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Estimation and Management of Wind Energy in Ikorodu Lagos Lagoon, Using Weibull Parametric Measurement to Electricity Production in Nigeria

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Abstract:- This paper is an approach on the estimation and approximation management of wind energy production around the lagoon axis of Ikorodu, Lagos state, Nigeria. The article concentrates on the availability of renewable resource such as wind to generate electrical energy in the greater Ikorodu metropolis of Lagos state Nigeria. Here, probability distribution function is used to generate the wind data. In this paper, three distinct methods are presented; Data time series analysis, Weibull probability function, and theoretical comparison with analytical concept. This research uses two important parameters for analyzing wind data: shape factor "k" and scale factor "c" from Weibull distribution function. The theoretical uses mathematical equations of popular methods such as: (a) Moment method, (b) Empirical Formula, or statistical standard deviation, (c) Peak likelihood, (d) modified peak likelihood, (e) double modified peak likelihood (f) graphical method or smallest mean square, and (g) energy sequence factor. The results obtained are tested to optimize the value from the Weibull parameters by adopting five techniques: (i) root average square error methodology, X2, power of agreement , MAPE, and RRMSE. The results expatiated on the practical and theoretical techniques design to confront the outcome of wind energy harnessed per 1.5 km2. Here, a differential optimization technique is used to determine the precision report. This serve as the basis of error litmus check existing between the wind energy determined by theory of statistical and mathematical Weibull Parametric function and the practical time-series data analysis in LSTM. Again, the wind data (speed and energy/power) were measured and recorded between January 2020 to December 2023 in the Ijede-Ikorodu Lagoon area of Lagos State. The optimized value for the shape factor k and scale factor c parametric measurement and management for maximizing the output electrical energy are obtained by using a well robust Weibull distribution function techniques and by absolutely determining and selecting the best position and location for installing the wind/wave alternators/generator. These generators come with turbines as a single unit. The measurement of the yearly average wind speed and average wind power are 10.09 ms-1 and 10.1 KWm-2, concurrently.

Keywords:- *Wind Generator/Turbine, Mathematical Modelling Techniques, Simulation Techniques, Weibull Probability Distribution, Wind Speed Wind Energy/Power, Average Wind Speed, Shape Factor, Scale Factor, Artificial Neural Network, the Absolute Average Wind Speed, the Wind Speed Standard Deviation Model.*

I. INTRODUCTION

Renewable resource such as geothermal, hydroelectric, biomass, wave, solar, wind, tidal etc., are now the alternative sources of energy today. Remarkable among renewable resource is wind energy for electricity production and distribution. The energy needed, supplied and consumed has absolutely increased in recent decades because of the increasing housing demands as a result of fast and rapid population bust which is due to exodus migration from other states to Lagos state in Nigeria. Sadly, almost all the means of meeting the said electricity demandsmost of this demand are through non renewable energy resource such as fossil fuels. Undoubtedly, the non-renewable form of energy has shown potential environmental damage, climate change and the degredation of the ecosystem through pollution. Although, the Egbin thermalpower station located in Ijede Ikorodu is non-renewable resource. The total operational output capacity 1320MW is not sufficient for Lagos state. Developed nations are taking steps in dealing with this menance by using renewable form of energy to solve the above drawbacks. On the other hand, the renewable resources are becoming increasing popular to be used as unconventional to its parallel resources because of their dependability and ecological friendliness [1-6]. The most commonly used renewable energy resource used in recent time is the wind energy. In recent times, wind power science and technology reserch and discoveries have been massively overwhelming and spreading across the globe as green energy is practically replacing the pollution driven non-renewable resource [2]. By the end of 2023, the global wind power capacity was attenuated approximately at 1,021GW [1-5]. Hence, wind energy/power has got high potential prospect with typical and traditional undiluted three aims: (1) for generating electrical energy and power, (2) For pumping water and (3) For desalination of water. However, the obvious advantage and merit of wind energy/power depends ultimately on the capacity available and the

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absolute average wind speed characteristics [2-3]. The newly installed global wind energy/power capacity from 2019 to 2023 is as shown in Figure 1.

