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Comparative Estimation of Onshore (Okada) and Offshore (Okerenkoko) Wind Speed for Potential Wind Energy Access in Delta State, Nigeria

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ABSTRACT: The low availability of reliable electrical energy in Nigeria; urban centres and rural area in particular is alarming. At the moment, average Nigerians readily depends on non-renewable energy sources such as fossil and wood fuel which is environmental unfriendly. However, wind energy is abundant, inexhaustible, affordable, environmentally preferable, and equally sustainable. Hence, the objective of this paper was to undertake a comparative estimation of onshore (Okada) and offshore (Okerenkoko) wind speed for potential wind energy access in Delta State, Nigeria using appropriate standard methods. The outcome of the results obtained reveal that offshore areas generated more wind speeds than the onshore area of Niger Delta. The percentage of onshore wind speed to offshore windspeed was established to be 46% to 54%. Besides, offshore shows a better tendency of wind power generation against onshore and this was due to high values of wind speed generated in offshore area. The amount of electricity produced by a turbine is mostly determined by wind speed. Above and beyond, Okerenkoko has a better wind energy potential than Okada and installation of wind turbine in Okerenkoko will help to boast a green sustainable renewable energy in the region.

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A number of factors, including the impending depletion of fossil fuels, the acceleration of global warming, the growth of the greenhouse effect, the scarcity of power supplies, the effort to mitigate the environmental effects of non-renewable energy sources, and above all the need to meet the world's expanding energy needs, have spurred research interest in a wide range of environmental and engineering applications of renewable energy sources. In order to achieve the requirement of Sustainable Development Goal (SDG) in Nigeria, which encourages the United Nation member states to focus on access to ecofriendly, sustainable and readily available renewable energy source (United Nations, 2015); it becomes necessary to assess the potential in the renewable energy sources available at our disposal such as wind energy. Due to its ability to be used for small-scale or commercial purposes to satisfy current energy demands, wind energy is becoming more and more popular as a renewable energy source worldwide. Wind Energy Technology (WET) serves as a suitable supplement and alternative to the rising cost of power generation from fossil fuel source and as well contributes towards global legislation against Greenhouse Gas (GHG) emission (Ohunakin, 2011; Mukasa *et al.,* 2013; Oghoghorie *et al.,* 2020; Aslam,

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2021). Wind energy by nature is clean and abundant, inexhaustible, affordable, and environmentally preferable (Oyedepo *et al.,* 2012; Erameh and Orhorhoro, 2018). In developed countries, such as Germany, United State of America, China, etc., wind energy is extensively used for the production of electricity (Akpinar and Akpinar, 2005; Gugliani *et al.,* 2018; Han and Chu, 2021). Nigeria makes insufficient use of wind as a renewable energy source (Adedipe *et al.,* 2018). A new report from the African Development Bank (AFDB) indicates that while South and Eastern African nations are expected to close the gap in the near future, North African nations like Morocco, Egypt, and Tunisia continue to lead the continent's wind energy market. The development of wind farms is still insufficient in nations in Central and West Africa. However, the notion to seek for a sustainable alternative to the intermittent energy situation of Nigeria has prompted the government as well as independent researchers to evaluate the nation's potentials for power generation using wind energy (Adedipe *et al.,* 2018).

According to results from researches and wind data from Nigerian meteorological stations, it has been established that wind speeds are generally weak in the southern part of Nigeria, except for offshore areas from Lagos through Ondo, Delta, Rivers, Bayelsa to Akwa Ibom state which were reported to have prospects for harvesting strong wind energy throughout the year (Okeniyi *et al.,* 2015; Adedipe *et al.,* 2018). States like Jos, Katsina and Maiduguri, possesses high wind speed amidst condition such as topography and roughness of surfaces. Further research revealed that wind speed of about 8.07 m/s can be harnessed from the northern part of Nigeria (Ahmad, 2016; Abdulkarim *et al.,* 2018; Audu *et al.,* 2019). Wind speed in the north varies from 4.0 to 7.5 m/s at 10 m, as Figure 1 illustrates. Similar to this, the southern region of Nigeria experiences moderate wind speeds, between 3.0 and 3.5 m/s. Despite the stated potential of offshore regions, the Nigerian Metrological Agency (NIMET) operates 44 stations, none of which are offshore (Olaofe, 2017; Eboibi *et al.,* 2018; Onoruoiza *et al.,* 2022). An anemometer placed in a suspended buoy system in the water can be used to measure offshore wind data, as adopted in other nations across the globe.

