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THE ESTIMATION AND ACCESSIBILITY OF WIND POWER POTENTIAL IN MADHYA PRADESH, INDIA

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Abstract: With one of the world's biggest and most goal-oriented sustainable power source programs, India can play a main role in a sustainable power source change both regionally and globally. The International Renewable Energy Agency (IRENA) has built up a guide to 2030 to investigate different energy, innovation alternatives, featuring approaches to expand the take-up of sustainable power source beyond the country's present policies and plans. The nation has already devoted significant interest to renewable power in its energy policy, becoming the first in the world to set up a ministry devoted fully to new and renewable energy sources as long ago as 1992.Wind and sun-based policy and targets have, however, only achieved mixed success over the past two and a half decades. India has set an objective to install 175 GW of sustainable power capacity by 2022, indicating a familiarity with how the commercial centre for sustainable power source advances is evolving. Wind energy has been the fastest developing sustainable power source sector in India. Energy is imperative for the nation's financial development and improving the life standard of its resident. India has spent lots of amount on expanding its energy limit since freedom. In this paper, details have been providing about the wind energy environment of India and especially about the wind power in one of its states Madhya Pradesh where 2519.89 MW wind power is being produced so far and the potential of wind power is around 19550 MW. In this paper, the wind data of 33 sites from wind monitoring stations of Madhya Pradesh has been considered.

Keywords: MNRE, Renewable energy, Madhya Pradesh (MP), Wind speed, Wind power potential, Wind density

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Introduction

India can start to lead the quantity in driving the energy change both local and universal with one of the biggest and sustainable power source programs any place in the world. Energy demand is a key aspect in the economy of a nation. The energy requirement in India increased rapidly to an average of 6.4% during 1990–2010. It has set an objective of 175 GW of introduced sustainable power source limit by 2022, including 100 GW of solar, 60 GW of wind, 10 GW of biomass and 5 GW of small hydropower. Government agencies are making more and more strong financial support schemes for renewable power. Support from regional and international development banks has reached over USD 1 billion per year, where now most of the focus has been on generating renewable power. Efforts on end-use are concentrated around improving energy efficiency and enabling access to modern energy services.

Energy is essential involvement to all sectors of any nation's economy Singh *et al. (2013).* It is significant for human advancement as human improvement is emphatically correlated to energy utilization Dwivedi *et al*. (2013). Till 1980s energy has been produced to a great extent by consuming coal, hydrocarbon oil and gaseous petrol prompting immense carbon outflows. Consequently, ecological crisis has become a concern for the present reality. Release of ozone depleting substances, controlled coal accessibility, rising costs of non-renewable energy sources and burden on foreign trade saves have made limit in the prolongation of these assets Mani *et al*. (2013).

The overall increments in the concern for utilization of energy since the last of the twentieth century might be ascribed to the rise of total population and fast development in countries, like, China, India, and Brazil refer to that non-renewable energy sources are generally affordable and hence they are most generally utilized. Other energy sources that are as of now being used incorporate atomic, hydroelectric, solar, and wind energy. Atomic energy offers an attractive energy source, yet it experiences high installation cost and risky radiation impacts. Solar energy generation is a keen flexibly that offers unlimited production, except for it isn't available through evenings or in cloudy condition.

Wind turbines offer the mainly attractive unlimited energy benefit since it produce extraordinary measure of electrical at minor cost dependent on endless wind power and causes no negative environmental effect. Indian government had embarked on giving attention to renewable energy in 1970s. Today, various plans are operating in India for promotion of renewable energy. Numerous renewable energy equipments are commercially available in the country. An Indian wind energy program which was initiated in the 1980s has increased the installation of wind energy substantially in the last few years. Wind energy policies issued by the Indian government are very much investor friendly and offer attractive tariff and regulation that provides well growth to this sector. Government of India has set up a separate ministry for renewable energy called Ministry of New and Renewable Energy (MNRE) which is responsible for planning and carrying out of the policy framework for renewable energy *Sangroya et al*. (2015).