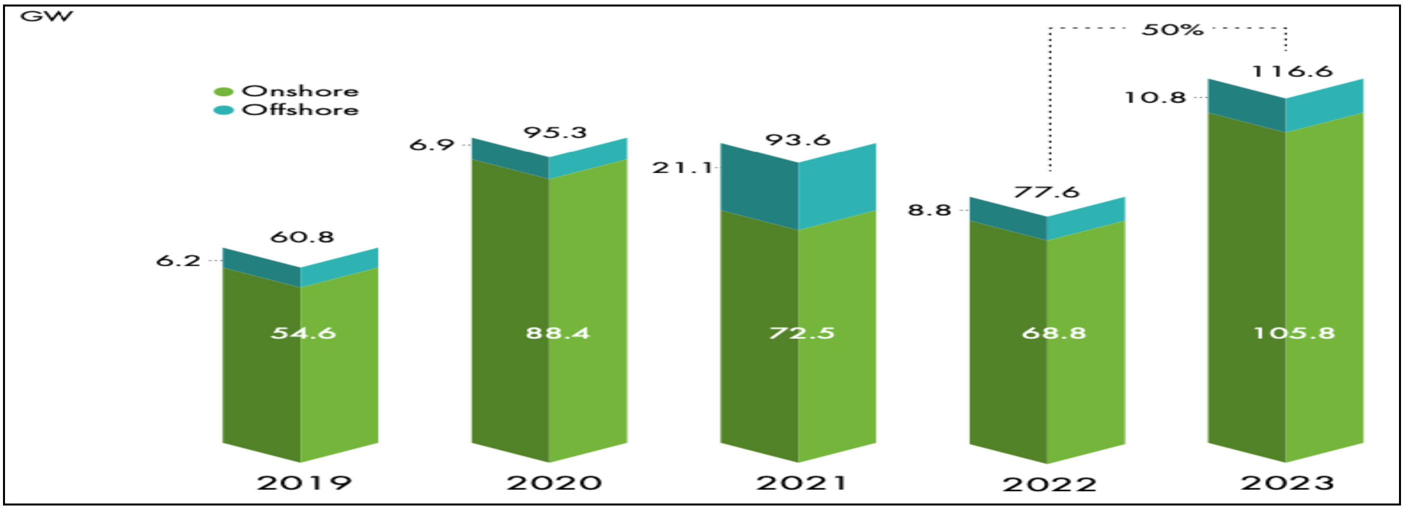

Fig 1 Newly Installed Global Wind Energy/Power and its Capacity

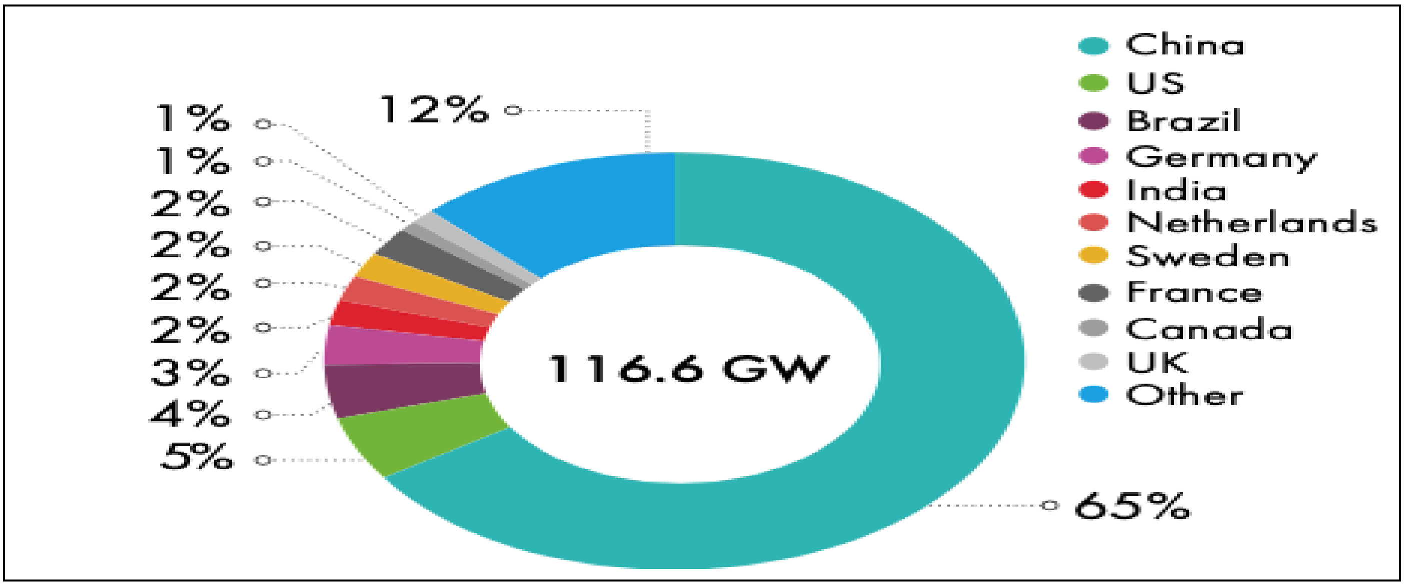

Fig 2 a: Global Installed New Wind Power Capacity 2023

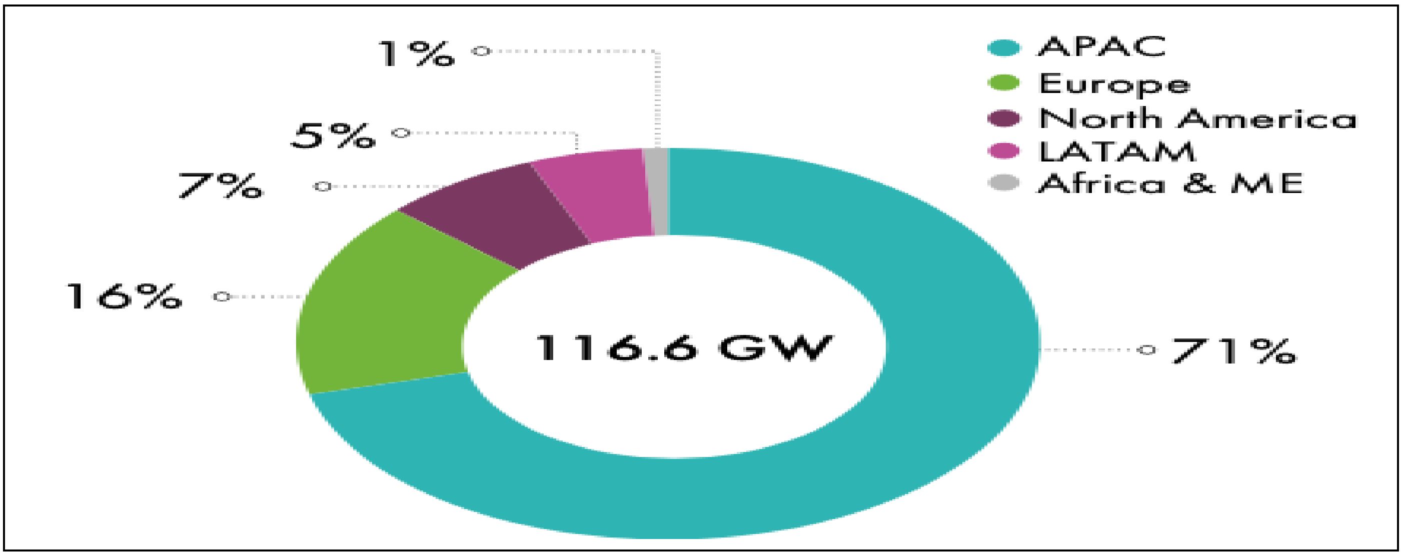

Fig 2 (b): New Installed Capacity 2023 and Top Five Market Share

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The total installations capacity of wind power was 117GW as at 2023. This value represents a yearly increment from the previous year. In 2023, there was a global growth of the wind power value. As a result of the steady growth and pollution free friendliness, 54 countries decide to built new wind power stations. Figure demostrate the top cummulative wind power capacity of the following areas/regions; The Asian Pacicific region (APAC), North America, Europe, The Latin America (LATAM) and the Africa/Middle East part. Nevertheless, tthere has been a gradual pattern in shortage of electrical energy/power and this has become mainstay problem on the globe exceptionally in tier 3 nations. Nigeria is a country of about 230 million people with a barely 4000 MW of electricity distributed. By standard, 1 million people are entitled to 1,000 MW of electricity and 230 million are entitled to 230,000 MW. So, as it stands, Nigeria needs huge investment in electricity and renewable energy is undoubtedly a source that has been undertapped in the generation of electricity on the continent of Africa. The unconventional and unorthodox source of energy/power such as solar or wind energy derived from wind speed has immensely become popular and increasely needed in the face instability of electrical power in the tier 3 nations., Countries like Nigeria has continuously faced interuption in electrical power due to number of factors; such as Niger Delta vandalism of fuel pipeline, banditry and kidnapping of electric power manpower and machineries [1-5]. Hence, we commence the wind energy research by obtaining (1) the wind speed, (2) average wind speed, (3) wind power density and (4) wind power density using frequency distribution function [1, 4, 6 and 9]. Recent researches show that the Weibull function compensate accurately for the wind probability distribution compactly when compared with other methods [7-15]. The Weibull function fits appropprately into the time series data. The optimized value for the shape factor k and scale factor c parametric measurement and management for maximizing the output electrical energy are obtained by using a well robust Weibull distribution function techniques and by absolutely determining and selecting the best position and location for installing the wind/wave alternators/generator. Furthermore, the shape and scale factors of Weibull distribution has proven significant in attaining and harnesssing the comparative advantage from the economic of scale hence, characterizing optimum maximization of the wind farm [1-14]. The algebraic sum of electrical energy/power produced from the wind farms depends on the following notable energy factors; the absolute average wind speed, the wind speed standard deviation model, and the site characteristics. In addition, this research takes a significant looks in determining the hidden correlation linking the average wind speed, the deviations obtained, and the obvious and significant parameter of the Weibull function siting Ijede-Ikorodu axis.

Therefore, this research work centralizes on the wind energy production in Ijede Lagoon area of Ikorodu Lagos State, Nigeria using analysis from wind data obtained from the wind farm. This is done by using absolute probability function. This information are collected and recorded from three lagoon towns: Ijede, Baiyeku and Oke-Ago/Oke Lisa axis from January 2020 till December 2023. These data are used to maximize the design and development of wind energy turbine/generator, in order to minimize the wind farm input and output costs.

II. ESTIMATION/APPROXIMATION OF THE WIND POWER DENSITY

The wind power density is the algebraic measured of the total wind energy available in site or geolocation. This density is measured using two pragmatic techniques; firstly, using the available power based on the measurement approximations from the average wind speed of weather meteorological data, and secondly, from the frequency distribution function using the Weibull distribution parameters. [1, 2, 16, 17, 18, 19 and 20].

This wind energy and wind power density are considerately salient in determining the prospective of wind energy resources which constitute the total sum of the wind energy/power available at different wind speed desire installation site. The evaluation, estimation and approximation analysis using statistical techniques of the wind energy/power data becomes significant in optimizing and maximizing the performance of the wind turbine/generator/alternators. This inference drawn from wind energy/power helps to determine the extent of the attainable energy in a given location. Literature has identified two pragmatic approaches as stated earlier for obtaining wind power density. [2, 21-26]. This research uses two important parameters for analyzing wind data: shape factor “k” and scale factor “c” from Weibull distribution function. The theoretical uses mathematical equations of popular methods such as: (a) Moment method, (b) Empirical Formula, or statistical standard deviation, (c) Peak likelihood, (d) modified peak likelihood, (e) double modified peak likelihood (f) graphical method or smallest mean square, and (g) energy sequence factor**.** The objectives and aim of the estimations and approximations are; (a) to retrospectively distinguish between the previous situations; (b) to help predict accurately the possible future value (c) to predict precisely the amount of power produced in a given site/location within the turbines in the wind farm (d) to gauge and scale accurately the weather meteorological records[1-2] and [27-34].

III. STATISTICAL AND MATHEMATICAL ANALYSIS OF THE MEASURED AND GENERATED WIND DATA

- *The Wind Power measured is Directly Proportional to the Cube Power/Index of the Wind Speed as given below:*

$$P(V) = \frac{1}{2}\rho A \upsilon_{avg}^{3} \tag{1}$$

Where ρ is the given air density at rtp equal to a value of 1.21kg/m^3, with a significant temperature value of approximately 15°C and a pressure of of 1 ATM. By

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substituting the above values into equation 1, the average power density for practical time series of wind speed data is given in equation 2

$$\overline{P} = \frac{1}{2n}\rho\sum_{i=1}^{n}\upsilon^{3} = \frac{1}{2}\rho A(\overline{\upsilon^{3}}_{avg}) \qquad (2)$$

Again, v, k and c are wind speed, dimensionless shape factor and the scale factor. The Weibull parameter, k, shows the absolute width of the wind speed, [1-3, 28-30]. The Weibull parameter, c, shows the coordinates of the wind distribution, thereby showing a windy location [2, 31-34]. The wind power density absolutely determines the basis of the Weibull distribution function as shown in equation 3.

$$\overline{P} = \frac{1}{2}\rho\int_{0}^{\infty}\upsilon^{3} f_{w}(\upsilon)d\upsilon = \frac{1}{2}\rho c^{3}\Gamma\left(1+\frac{3}{k}\right) \quad \left(\frac{w}{m^{2}}\right) \qquad (3)$$

The simulation and analysis of the electrical energy/power of the proposed concept wind turbine/ generator is desirable.

➢ *The Output Power from Turbine/Generator*

The output power from wind farm or turbine/generator is significantly expressed in equation 1 while the average value is shown in equation 2 and in figure 3. Figure 3 compares the global output power of solar PV output and that of the wind power output. The results demonstrate how the speed of the wind becomes a significant factor in determining the average wind output power. The power curve explains the relationship between cut in speed, that is the operating speed of the turbine and the speed of the rated capacity of the already operating turbine. The wind farm turbine/generator capacity usually swindle between 12m/s to 18m/s depending on a number of factors on the wind farm turbine design parameters.

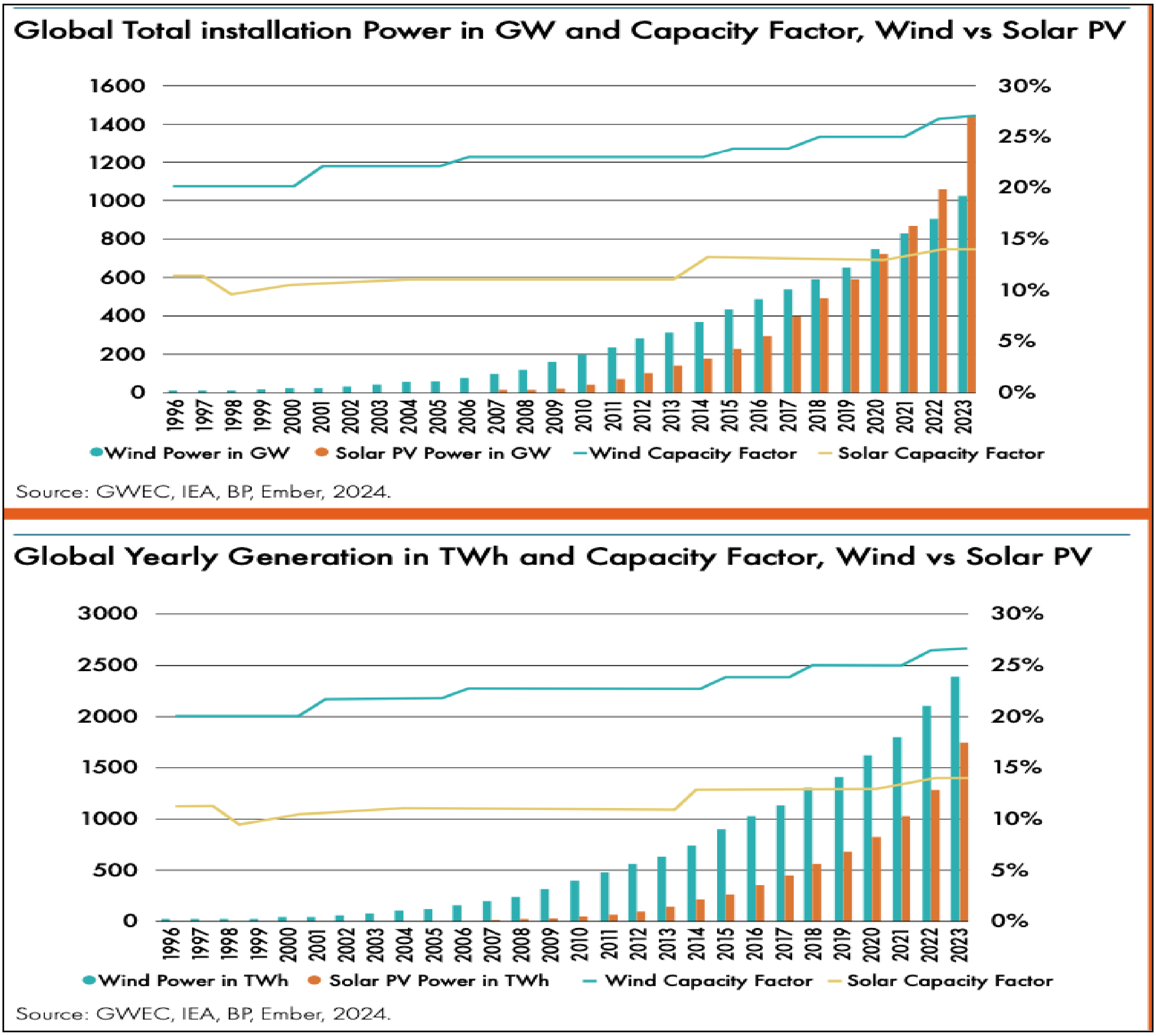

Fig 3 Wind Capacity and Turbine Output Power

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- *The Output Peak Power*

The output peak power of a wind turbine is maximum output power of the turbine capacity multiplied by the total hours in a year. That is wind turbine capacity * 8760 hours per year. This is the constant output power sustained above the rated power of wind farm turbine/generator. This wind turbine output power is converted to electrical energy/power in the proposed Ijede-Ikorodu site of the wind farm.