There is a lot of potential for offshore wind installation, as evidenced by a few findings from Nigerian oil-producing companies with suspended buoy installations. More researches are emerging in the analysis of wind speed for different locations in Nigeria and each of these in the limit of their uncertainties have proven that great potential exist for wind power generation in Nigeria. In Nigeria's offshore and onshore Niger Delta, adequate results have not yet been obtained despite a great deal of work being done in small-scale wind turbine modeling for domestic use. Nevertheless, when wind energy is appropriately harnessed, it can replace non-renewable energy sources like wood and fossil fuels. Hence, the objective of this paper was to undertake a comparative estimation of onshore (Okada) and offshore (Okerenkoko) wind speed for potential wind energy access in Delta State, Nigeria

MATERIALS AND METHODS

In the northern part of Nigeria, high onshore wind speeds are crucial, according to the most recent report from the Nigerian meteorological and meteorological agency (NIMET), which is based on the 40-year (1968–2007) available average of wind data from all 44 stations in Nigeria (Figure 1). Wind energy is readily available, and capturing its power does not deplete our natural resources. Adding wind power to the nation's energy mix will diversifies our clean energy portfolio and helps reduce reliance on fossil fuels (Baba and Garba, 2014; Ayodele *et al.,* 2016). Also, most electric power plants require water to operate, but producing electricity from the wind does not require water. Wind energy reduces smog, acid rain, and greenhouse gas emissions because electricity produced by wind turbines does not contaminate the water or air we breathe. According to research, the use of wind energy in the US in 2013 cut carbon dioxide emissions from the direct power sector by 115 million metric tons, or the same as removing 20 million cars' worth of emissions from the road. Additionally, 97,000 metric tons of nitrogen oxides and an estimated 157,000 metric tons of sulfur dioxide emissions were prevented (Gallup, 2013; Ouarda and Charron, 2018). Wind energy lowers medical expenses and environmental costs related to air pollution because it is a clean energy source. Because there are no fuel expenses involved, wind energy systems have low operating costs (Düzcan and Kara, 2021; Attabo *et al.,* 2023). Leading experts in the field came to the conclusion that system operating cost increases from wind variability and uncertainty amounted to only about 10% or less of the wholesale value of the wind energy, and that there are ways to reduce these costs (Deep *et al.,* 2020; Emenuvwe *et al.,* 2022). Large additions of wind energy may require additional generation to accommodate the variability of the wind energy. Customers are also shielded from fluctuating coal and natural gas prices by the lack of fuel costs. Furthermore, wind energy can lessen our sensitivity to price increases and supply disruptions by stabilizing the price of electricity.

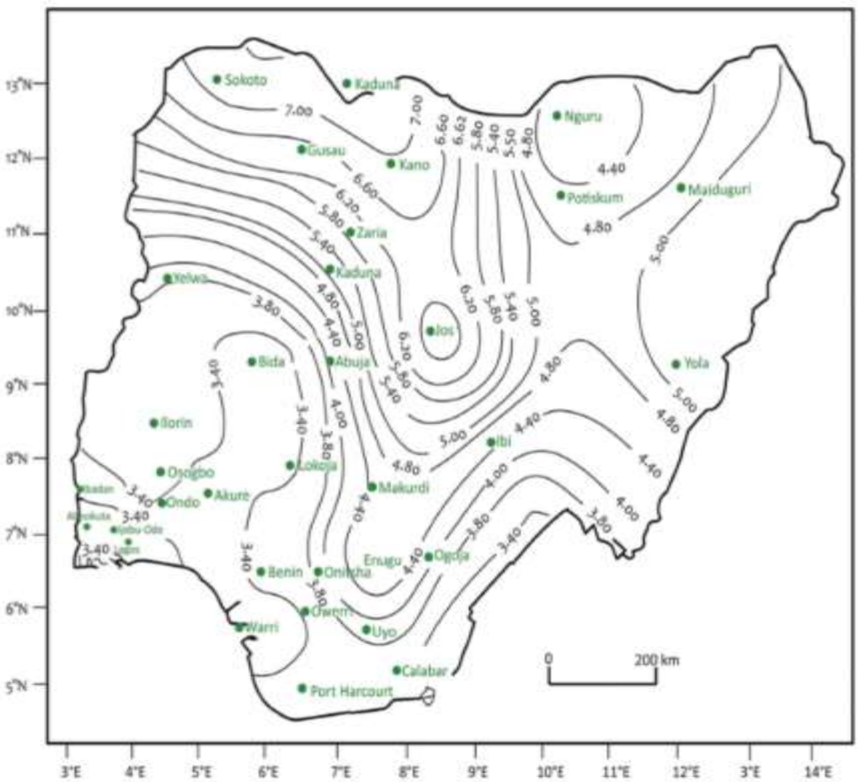

Fig. 1: Isovents in m/s determined from 40 year's measurements at 10 m height, obtained from Nigeria meteorological department, Oshodi, Lagos State, Nigeria (NIMET, 2009)