Renewable energy sources have many benefits, offer clean, uninterrupted, environmental impact-free electrical energy at reasonable cost. Studies indicate that wind and solar offer the cleanest and most cost-effective renewable energy. The study more show that wind turbine equipment is best suitable for irrigation, and food production in coastal regions. Wind turbines are effective for desalination of wat.

er in coastal areas where lack of fresh water. Any energy generating source or scheme requires correct installation and specific operating conditions to ensure cost-effective operation. Some power sources require huge initial investments during the installation phase, while others require unique operating environments available only in a specific geographic location or environment. As stated earlier, every energy source (coal-fired generation, nuclear power, hydraulic turbines, tidal wave turbines, geothermal and hydrothermal energy sources, biogas, conventional diesel generator, and wind turbines) suffers since some disadvantages. Coal-fired power generating sources create destructive polluting gases. Nuclear power plants need extreme initial asset and problem of radiation. Hydro-turbine installations need water reservoir to make sure steady water pressure, and tidal wave turbines need sea waves with particular features obtainable mostly in coastal areas. Geothermal and hydrothermal energy sources require low and high temperature underground regions to harness energy sources; such locations are known to exist only in Iceland. Biodiesel power sources require large supplies of raw materials.

With the lack of fossil fuel, unconventional power has been thrust into the nationwide attention as a most important requirement to remain up by the growing energy demands of the world. One of these alternative energies is wind power. By virtue of nonstop modern advancement clubbed with consumption of petroleum products and developing ecological awareness, the requests for alternative energy assets have been expanding exponentially in the 21st century. With developing interest for energy, expanded ecological pollution, and depleting energy sources, human culture

today faces various difficulties of progress towards a reasonable turn of events and the neediness eradication Kulkarni *et al*. (2016).

Wind energy has been the fastest growing renewable energy sector in India along with 7517 km of coastline and its territorial waters extend up to 12 nautical miles into the sea. India is the 3rd largest annual wind power market in the world and provides great business opportunities for both domestic and foreign investors. The ministry of non-conventional energy source of the Government of India managed and implemented the wind energy program in 1983–84 and has drastically increased in the last few years. Wind resource assessment is a continuous process for identification of potential areas for wind power generation Khare *et al*. (2013).

As many as 20 manufacturers are engaged in the production of wind turbine equipments. A large number of companies have tied up with foreign wind turbine manufacturers for joint venture/ licensed production of WECS (Wind energy conversion system) in India. Research and development activities are being undertaken through research institutions, national laboratories, universities and industry for the development of cost-effective technologies and systems to improve the quality of power generation from wind. R&D activities are coordinated through the Centre for Wind Energy Technology (C-WET) IRES Report (2010).

Madhya Pradesh (abbreviated as MP) is a state of India. The name "Madhya Pradesh" means "central region" and derives from its geological position. It is one of the few states of India that is surrounded by other states, having neither a boundary with another country nor a coastline. Estimation of Madhya Pradesh wind power potential is the main objective of this paper.

Global wind energy scenario

Today, all countries are developing rapidly in field of energy and are attracted towards pollution free and unlimited sources of energy. Wind energy is the best source because it is available throughout the year, and it does not have any effect of any season Ravindra *et al.* (2015). As in the case of solar energy, sunlight is not available at night and in the rain. World's total wind energy production has reached 734 GW by 2020 all countries are moving fast in it. Wind Energy Market Intelligence Report (2020), Wind Energy in Europe (2018), Global wind statistics (2020). The table 1 shows which countries in the world are leading in wind power.

Table 1. Global wind power scenario

S. No	Country	MW
1	China	2,81,993
2	United States	1,17,744
3	Germany	62,184
4	India	38,559
5	Spain	27,089
6	United Kingdom	24,665
7	France	17,382
8	Brazil	17,198
9	Canada	13,577
10	Italy	10,839

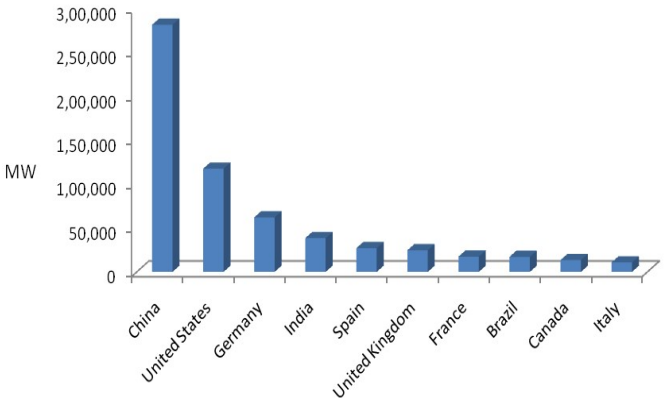

Fig 1. Top countries in wind power generation

The world wind power data is also described by Graphical representation in **Fig. 1** in which the power generation in MW is on the Y axis and the name of countries are shown on X axis.