- *The Cut in Wind Speed of the Turbine*

The cut in wind speed of the turbine is the absolute speed at which the turbine will start operation. It is used as a design parameter in obtaining the output power from the turbine.

- *The Cut out Wind Speed of the Turbine*

The programmable speed at which a running turbine is made to stop operation to avoid machine and environment damage is called the cut out wind speed of the turbine. [1-2, 5-9].

- *The Kinetic Energy of the Wind*

The kinetic energy of the wind as defined by the Weibull probability function, is the conceptual wind energy of the moving air molecules per unit surface of the chosen ambient environment in a given amount of time period, T. This moving energy is given in equation 4.

$$E_w = \frac{1}{2} \rho c^3 \Gamma\left(1 + \frac{3}{k}\right) T \tag{4}$$

Where ρ the moving air density of the wind.

The time series sums the energy equation as given in equation 5.

$$E_a = \frac{1}{2} \rho \upsilon^3 T \tag{5}$$

IV. EMPERICAL METHODS USED FOR OBTAINING WEIBULL PARAMETERS

- *The Different Methods for Obtaining Weibull Parameters are Described Briefly as follows:*

- *The Moment Method*

This method was used and recommended by Justus and Mikhail [2]. This method describes the average and the standard deviation of the component of used the conceptual design. This concept is based on the analytical iteration of the mathematical series which is proportional to the average and standard deviation of the speed of the wind in a given site location. [1-3,16, 31-32]. This method exemplifies the Weibull parameters from the wind farm. Moment one defines the origin of wind and moment two defines the average value of the wind. This moment method defines the shape and scale factors of the Weibull parameters.

- *The Actual Method*

The actual method is also known as the empirical method. It is a simple method to use and implement. It uses the knowledge of avaerage wind speed and the value of the standard deviation of wind speed and the cube of this two values to calculate the cummulative outcome of the Weibull functionon. Here, the scale is obyained from the sequence factor.

- *The Peak Likelihood Method*

The peak Likelihood Method is also known as the Maximum likelihood Method. This method was invented by Fisher [2]. However, Steven and Smulders were the first to apply this concept in obtaining wind speed parameter [2]. It used the inverse of analytical iteration method of the empirical method to determine the shape factor of the Weibull parameter. Although, this method is more to implement but it comes with desirable and effective output of the wind parameter [1]. It is a robust mathematical equation method used for wind speed data in time series analysis. The iteration algorithms are more complex in determining the shape and scale factors of the Weibull functions/parameters.

- *Modified Peak Likelihood Method*

This statistical method can only be simply used when the wind data are given or iterated in the frequency domain instead of time domain.. Also, this method requires a significant number iteratic algorithms in order to produce the adequate Weibull. The shape and the scale factors for the Weibull probability function are given by equation 6 and 7 respectively.

$$k = \left[\frac{\sum_{i=1}^{n} \upsilon_i^k \ln(\upsilon_i) f(\upsilon_i)}{\sum_{i=1}^{n} \upsilon_i^k f(\upsilon_i)} - \frac{\sum_{i=1}^{n} \ln(\upsilon_i) f(U\upsilon_i)}{f(\upsilon \geq 0)} \right]^{-1} \tag{6}$$

$$c = \left[\frac{1}{f(\upsilon \geq 0)} - \sum_{i=1}^{n} \upsilon_i^k f(\upsilon_i) \right]^{1/k} \tag{7}$$

- *The Second Modified Peak Likelihood Method*

This method was an improvement on the modified peak likelihood method by outstanding researchers referred as Christofferson and Gillette by developing a new iteration for the shape factor. [2] The shape factor of the second modified peak likelihood method is given in equation 8.

$$k = \frac{\pi}{\sqrt{6}} \left[\frac{N(N-1)}{N\left(\sum_{i=1}^{N} \ln^2 vi\right) - \left(\sum_{i=1}^{N} \ln vi\right)^2} \right]^{0.5} \tag{8}$$

The method does not require iteration technique or the sorting of the wind data [2]. Therefore, we chosen this method for shape factor calculation for the proposed Ijede-Ikorodu site of Lagos state.

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- *The Asolute Graphical Method*

This method is significantly put to use by using the cumulative distribution function of statistical evaluation of the wind data. Here, the wind speed data from the wind farm are interpolated using the wind square regression analysis for evaluation. Purportedly, the wind speed data has to been simplified and grouped based on functionality and derivativeness of the function. The concept, finds its application in logarithm and exponential while determining the cumulative Weibull functions/parameters[1-2].

- *The Energy Sequence Factor Method*

This method is proportionately used with the average wind speed data available from the wind farm. This is expressed by equation 9 and 10.

$$E_{pf} = \frac{\overline{\upsilon}^3}{\overline{\upsilon}^3} \tag{9}$$

Where $\overline{\upsilon}$ is defined in the previous equation.

$$k = 1 + \frac{3.69}{(E_{pf})^2} \tag{10}$$

Where E_{pf} is defined as the energy sequence factor for iteration.

V. GOODNESS OF BEST FIT AND STATISTICAL ERROR ANALYSIS

To analyse, evaluate and optimise the system performance from the wind farm looking squarely of the wind speed data of a geographical location, it is cognizant to use the seven parameter estimation, approximation and mangement method of the Weibull distribution function for deriving the wind power density. The is managed by using reliable statistical distribution. In this specific research different statistical parameter are considered. These includes the relative percentage error, average absolute percentage error, average absolute bias error, root mean square error, relative root mean square error, correlation coefficient and the absolute index of agreement. The assessment done here includes the above mentioned statistical method and relative non index statistical and analytical methods. The description of the various statistical methods used in Ijede-Ikorodu site analysis are given below:

- *The Root Mean Square Error*

This system is called RMSE for short and is used to determine the performance accuracy by way of comparison between the values obtained Weibull function with the ones from measurement data of the given site location. The RMSE value used in the analysis of this research based on the measurement from Ijede site location is given in equation 11.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(P_{i,W} - P_{i,M}\right)^2} \tag{11}$$

- *The Chi-Square Test Method X^2*

This method is practically used to analyse the proportionate concept of the independent variables and any excruciating discrepancies that exist between the observable frequencies and the expected frequencies of the probable event occurring within the sample space [2]. It is pragmatically inappropriate to use a small sample space for this method. Hence, a non-parametric test that is completely independent of notable factors like the mean and variance of the population is used. While using this model, some essential and definitive criteria has to be met: the group data has to be independent; random selection of the items has to be adopted; the observation should be frequency based and each observation should fit into each frequency group.

The chi-square test is given by equation 12.

$$\chi^2 = \sum_{i=1}^{N} \frac{(y_{i,m} - x_{i,m})}{x_{i,m}} \tag{12}$$

Where y is the observed value and x is the expected value.

- *The Index of Agrement*

The index of agreement is a statistical tool that is used to normalize the prediction error obtained from mean square error to potential error. This iteration guarantees a holistic approach of the model performance by evaluating both systemic and random disparities among the predicted values and the measured values. This method normally shows the level of precision of the predicted values when compared to the measured values. This model is demonstrated in equation 13 as shown below.

$$IA = 1 - \frac{\sum_{i=1}^{n}\left|P_{i,W} - P_{i,M}\right|}{\sqrt{\sum_{i=1}^{n}\left|P_{i,W} - P_{M,avg}\right| + \left|P_{i,M} - P_{M,avg}\right|}} \tag{13}$$

P_{iW} is the power density from Weibull distribution function. The other parameters such as; $P_{W;avg}$ and $P_{M;avg}$ are the mean of $P_{i,W}$ and $P_{i,M}$ values and n is the algebraic sum of all the observations.

- *Average Absolute Percentage Error*

The mean absolute percentage error is also called the mean absolute percentage deviation. It is the measure of prediction accuracy for a forecasting technique. It gives the difference between the computed wind power when using the Weibull function and the ones obtained from measurement. This model is given below in equation 14

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{P_{i,W} - P_{i,M}}{P_{i,M}}\right| \times 100 \tag{14}$$

- *The Relative Root Mean Square Error*

The relative root mean square error is the normalized model used for measuring the differences between the predicted values and the observed values. This is obtained

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by dividing the root mean square error with the average values obtained from the wind power obtained from measurement applications. This model is given below in equation 15

$$RRMSE = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(P_{i,W} - P_{i,M}\right)^2}}{\frac{1}{n}\sum_{i=1}^{n}P_{i,M}} \times 100 \qquad (15)$$

VI. WIND SPEED OF LAGOON PLAIN IN IKORODU LAGOS AS A CASE STUDY

Ikorodu Lagos is located in West Africa along the Lagoon of Atlantic Coast. This study focuses on the south coast of Atlantic Ocean. The Lagoon area has two main seasons; Spring/rainy season (April to November) and the dry/hammattan season (November to March). The weather and climate in the Lagoon area of Ikorodu is warm and wet in the rainy season and dry and cold in the hammattan season. The wind speed in the Lagoon area of the greater Ikorodu axis is usually below 18m/s for most of the in a given year. The strong wind which normally occurs occasionally usually hovers around 25m/s in any given year.