Description of the Study Area: Two major towns were used in this research work. Okada is located in an onshore while Okerenkoko is located within Atlantic Ocean (offshore). Okada is situated in the Nigerian region of Edo State. Benin City, the capital of Edo state, is roughly 51 kilometers (32 miles) from Okada. The town is situated in Ovia North-East Local Government Area, Edo State, Nigeria. Geographically, it is located at 6° 44' 0" North and 5° 23' 0" East. Okada photographs and images from the satellite below are displayed in Figure 2.

Fig 2. Okada images from satellite, explore the aerial photographs of Okada in Nigeria (Maplandia.com, 2024)

The wet season in Okada town is warm, muggy, and partly cloudy, while the dry season is hot, muggy, and partly cloudy. The average annual temperature fluctuates between 68°F and 89°F; it is seldom lower or higher than 61°F or 93°F. With an hourly average wind vector (speed and direction) at 10 meters above the ground, the town is spread out over a large area. Instantaneous wind speed and direction vary more than hourly averages, and the wind experienced at any given location is highly dependent on the topography of the area as well as other factors. Throughout the year, there is some seasonal variation in Okada's average hourly wind speed. From June 5 to September 20, which is the windiest part of the year, there are 3.5 months of average wind speeds of over 3.6 miles per hour. In Okada, August has the highest average hourly wind speed of 4.4 miles per hour, making it the windiest month of the year. The quieter season begins in September and lasts for 8.5 months. At 2.7 miles per hour on average, November is the calmest month in Okada during the year. Figure 3 shows Okada monthly weather conditions while Figure 4 shows the average of mean hourly wind speeds.

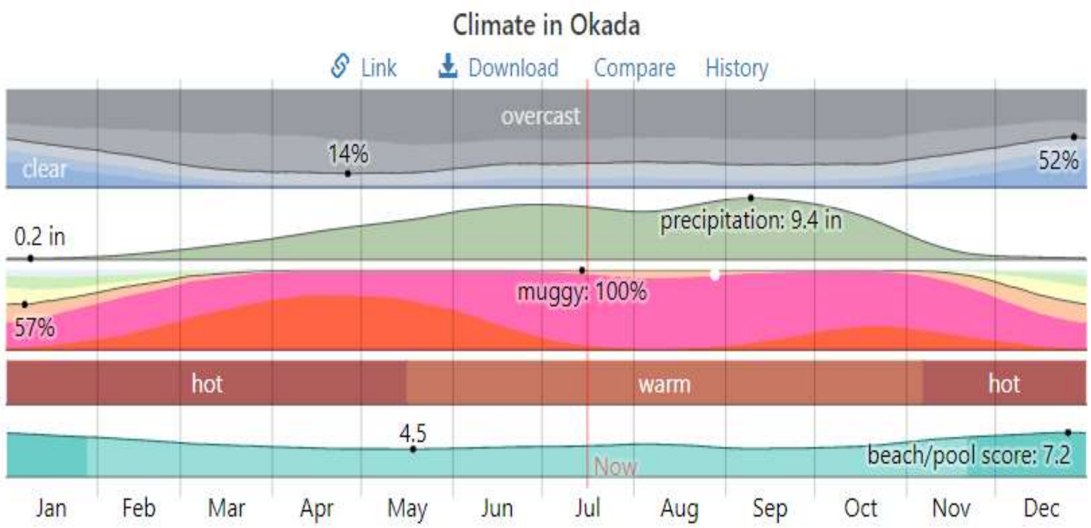

Fig 3. Okada weather by month (SRTM, 2023)