Wind power in India

Wind power generation limit in India has essentially expanded in recent years. As on 28 February 2021 the total wind power generation was 38,789 MW, which is the fourth biggest installed wind power generation in the world. Ministry of New and Renewable Energy (2020), and Global Wind Statistics (2017).

Wind power generation is basically spread over the southern, western and northern areas. In a country like India, where the population is very large, the energy requirement is also more, keeping this in mind; the Indian government is working on its energy policy and is constantly increasing its energy production and India has reached the fourth position in the world in wind power and will go further in the coming years. Table 2 shows that the India has increased wind power production year wise.

We can see in **Fig. 2** that the wind power sector in India is continuously increasing, and it was the highest in the year 2016-17. In this graph, wind power generation in MW is shown in Y axis and year wise genration on X axis.

Table 2. Indian wind power growth Year wise

S. No.	Year	Capacity in MW
1	2011-2012	18,421
2	2012-2013	20,15
3	2013-2014	22,465
4	2014-2015	23,447
6	2015-2016	26,777
7	2016-2017	32,28
8	2017-2018	34,046
9	2018-2019	35,626
10	2019-2020	37,669
11	2020-2021	38,785

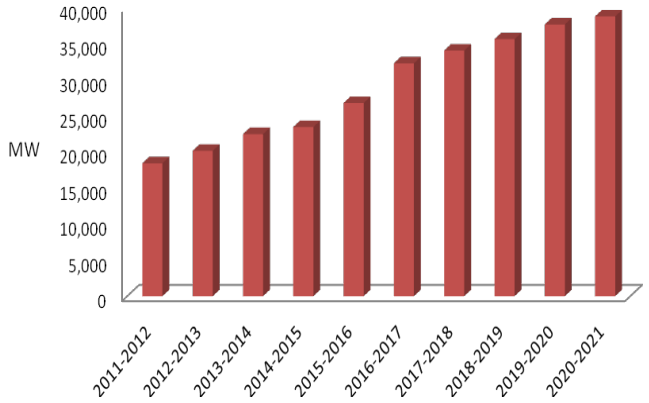

Fig. 2 Year wise generation growth in Indian wind power

Now in **Table 3** we have mentioned about the contribution of different states in India in terms of wind energy generation. As we know that wind energy is very much dependent on the geographical condition Renewable Energy Installed Capacity (2020), and NREDCAP (2019).

Wind energy technologies use the kinetic energy of wind for different purposes, such as generating electricity, charging batteries, pumping water, and grinding grain Choubey *et al.* (2019). Wind turbines come in different sizes and types, depending on power generating capacity and the rotor design. Small wind turbines with output capacities below 10 KW are used primarily for residences, communications dishes, and irrigation water pumping applications Choubey *et al. (2020)*.

As we can see in the **Table 3**, Tamil Nadu is at the top position in India in the wind power generation. Tamil Nadu is a seaside state where both the parameters wind speed and wind density are most suitable for power generation. Madhya Pradesh comes at number seven, which has about 6.8% of India's wind power (as of October 2019).

The status of these states in wind power generation in MW is also expressed by graphical representation in **Fig. 3** Renewable Energy Installed Capacity (2020), in which the power generation is on the Y axis and the name of states are shown on X axis.

Table 3. State wise wind power generation in MW

S. No.	Name of State	Total Capacity in MW	% Wise Contribution
1	Tamil Nadu	9231.77	24.9
2	Gujarat	7203.77	19.4
3	Maharashtra	4794.13	12.9
4	Karnataka	4753.40	12.8
5	Rajasthan	4299.73	11.6
6	Andhra Pradesh	4077.37	11.0
7	Madhya Pradesh	2519.89	6.8
8	Telangana	128.10	0.3
9	Kerala	62.50	0.2
10	Others	4.30	–