Figure 4 shows the transversal challenges of the wind energy/power in short and long terms in the south lagoon area of Lagos. The chart shows that the mean wind speed which is around 9 m/s and is relatively below the average value of the total which amount to 180 days. The mean average wind speed between 9 m/s and 18 m/s is around 180 days. This is about 45% of the total wind speed and it's the most convenient and outstanding wind to generate electricity. This is used as the rated power wind. The Mean wind speed in the Lagos Lagoon area of the greater Ikorodu metropolis are usually well above 45% of the total wind available in Lagos Nigeria. Table 1 Lists of actual maximum wind speed, MWS records and standard deviation from January 2020 to December 2023 in the greater Ikorodu metropolis. The highest average speed in hammattan season reaches 25 m/s. These recorded data are done regularly by the meteorological station of Lagos state and this form the bases for our MWS. The result shows that there was a a grammatic decrease from February to April in the year 2020, reaching an over whelming low value of 3.5 m/s and goes as high as 6m/s during January of same year.

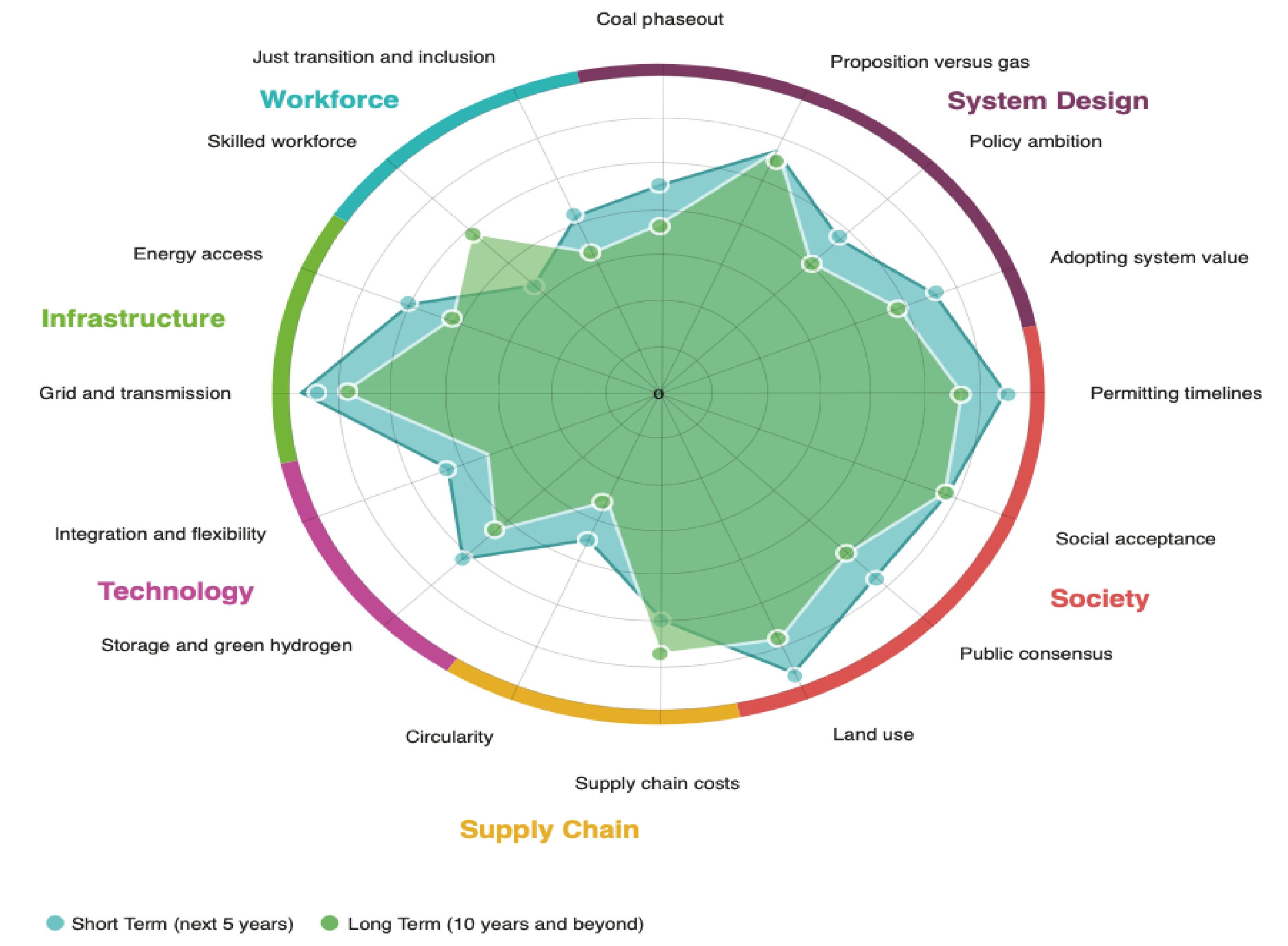

Fig 4 Transversal Challenges to Wind Energy's Growth in the Short and Long Term

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Moreover, the value of mean wind speed decreases in the last phase of the year. By 2020, MWS increases exponentially reaching a moderate value of 5.8 m/s in the month of April. By 2021, a notable increase was observed from January to August exceeding a value of 5.9 m/s before a dropdown experience in the last four months of the same year. By 2022, the MWS sky rocketed in value in the month of January to 6.2 m/s, and later fluctuate to reach its peak value the month of June of the same year. Again, this same MWS decreases massively within July to December to all time low speed of 3.5 m/s Overall, The MWS values fluctuate during this time between 3.5 m/s and 6 m/s. These values fluctuate in similar manner from 2020 to 2024 [1-2].

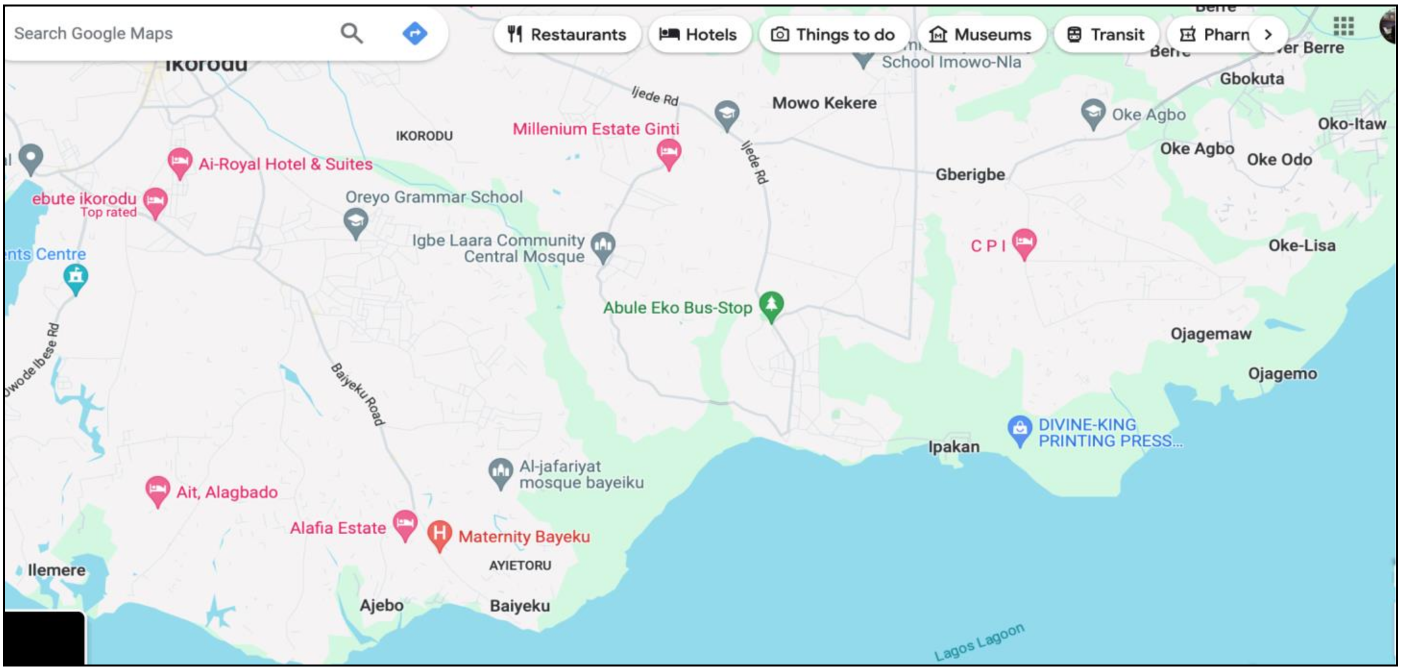

Fig 5 The Lagoon Atlantic Coast of Lagos Nigeria.

Figure 6, 7, 8 and 9 graphs illustrate the probability density functions against the actual MWS measured or recorded from the greater Ikorodu location site between January 2020 to December 2023 of lagoon-coastal area of Ikorodu city of Lagos State. While figure 10, 11, 12 and 13 shows the cumulative frequency function against the wind speed of the same measurement location.

VII. RESULTS AND DISCUSSION

The results from the Mean Wind Speeds are observed from January 2020 until 2023 in Ikorodu Lagos. Here, we selected a sample data to test the performance of the system to ensure adequate and sufficient wind power to electricity production. We use the greater Ikorodu metropolis for the desirable months in these four years by using the seven numerical analysis methodology. This research work uses the actual or experimental data to calculate the peak or maximum wind speed, its kinetic energy and power density. We calculated the MWS and the standard deviation monthly for the period of four years. The peak wind speed for 2020, 2021, 2022 and 2023 has been **9.98, 9.87, 9.47 and 9.22 m/s**, respectively. The average peak wind speed for the whole four years is about **9.64 m/s**. The actual or experiment mean wind speed is around **5.08, 5.82, 5.02, and 5.53 m/s** for 2020, 2021, 2022, and 2023, respectively. The average mean wind wind recorded is about **5.36 m/s**. From the MWS recorded data, wind speed in the Lagoon area is somewhat affected by environment condition of rainfall, sunshine, humidity, temperature and climate change. This usually affect the amount of electricity produced when considering higher Megawatts of production. This result to some challenges to higher power production in the previously reported literature. This paper has resolved the challenges to by improving the cut in wind speed to 9 m/s which is the standard mean wind speed for large scale electricity production by the proposed installable turbine.

The actual power can be calculated by using equation 1 and 2 of this research. The maximum amount of power in 2023 has been around **1,194 W/m^2**. This is due to the value of the mean wind speed available in this year. The reported total power in this four years period from 2020, 2021, 2022 and 2023 is given respectively as; **1,077, 944, 908 and 1,194 W/m^2** respectively. The wind energy between 2020 to 2023 recorded was **25.45, 19.86, 21.40, and 28..02 KWm^{-2},** respectively.

In any given geographical location, the wind speed changes from time to time. In any case the relationship between power and energy is directly proportional to the cube of the wind speed. This research has holistically looked the wind speed, mean wind speed for electrical power and energy production, evaluation and optimization in a larger scale. The experimental wind power evaluation or peak wind speed was 7024;1, **5119.1, 5576.2 and 5991.6** from 2020 to 2023, respectively; while the highest amount of wind energy in 2020 due to the wind speed. The wind

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energy evaluation for 2020 to 2023 was **72771.12, 56083.19, 60087.51 and 53726.78 KW/m^2**, respectively as shown in Table 3.

