic and environmental sustainability in Pakistan. *Heliyon, 4*(10). doi: http://dx.doi.org/10.1016/j.heliyon.2018.e00854

Sher, H. A., Murtazs, A. F., Addoweesh, K. E. & Chiaberge, M. (2015). Pakistan's progress in solar PV based energy generation. *Renewable and Sustainable Energy Reviews, 47*, pp. 213–217. doi: http://dx.doi.org/10.1016/j.rser.2015.03.017

Shoaib, M., Siddiqui, I., Amir, Y. M. & Rehman, S. (2017). Evaluation of wind power potential in Baburband Pakistan using Weibull distribution function. *Renewable and Sustainable Energy Reviews, 70*, pp. 1343–135. doi: http://dx.doi.org/10.1016/j.rser.2016.12.037

Solar Radiation Measurement Data. Retrieved from https://energydata.info/dataset/pakistan–solar–measurement–wbg–esmap

Tahir, Z. R. & Asim, M. (2018). Surface measured solar radiation data and solar energy resource assessment of Pakistan: A review. *Renewable and Sustainable Energy Reviews,* 81(P2), pp. 2839–2861. doi: http://dx.doi.org/10.1016/j.rser.2017.06.090

Usman, M., Hussain, M., Ahmad, M. S. & Javed, Z. (2015). Impact of Solar Energy Based Power Grid for Future Perspective of Pakistan, *World Academy of Science, 9*(1).

Wakeel, M., Chen, B. & Jahangir, S. (2016). Overview of Energy Portfolio in Pakistan. *Energy Procedia, 88*, pp. 71–75. doi: http://dx.doi.org/10.1016/j.egypro.2016.06.024

DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141

World Bank Data. Retrieved from https://energydata.info/dataset/pakistan–solar–measurement–wbg–esmap

Yuan, X. C., Lyu, Y. J., Wang, B. Liu, Q. H., & Wu, Q. (2018). China's energy transition strategy at the city level: The role of renewable energy. *Journal of Cleaner Production, 205*, pp. 980–986. doi: http://dx.doi.org/10.1016/j.jclepro.2018.09.162

AUTHORS

Muhammad Shahid

Lecturer, Department of Electronic Engineering, Dawood University of Engineering and Technology, Karachi, Pakistan.

Sabir Ali Kalhoro

M.Engg (Industrial Electronics), Department of Electronics Engineering NED University of Engineering and Technology Karachi Pakistan.

Darakhshan Ara

Lecturer, Department of Humanities, Mathematics and Basic Sciences, Dawood University of Engineering and Technology, Karachi, Pakistan.

Noor Bano

Lecturer, Department of Sciences and Technologies. Indus University, Karachi.

Rubina Perween

Assistant Professor, Department of Chemistry, Federal Urdu University of Arts, Sciences and Technology, Karachi.

Edición Especial Special Issue Mayo 2019
DOI: http://dx.doi.org/10.17993/3ctecno.2019.specialissue2.116-141