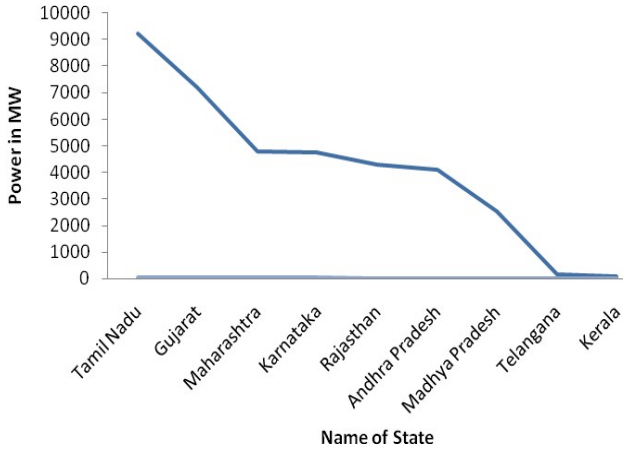

Fig. 3 Wind power contribution of states

Renewable energy potential in Madhya Pradesh

Energy is a prime mover of development of any economy. While conventional fuels like coal and oil have been the primary sources for energy, their long-term availability has been pointing of concern. Additionally, their improved procedure has led to high concentrations of greenhouse gases in the environment, which is a rising distress with view to global warming and resulting climate change.

The recent power necessity of Madhya Pradesh state is greatly dependent on conventional power sources. The administration of Madhya Pradesh acknowledges the growing concern correlated to weather variation and global warming. Due to this reason the encouragement of renewable power is one of the step measures taken by the administration. In Madhya Pradesh renewable energy has a significant potential, be it solar power or wind power.

The information has been shared in the **Table 4** that how much potential of different renewable energy sources is available in Madhya Pradesh. Data from M.P Urja Vikas Nigam and MNRE have been used for this paper. The same data is represented by a **Fig. 4** in which the potential in MW is on the Y axis and the different energy sources are shown on X axis.

Table 4. Potential of Renewable Energy Sources in M.P

S. No	Renewable Energy Technology	Potential in MW
1	Solar	88364
2	Wind	19550
3	Biomass	1462
4	Small Hydro	411
	Total	109787

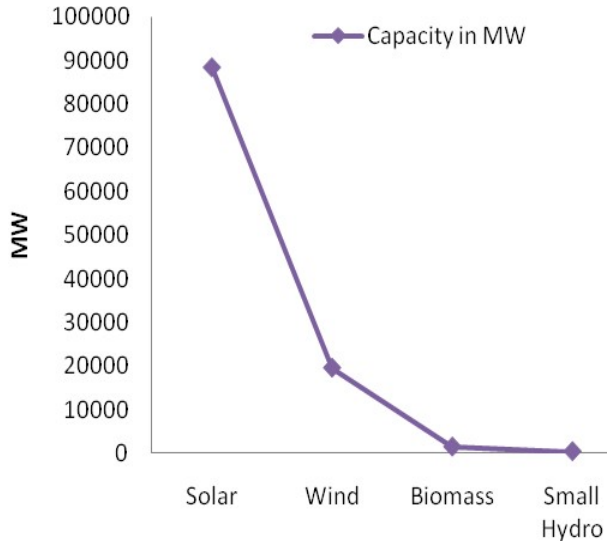

Fig. 4 Potential of different renewable resources in M P

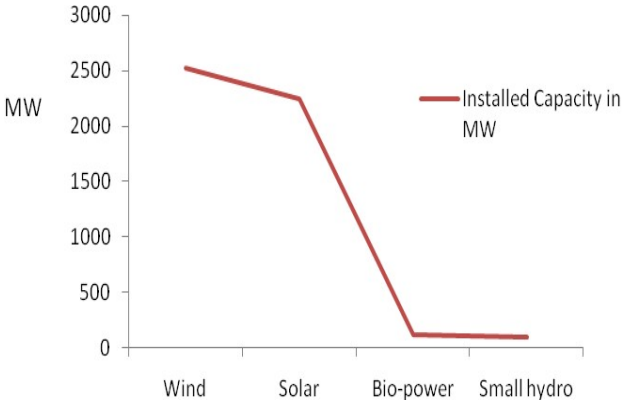

Fig. 5 Installed renewable energy power in M.P

A memorandum of understanding (MOU) between Madhya Pradesh Urja Vikas Nigam, Indian Renewable Energy Development Agency (IREDA) and Consolidated Energy Consultants Limited (CECL) established a joint sector company called M.P. Wind-farms Ltd to develop wind energy projects in the state. Between 1995 and 1999, the company implemented a 13 MW wind power project in Dewas, setting up a platform for commercial wind power projects. Since then, the state has installed 2519.89 MW of wind energy projects in various locations such as Dewas, Ratlam, Indore, and Ujjain (Sangroya *et al*., 2015). So far, the renewable energy potential has been estimated according to which the installation is quite low, and it is shown in Table 5 (Source-MNRE)

Table 5. Installed capacity of renewable energy power in M.P

S. No	Renewable Energy	Installed Capacity in MW
1	Wind	2519.89
2	Solar	2237.49
3	Bio-power	120.75
4	Small hydro	95.91
	Total	4974.04 MW

The same data is represented by a graph in **Fig. 5** in which the installed capacity in MW is on the Y axis and the different energy sources are shown on X axis.