The measured and the theoretical value obtained using the Weibull probability density function ((PDF) are given in Figure 6-9 from 2020-2023 from the actual measurement of the wind speed data. The theoretical estimated methods is based on generated data and is obtained using the seven numerical method. From the result obtained, it can be predicted that the MMLHM measured data are the most precise and accurate with a wind speed around 5-7 m/s. Moreover, for higher speed values, other method over-estimated the measured value unless the second modified method. The probability distribution function of the measured values are shown in Figure 6 -9 for the year 2020 to 2023. It is demonstrated that the second modified Likelihood method is best precision and accurate method for the 2021 measurement as demonstrated in figure 7. In figure 8, the most accurate method used is the EPF and the MLHM when compared to the observable data of figure 8 of the year 2022. The most precise and accurate method used in this year analysis are the MLHM and the EPF seconded by the FMLHM and SMLHM when comparing these observable data with the measured data of figure 9 in the year 2023.

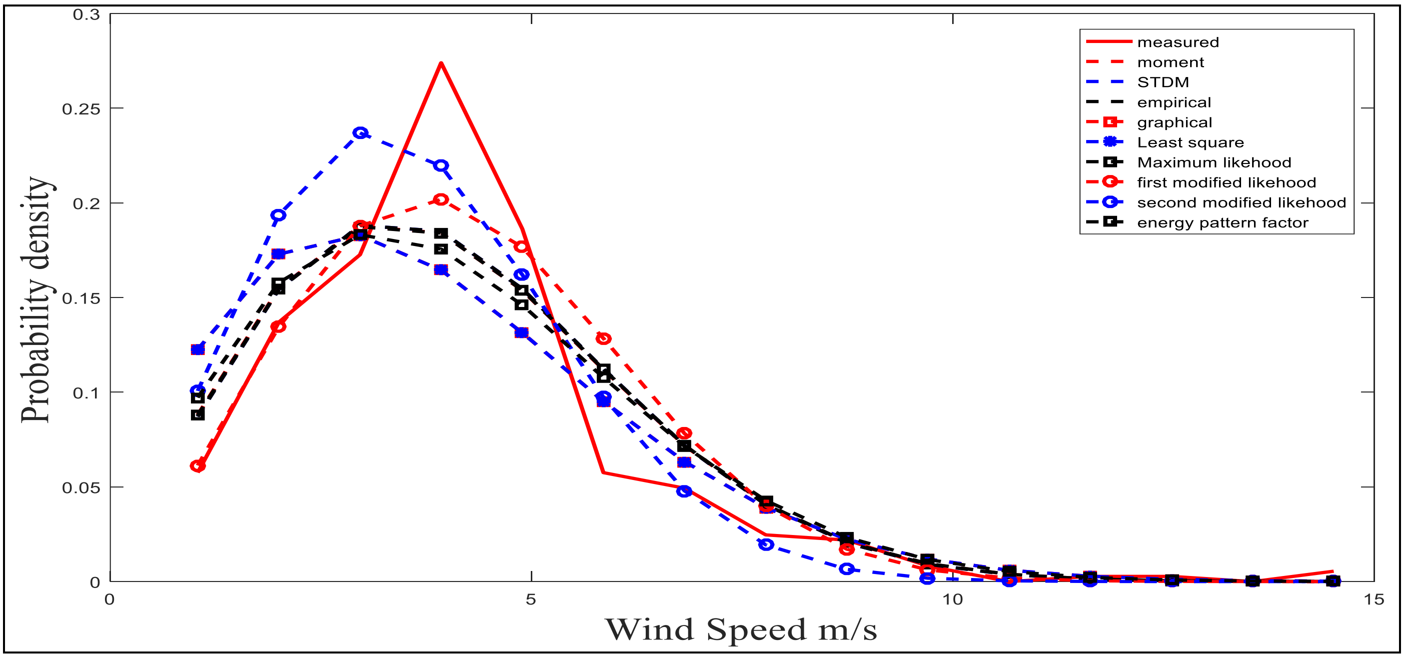

Fig 6 Comparison of Weibull Probability Density Function ((PDF) of Measured and Estimated values for Ikorodu Site of 2020

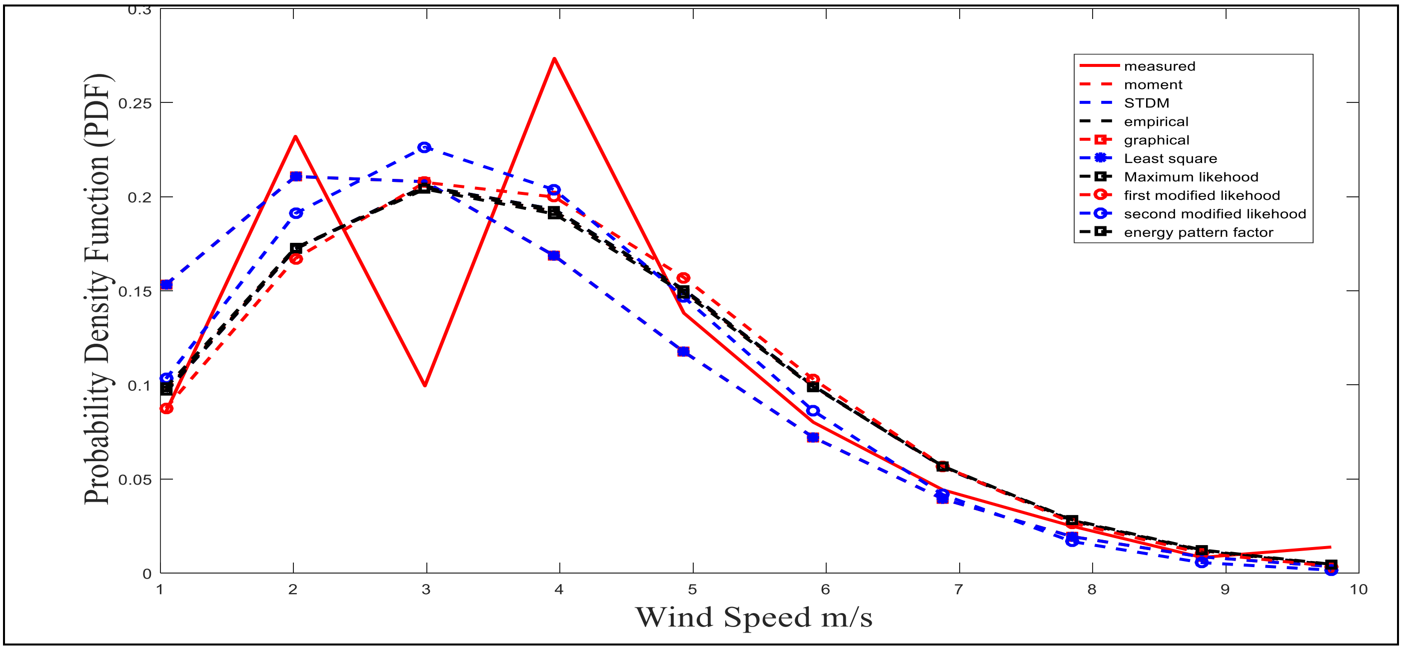

Fig 7 Comparison of Weibull Probability Density Function ((PDF) of Measured and Estimated values for Ikorodu Site of 2021.

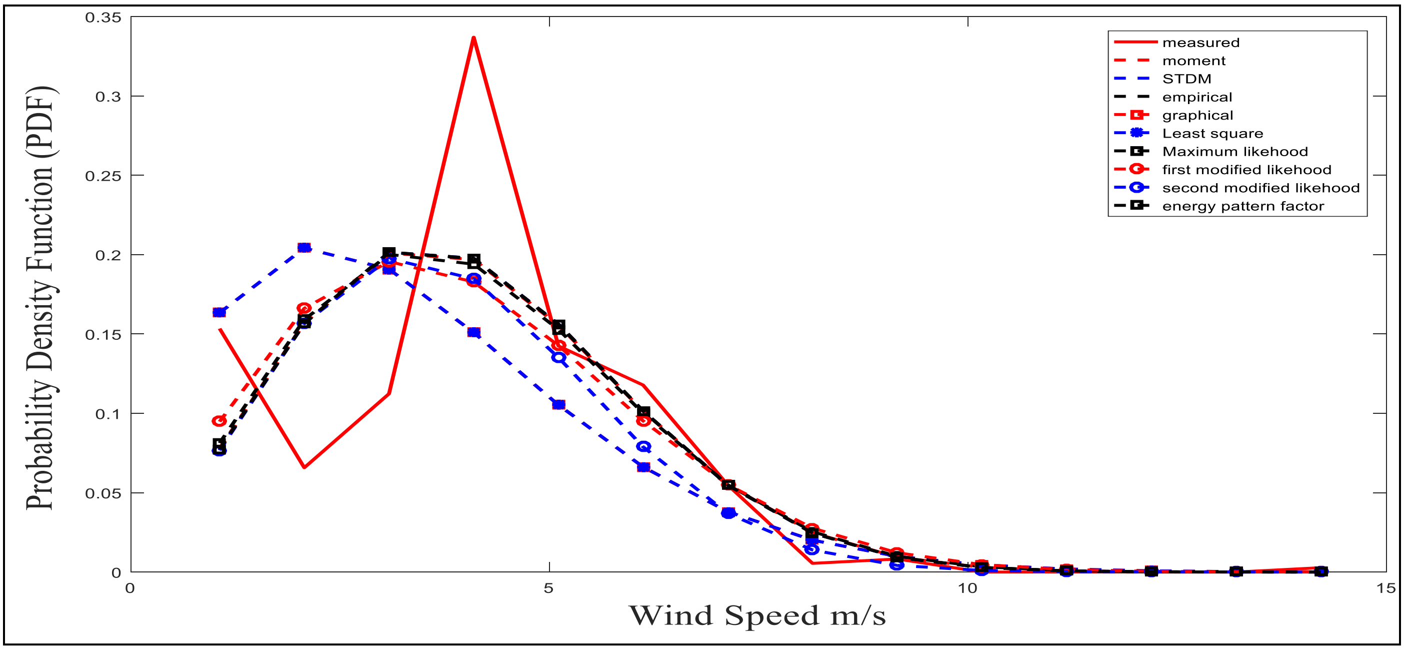

Fig 8 Comparison of Weibull Probability Density Function ((PDF) of Measured and Estimated values for Ikorodu Site of 2022.