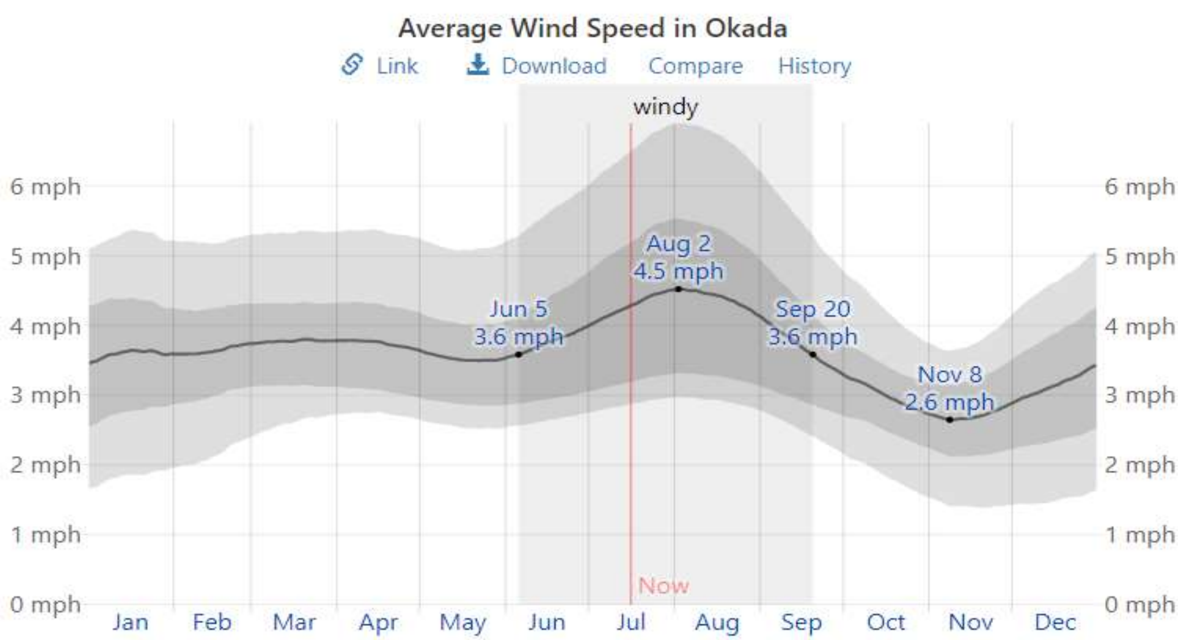

Fig 4. The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands (SRTM, 2023)

The coordinates of Okerenkoko are 5.407013999999999 and 5.618730999999999. The community is located in Gbaramatu Kingdom, Warri South-West Local Government Area, Delta State, Nigeria. The Okerenkoko community is one of the communities that make up the Gbaramatu kingdom. The renowned Escravos Tank Farm and Terminal, run by the NNPC/Chevron Joint Venture, and the Atlantic Ocean, which is roughly 35 nautical miles from Warri, the closest urban center, are both conveniently close to the Okerenkoko community. Because of its advantageous location, the Okerenkoko community in Gbaramatu Kingdom opens up to the Atlantic Ocean via the Escravos River. This river serves as a path for ocean-going vessels involved in the oil and gas sector, which has historically been the backbone of the Nigerian economy. Figure 5 shows the wind direction of Okerenkoko.

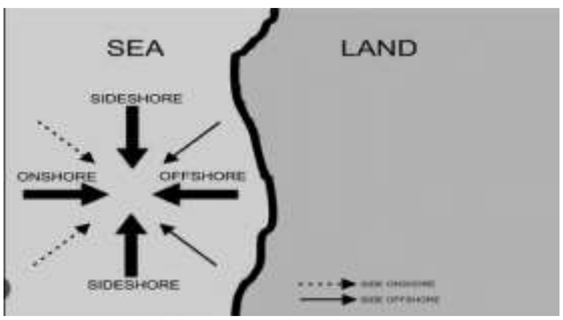

Fig 5. Wind direction in Okerenkoko (NWM, 2023)

Determination of the Wind Speed: A UT363 Anemometer shown in Figure 6 was used to measure the wind speed. The UT363 is a miniature wind speed capable of measuring wind speeds of up to 30m/s. The meter utilizes a magnetic sensor to measure the data accurately and display on the LCD screen. This makes it suitable for navigation, sports events and other wind measurement applications.