Wind power in Madhya Pradesh

Madhya Pradesh is an agricultural state situated in the middle of India, the wheat of M P. is very famous in the world and the soil is very fertile. The wind power potential is also very high, so to utilize the potential of wind energy the wind farms are being continuously installing.

The Government of Madhya Pradesh has been promoting the renewable power-based power plants as well as wind power plants with different strategic proposal for the encouragement of the investor/developers. Wind power project applications are being sanctioned at possible sites where wind power density (WPD) is equivalent or more than 200 W/m^2 at the above 50 m from ground level. At present setup capacity of wind farm project is to 2519.89 MW. According to the wind condition in some selected locations it has been estimated that how much wind power can be produced. Data from M.P. Urja Vikash Nigam and MNRE have been used for this paper. In **Fig. 6**, all the districts of the Madhay Pradesh are shown, so that it will be easy to understand the possible location or site of wind power plant.

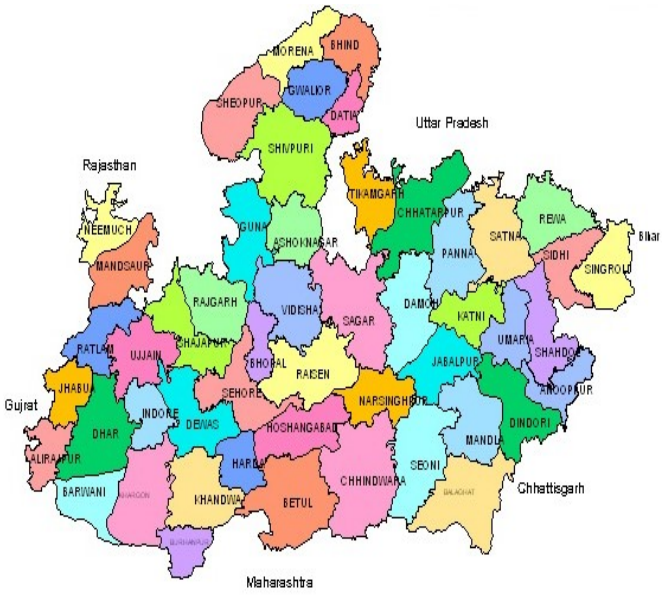

Fig. 6 Map of Madhay Pradesh State

Table 6. Wind power potential in the state of Madhya Pradesh (MW)

Site	District	Gross potential (MW)
Alot	Ratlam	501
Baroli	Indore	582
Belma	Indore	582
Bodhina	Ratlam	501
Chorasia Badhalia	Ratlam	501
Jamgodrani	Dewas	1678
Kheda	Dhar	1294
Kukru	Betul	517
Lahori	Shajapur	1120
Machla	Indore	582
Mahuriya	Shajapur	1120
Mamatkheda	Ratlam	501
Mirzapur	Sehore	843
Nagda	Dewas	1678
Sendhva	Badwani	2832
Sodang Hill	Ujjain	764
Tanoriya	Shajapur	1120
Vallyarpani	Badwani	2832

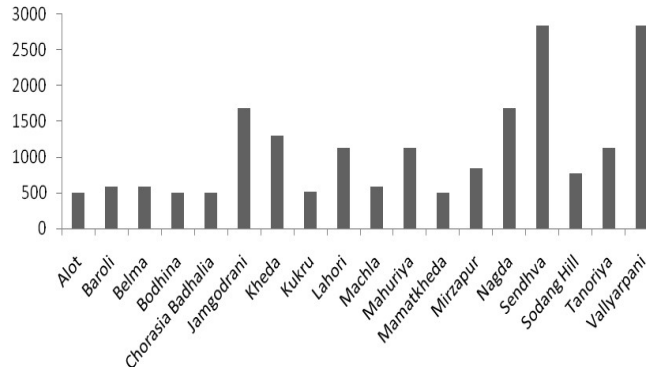

Fig. 7 Gross potential of wind power in M.P

Some places in Madhya Pradesh are suitable for wind energy plants, which we have shown in the table and also how much is the possibility of wind power. The information of those places is shown in the table 6 and the graphical representation also shown by the **Fig. 7**.