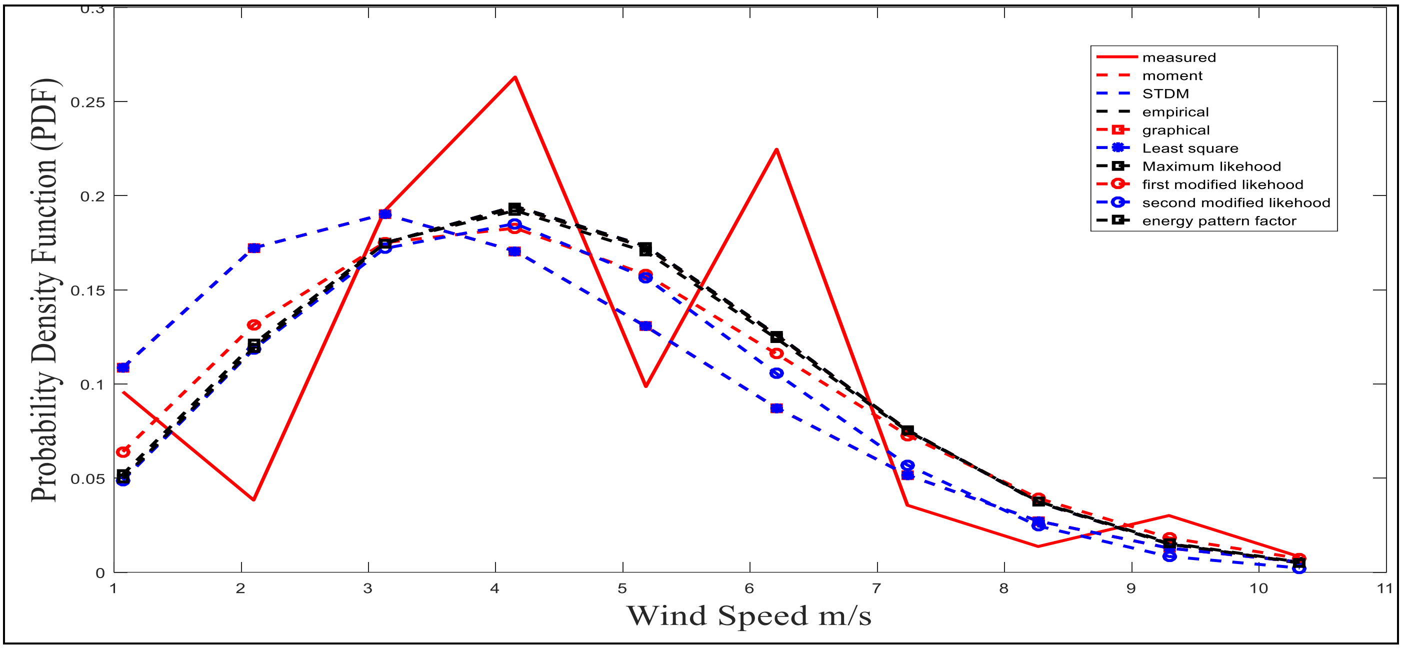

Fig 9 Comparison of Weibull Probability Density Function ((PDF) of Measured and Estimated values for Ikorodu Site of 2023.

The measured and estimated values for the CDF for 2020 are shown in Figure 10. The estimated CDF values are based the generated from the Ikorodu site location and the analysis is done using the seven numerical analysis methods. The seven different methods used for the analysis are; MM, EM, GM, MLH, MLH2, SMLH and EPF. The secon modified method shows the best values from the curve when compared with other methods.

From figure 10, the LSM is the most precise and accurate method seconded by SMLHM. LSM is the most precise and accurate for a system with a speed greater than 5 m/s. From table 4, 5, 6 and 7, of the Weibull parameter is calculated using the data from the seven numerical methods. The estimated MWS from 2020 to 2023 demonstrate similar behavior as the lowest value obtained in 2021 and the peak value for the whole four year was in 2023 as observed. The peak estimated and approximated power due to maximum MWS power in 2023 is proportional to the cube of MWS. MLHM demonstrate the best predicted value as shown from the calculated value of measurement application.

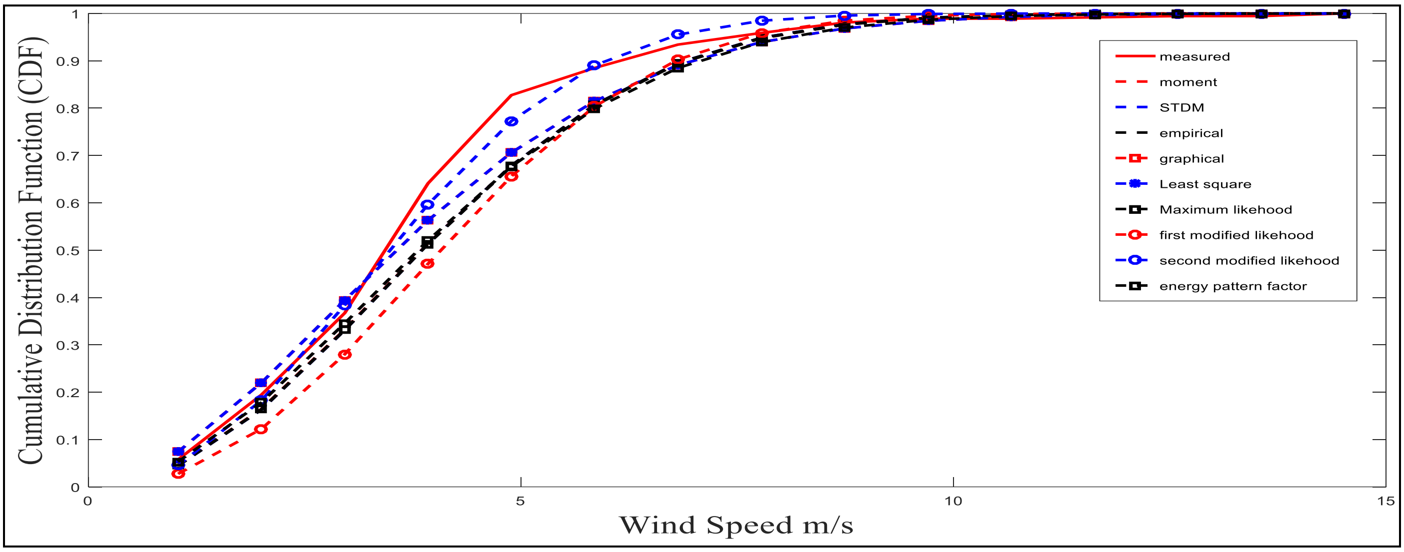

Fig 10 Comparison between the Cumulative Distribution Function (CDF) and the Estimated/Approximated values of Ikorodu Site in year 2020

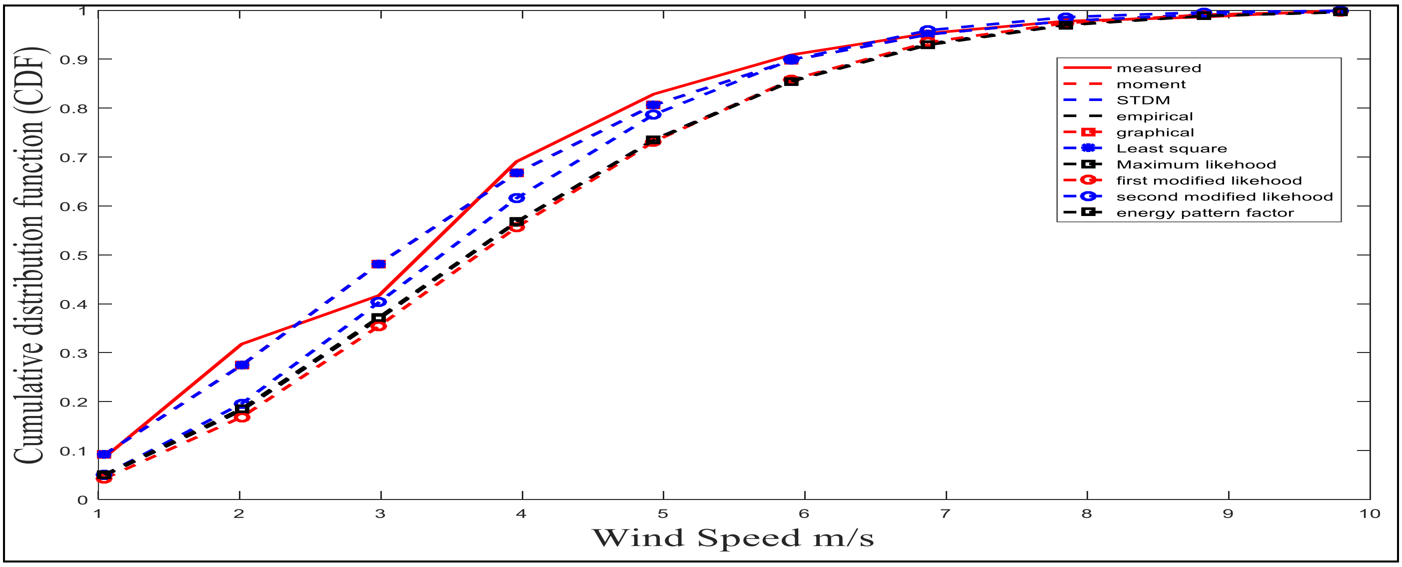

Fig 11 Comparison between the Cumulative Distribution Function (CDF) and the Estimated/Approximated values of Ikorodu Site in year 2021.