Fig 6. UT363 Anemometer

Power of Wind: The power of the wind is directly proportional to air density, area of the segment of wind being considered, the natural wind speed. Mathematically, the relationships between density, area of the segment of wind and wind speed is given by Equation (1).

$$P_w = \frac{1}{2}\rho A V^3 C_p \quad (1)$$

Where: P_w = Power of the wind (watts); ρ= Density of air (1.23 kg/m^3); A= Area of a segment of the wind being considered (m^2); V = Wind speed (m/sec): Determined with UT363 Anemometer; C_{pmax} = Power coefficient = 0.56

However, at a standard pressure and temperature, Equation (1) becomes,

$$P_w = \frac{1}{2}\rho A V^3 C_p \quad (2)$$

Figure 7 shows the packet of air moving with speed (V).

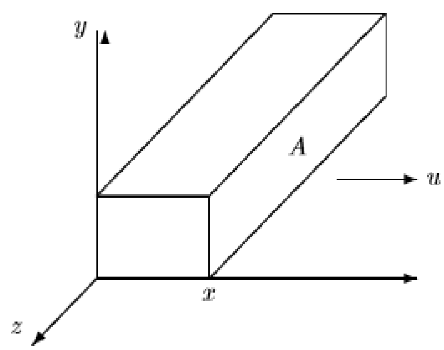

Fig 7. Packet of air moving with speed (V)

RESULTS AND DISCUSSION

A comparative analysis of the wind speed generated in onshore (Okada) and offshore (Okerenkoko) shown that the wind speed generated in offshore is higher as depicted in Figure 8 and Figure 9 respectively. Also, the average values obtained for both offshore (3.39 m/s) and onshore (2.88 m/s) were lower than wind speed values obtained in Northern Nigeria as established in literature review. These results are consistent with the study conducted by Adedipe *et al.* (2018). Their research indicates that wind speeds are generally lower in southern Nigeria than they are in northern states like Jos, Katsina, and Maiduguri, where factors like topography and surface roughness contribute to high wind speeds. Additional investigation showed that wind energy in the northern region of Nigeria can reach 8.07 m/s (Ahmad, 2016). Furthermore, high onshore wind speeds are crucial in the northern region of Nigeria, per the most recent report from the Nigerian Meteorological and Observatory Service (NIMET), which was based on the 40-year (1968–2007) available average of wind data from all 44 stations in Nigeria (Figure 1).

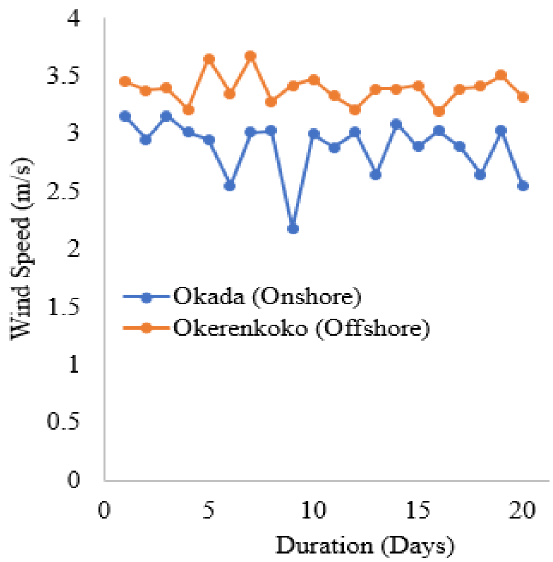

Fig 8. Comparative analysis of daily wind speed generation in offshore and onshore Niger Delta region

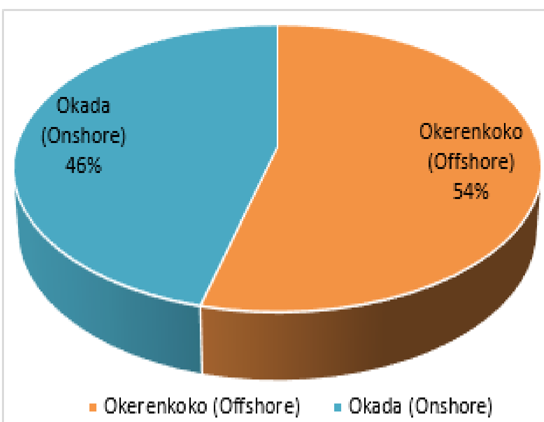

Fig 9. Comparative analysis of percentage average wind speed of Okerenkoko and Okada

Similar to this, the southern region of Nigeria experiences moderate wind speeds, between 3.0 and 3.5 m/s. Moreover, the percentage average wind speed generated in Okada town (onshore) and Okerenkoko town (offshore) were and 46% and 54% respectively.