Wind condition (wind speed, density & wind shear) has been mentioned many times in this paper, so we also need to know about it. Wind speed is an essential atmospheric value, generally caused by the movement of air from high pressure to low pressure due to temperature changes it is measured in m/s. Wind energy density (WPD) is a quantitative assess of the available wind energy at any location. It is the regular annual power available per square meter of turbine sweep area, calculated for different heights above the ground Mathew *et al.* (2006).

Wind Shear- The friction of the moving air masses against the earth's surface slows down the wind speed from an undisturbed value at great altitude to zero directly at ground level Hau *et al*. (2005). The flow of air above the ground is retarded by frictional resistance offered by the earth surface Mathew *et al.* (2006).

Table 7. Wind condition in possible locations of the state M.P

Name of Location	District	Wind Speed (m/s)	Wind Power Density (W/m^2)	Wind Shear
Alot	Ratlam	4.63	148	0.14
BanbirKheri	Guna	5.62	145	0.14
Barkheri	Ujjain	5.11	150	0.14
Barodiya	Mandsaur	4.74	92	0.14
Baroli	Indore	4.47	151	0.14
Belma	Indore	4.18	138	0.14
Bodhina	Ratlam	5.14	189	0.14
Bori	Barahanpur	5.24	151	0.14
Chorsia	Ratlam	4.95	174	0.14
Garihdadr	Shadol	5.16	111	0.14
GhatPipariy	Betul	4.89	112	0.14
Jaithal Hill	Ujjain	4.53	110	0.14
Jamgodarni	Dewas	5.00	220	0.19
Kalaphad	Sehore	3.94	88	0.14
Kanchroot	Dhar	5.26	119	0.14
Kawasa	Ratlam	4.22	127	0.22
Kukru	Betul	5.28	255	0.14
Lahori	Shajapur	4.81	145	0.14
Machla	Indore	4.7	153	0.13
Mahuriya	Shajapur	5.28	255	0.14
Mamatkhed	Ratlam	5.57	255	0.14
Mandwa	Khargone	5.1	123	0.24
Mirzapur	Sehore	4.27	146	0.14
Nagda	Dewas	6.25	371	0.14
Pahari	Satna	4.03	63	0.14
Purtala	Chindwara	5.02	101	0.14
Sanawad	Khargone	3.86	117	0.14
Searmau	Betul	4.97	115	0.14
Sodang Hill	Ujjain	4.95	162	0.14
Tanoriya	Shajapur	4.38	148	0.14
Ubhariya	Betul	5.11	114	0.14
Vallyarpani	Badwani	5.25	287	0.14

The instantaneous increase in wind speed with elevation depends on several meteorological factors, which determine the atmospheric stability. However, the mean value to be expected statistically over a long term at a particular height is largely determined by the roughness of the earth's surface.

The surface roughness of a terrain is usually represented by the roughness class or roughness height Choubey *et al.* (2019). The data of about 33 places wind speed, density and wind shear has been collected from wind monitoring stations of MNRE from which the wind power potential can be estimated. The power efficiency of wind energy systems has a high impact in the economic analysis of this kind of renewable energies Tenguria *et al*. (2011).

The wind properties of the possible sites of Madhya Pradesh States are shown in **Table 7**. In **Figs. 8–10** it has been explained by the graph that what kind of changes are being in the wind condition according to the sites or location. In the graph the wind parameters are on the Y axis and the different locations are shown on X axis.