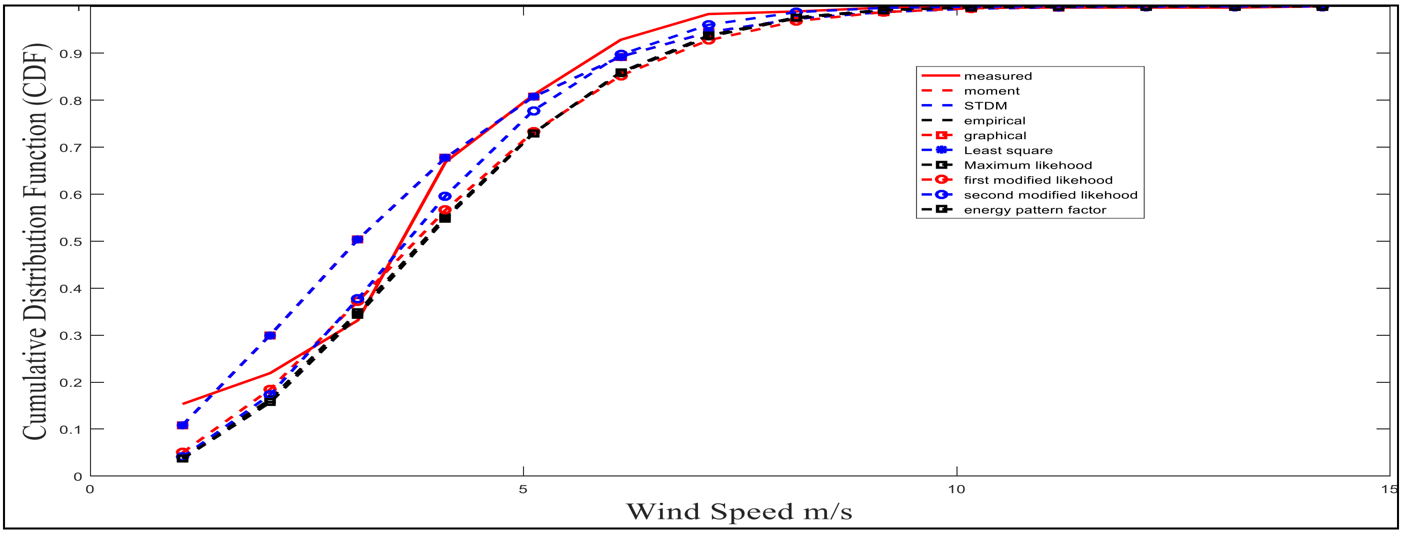

Fig 12 Comparison between the Cumulative Distribution Function (CDF) and the Estimated/Approximated values of Ikorodu Site in year 2022.

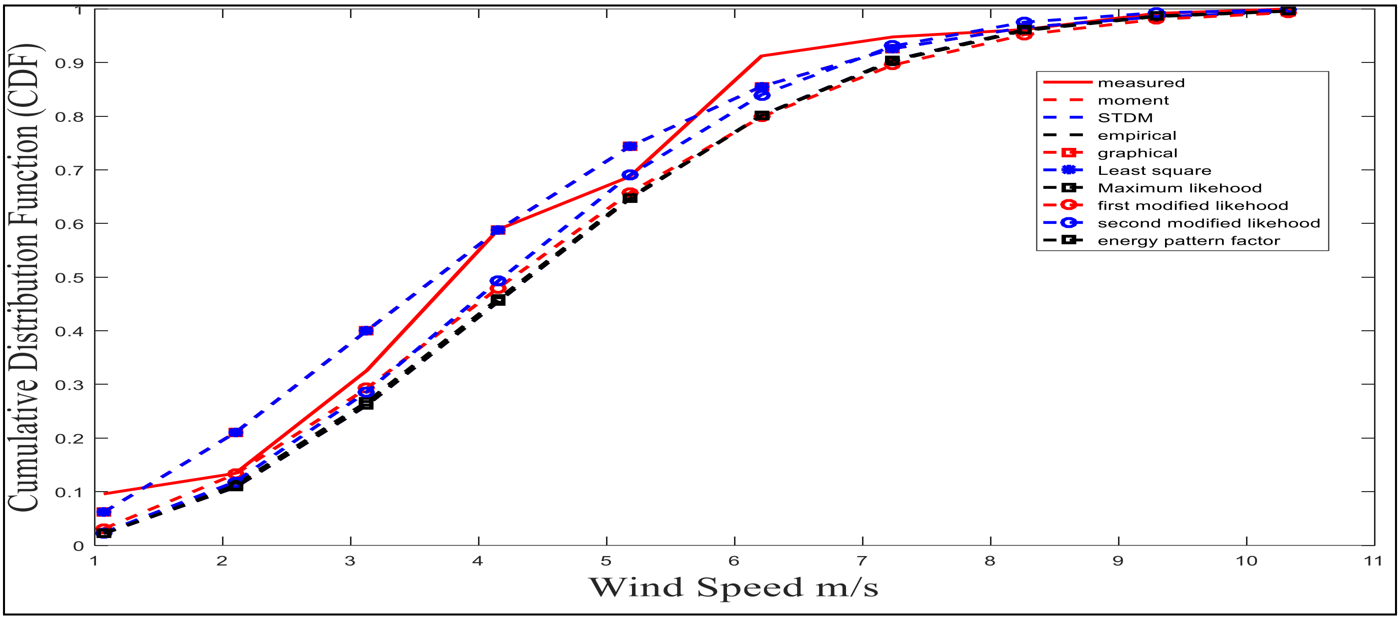

Fig 13 Comparison between the Cumulative Distribution Function (CDF) and the Estimated/Approximated values of Ikorodu Site in year 2023

The Weibull parameter is estimated using the GM yearly. In order to find or calculate this Weibull parameter, a linearized region is obtained. In case, k become the slope of linearized region of the response curve (shape factor) while c becomes equal to exponential value of (b/k). Where b is the y- intercept of the linearized response curve. **This is a second contribution of our work in this research.**

The statistical error analysis of the chosen five are obtained and presented in tables 8, 9, 10 and 11. It is observed that no one method is suitable for the error analysis. In table 8 and 9 the GM shows the best predicted techniques to be used for this error analysis while using RMSE, X^2, IA, and RRMSE but become worst using MAPE. However, some techniques such as MM, MLM and EPFM shows average prediction accuracy when considering all available statistical methods. On another note, the favorite MMLM demonstrate the worst case scenario when considering all statistical techniques except MAPE.

VIII. CONCLUSION

This research was carried out the wind speed data determined using the Weibull distribution functions and statistical analysis for a period of four years was carried out. Here, the mean wind power of the greater Ikorodu axis was carried out and we were able to predict the most suitable location based the available Weibull parameters. This MWS was optimized to generate electrical energy and power that is capable of being connected to the grid system in Nigeria. In the previous literature, only a small scale production was possible. As a contribution in this paper/article, we were able to scale the MWS to a value acceptable for large scale production of about 9 m/s which is sufficient wind speed high scale turbine for industrial generation and production of electricity. This will amount to a sufficient fraction of the total grid system in Nigeria. This study shows the estimation/approximation and management of the of the wind energy potential of the greater Ikorodu axis of Lagos state in Nigeria. These results find application by helping engineer, scientist and industrialist to find the most suitable location of the greater Ikorodu axis or could be applicable to other site location with similar wind speed data. Again, we have obtained the mean wind speed, standard deviation, variance and the coefficient the variance for electrical engineering application of different site locations. Furthermore, the wind and peak wind power that are based on the experimental or actual measurement using the Weibull probability distribution function and the cumulative distribution function have been determined in this research for the chosen site location. This will generate electrical power on a larger scale which is a greater fraction of the grid network in Nigeria. Hence, the use of wind speed for electricity production could possibly and outrightly beneficial for to houses, organizations and industries as an alternative energy resource. This research has contributed to literature in another dimension by analyzing the wind data of a chosen location and using the Weibull probability distribution to determine the wind energy and doing necessary conversion characteristics of the greater Ikorodu axis and its corresponding axis/areas of Lagos Nigeria proven the obvious contribution of the research work. The studies calculated the Weibull parameters by using the seven numerical methods: **(a) Moment method, (b) Empirical Formula, or statistical standard deviation, (c) Peak likelihood, (d) modified peak likelihood, (e) double modified peak likelihood (f) graphical method or smallest mean square, and (g) energy sequence factor.** The energy sequence factor method) is commonly used to determine the shape factor (k) and the scale factor (c) while using the measured data for its iteration. Again, as another contribution to the body of knowledge this study also help in calculating the percentage error while using the five different test methods (using Goodness of fit test and obtaining linearized regions of the response curve) for the chosen location of Coastal-Lagoon area of Ikorodu area of

Lagos State Nigeria for four years. In a nut shell, the obtained wind power resource has been proven to harness sufficient wind that can support industrial production of electricity in Lagos state in particular and Nigeria in general. This article nevertheless, is the second and upgraded ways of installing wind turbines/generators Ikorodu Lagos Nigeria. This determined theories and experiment are based our calculated PDF and CDF of Ikorodu site wind data, whose results are analyzed and presented in both graphical and tabular data presentation.

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APPENDIX

Table 1 Lists of Actual Peak Wind Speed, MWS and Standard Deviation from January 2020 to December 2023.

Period	The Actual or experimental data for wind speed (m/s)														
Months	Peak Wind Speed (m/s)					MWS (m/s)					Standard Deviation (m/s)				
	2020	2021	2022	2023	All year	2020	2021	2022	2023	All years	2020	2021	2022	2023	All years
Jan.	11.39	7.22	7.22	10.83	9.17	6.28	3.97	3.48	4.80	3.63	2.1771	2.0640	1.8853	2.1771	2.075875
Feb.	15.00	8.06	8.06	9.72	10.21	6.29	4.71	3.42	6.02	6.36	3.0578	2.1333	1.8962	3.0578	2.53275
Mar.	9.17	9.17	7.50	8.89	8.68	5.31	5.31	3.45	6.88	6.24	2.3936	2.4573	1.6586	2.3936	2.225775
Apr.	5.56	10.78	7.22	10.83	8.60	4.19	5.60	6.08	5.36	6.31	1.9926	2.5309	1.6637	1.9926	2.04495
May	9.72	6.67	6.67	8.89	7.99	4.83	6.76	6.48	5.13	6.30	1.5874	1.6633	1.5726	1.5874	1.602675
Jun.	8.56	9.78	6.67	6.67	11.67	4.95	6.09	5.60	5.53	5.54	0.9266	1.4895	1.2879	0.9266	1.157650
Jul.	8.56	9.56	6.39	9.67	9.05	6.09	5.31	5.78	5.11	5.58	0.8507	1.4895	0.8884	0.8507	1.019825
Aug.	6.67	8.28	8.50	9.67	9.53	5.04	4.29	6.87	4.78	5.24	0.8679	0.9103	1.0827	0.8679	0.932200
Sep.	9.67	6.39	8.67	9.38	9.53	5.05	4.95	6.77	4.35	5.28	0.9208	1.1550	1.2658	0.9208	1.065600
Oct.	7.78	9.72	14.72	6.38	9.65	5.04	5.13	5.61	4.89	5.17	1.3264	1.7579	2.3828	1.3264	1.698375
Nov.	9.72	8.89	9.44	10.83	9.72	4.51	4.23	4.00	4.50	4.56	2.5956	2.0104	2.8651	2.5956	2.516675
Dec.	9.72	10.28	6.39	8.89	8.82	5.39	4.48	3.68	3.98	4.13	1.9752	2.5305	1.6046	1.9752	2.021375
Mean	9.54	9.98	9.87	9.47	**9.64**	5.08	5.82	5.02	5.53	**5.36**	1.9873	1.9179	1.8993	1.9873	1.741438

Table 2 Lists of Actual or Experimental Wind Power and Energy Evaluations from January 2020 to December 2023.