The results of the comparative analysis of power of wind in offshore and onshore Niger Delta is shown in Figure 10 and 11 respectively. The wind power which is the technique of using the wind to produce mechanical power or electricity is evaluated for a duration of twenty days using generated wind speed data and Equation 2. It was observed that offshore with better wind speed values shows a better tendency of wind power generation against onshore. Thus, the amount of electricity produced by a turbine is mostly determined by wind speed. Therefore, higher wind speed produces more power, thus, increase mechanical and electrical power.

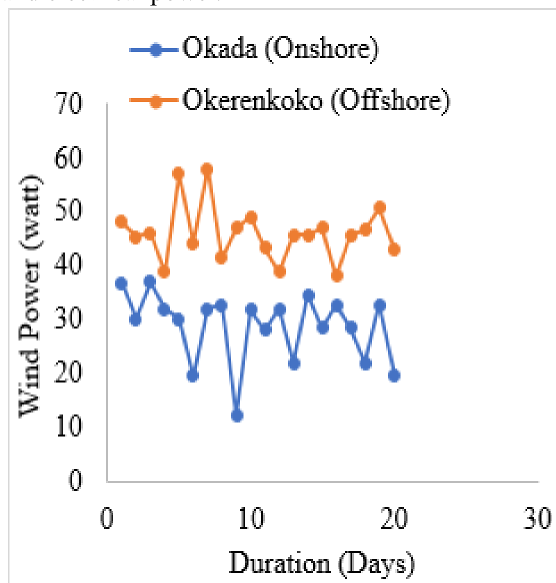

Fig 10. Comparative analysis of wind power generation in offshore and onshore Niger Delta region

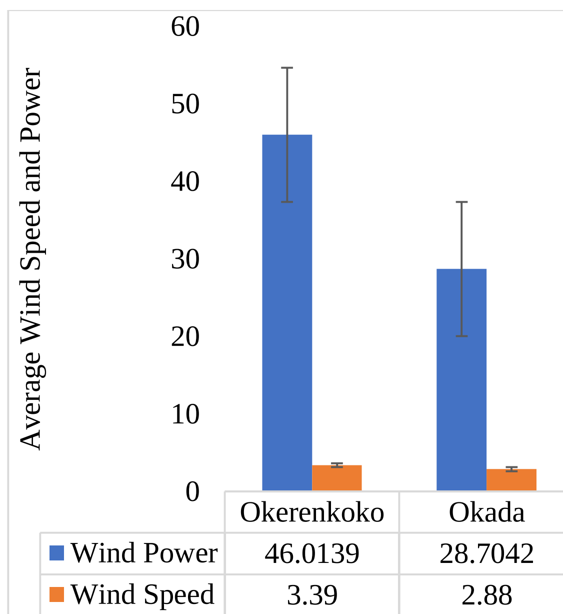

Fig 11. Comparative analysis of effect of average wind speed on wind power generation

Also, with the optimization of the turbine, there is every possibility of harnessing more wind to produce mechanical power or electrical energy since the kinetic energy of the wind is transformed into mechanical power by wind turbines. This mechanical energy can be transformed into electricity by a generator or used for specialized purposes like pumping water, electricity generation, crushing grain, drying fish etc. Consequently, this can aid the industrial activities of the oil rich Niger Delta. As depicted in Figure 11, wind speed has direct effect on power of wind. This means that even a small increase in wind speed results in a large increase in wind energy, thus, the most important factor affecting wind energy is wind speed. However, wind speed is not constant as shown, it fluctuates with the varying of air temperature over a period of time in different geographic locations and seasons (Wang and Liu, 2021). Thus, a better values of wind speed and corresponding wind power in Okerenkoko unlike in Okada.

Conclusion: In this study, a comparative analysis of onshore and offshore wind energy potential of Niger Delta using Okada and Okerenkoko is evaluated. The daily wind speeds of both towns were ascertained, data was generated, and comparisons were made. The study's conclusion showed that towns in the Niger Delta have the ability to produce wind speed. Additionally, it was noted that the Niger Delta's offshore regions tend to generate higher wind speed and power than the region's onshore portion. It was determined that the ratio of offshore wind speed to onshore wind speed was 54% to 46%. Therefore, in order to meet some of the commercial demand for wind power in Niger Delta areas of Nigeria, there is need to installed wind turbine in offshore areas of Nigeria Niger Delta.

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