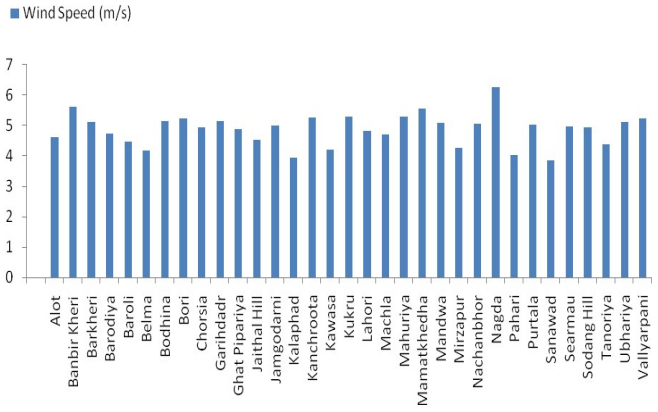

Fig. 8 Wind speed (m/s) in several locations

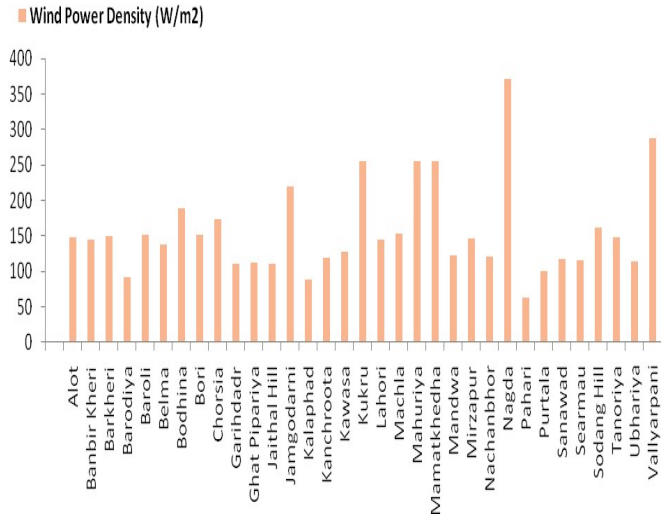

Fig. 9 Wind power density (W/m²) several locations

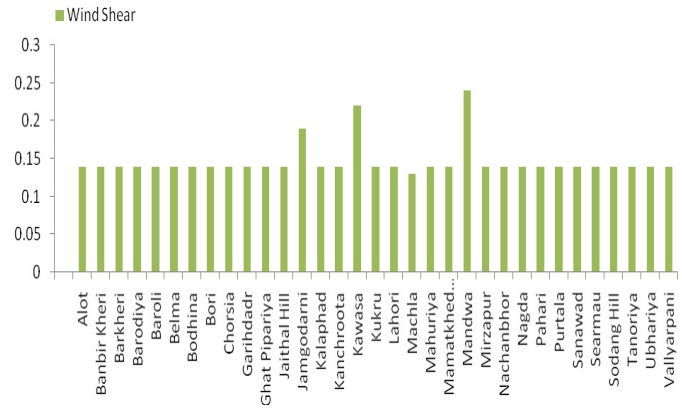

Fig. 10 Wind shear in several locations

Results

India is facing the challenge of sustaining its fast economic development. The hazard of environment arises from the emissions of greenhouse gases produced from constant generation of power from non-renewable sources, high industrial development, and advance lifestyles. It is necessary that clean energy be generated in huge quantity at low cost. One approach is to use renewable energy resources like wind power. This work has discussed in fact the existing situation of wind power in India with a focus on the potential in the state of Madhya Pradesh.

According to the study so far, China has done a great job on wind energy and is in the first place in the world with very excellent productivity. China's wind power production is about 281993 MW and India is at 38559 MW. Tamil Nadu State also ranked first in India with 9231.77 MW and Madhya Pradesh on which this paper has been studied, comes in seventh place with 2519.89 MW. As per the data taken from the monitoring station, we find that there is immense potential for wind energy in Madhya Pradesh which is about 19550 MW. In this paper, the wind data of 33 sites from wind monitoring stations of Madhya Pradesh has been considered. So that we can explore the possibility of wind energy generation.

Conclusion

Gradually, the globe populace is growing at an exponential speed due to which the requirement for power is increasing. Production of energy is considered an essential element of life. There exists a straight connection between progress and energy utilization. Hence, we require generating more power to be progressive. To produce more power, we depend on fossil fuels. To utilize of fossil fuels increases the release of pollutants such as SOx, NOx, and carbon monoxide that have a harmful effect on the atmosphere.

Every country is now becoming dependent on renewable energy resources. It has also become necessary because pollution has become a big problem and in countries like India where the population is so much that reaching energy to all is a big problem. But India has done a good work in the field of renewable energy accepting this challenge and has made a place in the world. According to the study Madhya Pradesh, India, has immense potential for wind energy generation. In this paper, the condition of wind like speed, density and wind shear are also consider at different possible sities of state. The condition of the wind at different sites of MP indicates that there is immense potential for wind power.

The information of present installations, their capability, and wind sites beside with wind-power density has been given in detail. A complete literature survey has been done, and adequate relevant information has been provided.

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