Period	**Experimental data of wind power and wind energy for MWS per 1 m^2 on a monthly basis**								
Months	**Wind Power (Wm^{-2})**					**Wind Energy ($KWm^{-2}h$)**			
	2020	**2021**	**2022**	**2023**		**2020**	**2021**	**2022**	**2023**
Jan.	156.1947	41.7336	29.0061	71.1442		3.7487	1.0016	0.69615	1.7075
Feb.	255.5118	64.6195	47.9561	161.3793		6.1323	1.5509	1.1509	3.8731
Mar.	97.4782	97.4782	42.5238	121.8650		2.3395	2.3395	1.0206	2.9248
Apr.	30.3390	115.4003	61.0719	133.5769		0.72813	2.7696	1.4657	3.2058
May	61.8241	51.0441	72.6317	103.0403		1.4838	2.2251	1.7432	2.4730
Jun.	42.5978	57.9057	71.8563	110.0621		1.0223	2.3897	1.7246	2.6415
Jul.	47.9119	52.1848	72.6806	87.0722		1.1499	1.2524	1.7443	2.0897
Aug.	47.8722	46.2754	80.0334	72.4121		1.1489	0.63061	1.9208	1.7379
Sep.	48.2818	66.5969	78.0520	56.5640		1.1588	1.1183	2.8732	1.3575
Oct.	54.7138	87.5857	123.2901	47.4861		1.3131	1.6221	2.9590	1.1397
Nov.	66.0400	68.5239	104.1244	78.3889		2.5850	1.1646	2.4990	2.8813
Dec.	168.2613	194.6780	124.9695	141.3751		2.6383	1.7923	1.59927	1.99300
Total	**1077.0266**	**944.0261**	**908.1959**	**1194.366**		**25.44873**	**19.85671**	**21.39672**	**28.0248**

Table 3 Lists of Experimental Power and Energy Evaluation for Peak Wind Speed from January 2020 to December 2023.

Period	**Actual data from maximum w per 1 m^2 for every single month**								
Months	**Wind Power (Wm^{-2})**					**Wind Energy ($KW^{m-2}h$)**			
	2020	**2021**	**2022**	**2023**		**2020**	**2021**	**2022**	**2023**
Jan.	893.7	227.9124	227.9	769.2043		7828.812	1996.513	1996.404	6738.23
Feb.	2042	316.2583	316.3	555.9708		17887.92	2770.423	2770.788	4870.304
Mar.	466.0	466.0041	255.2	424.9108		4082.16	4082.196	2235.552	3722.219
Apr.	303.7	656.8301	227.9	769.2043		908.412	5753.832	1996.404	6738.23
May	756.0	179.2593	179.3	424.9108		4870.56	1570.311	1570.668	3722.219
Jun.	103.7	284.6571	179.3	179.2593		908.412	2493.596	1570.668	1570.311
Jul.	103.7	103.7380	157.8	279.2593		908.412	908.7449	1382.328	1570.311
Aug.	179.3	88.9424	255.2	279.2593		1570.668	779.1354	2235.552	1570.311
Sep.	379.3	357.7725	379.3	257.7725		1570.668	2382.087	1570.668	1382.087
Oct.	484.7	855.9708	3930.5	457.7725		3493.972	4870.304	26911.18	1382.087
Nov.	556.0	724.9108	809.7	969.2043		7870.56	4722.219	4464.972	7738.23
Dec.	756.0	956.8301	557.8	624.9108		7870.56	5753.832	2382.328	4722.219
Total	**7024.1**	**5119.1**	**5576.2**	**5991.6**		**72771.12**	**56083.19**	**60087.51**	**53726.76**

Table 4 Lists of Estimation of Weibull Parameter and the Estimation of Wind Power and Energy for Peak Wind Speed for 2020.

Year 2020	**Estimated shape and scale factor while using 7 Numerical methods for Ikorodu 2020**						
	c	***k***	**MWS (m/s)**	**Standard divination σ (m/s)**	**Variation coefficient (%)**	**Power density (Wm^{-2})**	**Energy (Wm^{-2})**
MM	4.5988	2.0608	4.0738	2.0729	50.8836	75.8631	6.6456e+05
EM, STDM	4.5991	2.0725	4.0738	2.0624	50.6248	75.4533	6.6097e+05
MLHM	4.6053	2.0616	4.0795	2.0751	50.8663	76.1557	6.6712e+05
MMLHM	4.7555	2.3526	4.2142	1.9041	45.1831	74.8012	6.5526e+05
SMMLHM	4.1000	2.2322	3.6313	1.7198	47.3613	49.9757	4.3779e+05
GM, LSM	4.3642	1.7848	3.8827	2.2492	57.9291	76.5093	6.7022e+05
EPF	4.5946	1.9559	4.0738	2.1727	53.3336	79.9115	7.0003e+05
Measured	4.6053	2.0616	4.0800	1.9873	51.1173	80.3672	7.04016e+5

Table 5 Lists of Estimation of Weibull Parameter and the Estimation of Wind Power and Energy for Peak Wind Speed for 2021.

Year 2021	**Estimated shape and scale factor while using 7 Numerical methods for Ikorodu 2021**						
	c	***k***	**MWS (m/s)**	**Standard Deviation σ (m/s)**	**Variation Coefficient (%)**	**Power Density (Wm^{-2})**	**Energy (Wm^{-2})**
MM	4.3076	2.0990	3.8152	1.9095	50.0496	61.2387	5.3204e+05
EM, STDM	4.3077	2.1105	3.8152	1.9002	49.8045	60.9279	5.2934e+05
MLHM	4.3119	2.1006	3.8190	1.9101	50.0166	61.3785	5.3326e+05
MMLHM	4.3513	2.1937	3.8536	1.8538	48.1071	60.6325	5.2677e+05
SMMLHM	4.0403	2.1865	3.5781	1.7264	48.2480	48.6784	4.2292e+05
GM, LSM	3.7570	1.8225	3.3391	1.8981	56.8458	47.5057	4.1273e+05
EPF	4.3074	2.0834	3.8152	1.9224	50.3863	61.6694	5.3578e+05
Measured	4.3119	2.1006	3.8200	1.9179	50.2685	62.0054	5.3870e+05

Table 6 Lists of Estimation of Weibull Parameter and the Estimation of Wind Power and Energy for Peak Wind Speed for 2022.

Year 2022	**Estimated shape and scale factor while using 7 Numerical methods for Ikorodu 2022**						
	c	***k***	**MWS (m/s)**	**Standard Deviation σ (m/s)**	**Variation Coefficient (%)**	**Power Density (Wm^{-2})**	**Energy (Wm^{-2})**
MM	4.5376	2.2464	4.0190	1.8927	47.0934	67.3882	5.9032e+05
EM, STDM	4.5374	2.2570	4.0190	1.8847	46.8951	67.1206	5.8798e+05
MLHM	4.5231	2.2089	4.0058	1.9152	47.8094	67.6972	5.9303e+05
MMLHM	4.4696	2.0668	3.9592	2.0093	50.7497	69.4444	6.0833e+05
SMMLHM	4.2750	2.2924	3.7872	1.7514	46.2446	55.4362	4.8562e+05
GM, LSM	3.8086	1.6942	3.3990	2.0644	60.7359	54.6827	4.7902e+05
EPF	4.5375	2.2536	4.0190	1.8873	46.9588	67.2064	5.8873e+05
Measured	4.5231	2.2089	4.0200	1.8993	47.2570	67.3838	5.9028e+05

Table 7 Lists of Estimation of Weibull Parameter and the Estimation of Wind Power and Energy for Peak Wind Speed for 2023.

Year 2023	**Estimated shape and scale factor while using 7 Numerical methods for Ikorodu 2023**						
	c	***k***	**MWS (m/s)**	**Standard Deviation σ (m/s)**	**Variation Coefficient (%)**	**Power Density (Wm^{-2})**	**Energy (Wm^{-2})**
MM	5.0981	2.4321	4.5205	1.9827	43.8593	89.9802	7.8823e+05
EM, STDM	5.0977	2.4414	4.5205	1.9759	43.7096	89.7214	7.8596e+05
MLHM	5.0839	2.3990	4.5068	2.0010	44.3994	90.0969	7.8925e+05
MMLHM	5.0234	2.2321	4.4491	2.1073	47.3645	91.9197	8.0522e+05
SMMLHM	4.8565	2.4650	4.3075	1.8666	43.3344	77.0699	6.7513e+05
LSM, GM	4.4173	1.9389	3.9174	2.1057	53.7534	71.7013	6.2810e+05
EPF	5.0981	2.4315	4.5205	1.9831	43.8692	89.9973	7.8838e+05
Measured	5.0839	2.3990	4.5300	1.9873	43.9606	89.7332	7.8606e+05

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Table 8 Lists of Error Percentage for Checking more Accurate Numerical Methods for 2020.

2020		Goodness of fit test for Lagoon Coastal area of Ikorodu 2020									
Numerical methods		Comparative Analysis									
		RMSE	Ranking	X^2	Ranking	IA	Ranking	MAPE	Ranking	RRMSE	Ranking
1	MM	0.0074	3	0.9780	4	0.7893	3	0.0196	3	11.1391	3
2	EM,STDM	0.0075	4	1.0926	5	0.7912	5	0.0194	2	11.2563	5
3	MLM	0.0074	3	0.9610	3	0.7895	4	0.0196	3	11.1577	4
4	MMLM	0.0089	5	13.5805	6	0.8316	6	0.0158	1	13.3614	6
5	SMMLM	0.0223	6	222.8923	7	0.7795	2	0.0215	5	33.3957	7
6	LSM,GM	0.0043	1	0.3073	1	0.7415	1	0.0239	6	6.4394	1
7	EPFM	0.0066	2	0.4346	2	0.7705	2	0.0212	4	9.9210	2

Table 9 Lists of Error Percentage for Checking more Accurate Numerical Methods for 2021.

2021		Goodness of fit test for Lagoon Coastal area of Ikorodu 2021									
Numerical methods		Comparative Analysis									
		RMSE	Ranking	X^2	Ranking	IA	Ranking	MAPE	Ranking	RRMSE	Ranking
1	MM	0.0053	3	0.1393	2	0.7229	4	0.0317	3	5.2971	5
2	EM,STDM	0.0054	4	0.1402	3	0.7239	5	0.0316	2	5.4297	4
3	MLM	0.0053	3	0.1393	2	0.7224	3	0.0318	4	5.3135	3
4	MMLM	0.0063	5	0.1493	4	0.7254	6	0.0317	3	6.2557	6
5	SMMLM	0.0071	6	0.2126	6	0.7509	7	0.0295	1	7.1193	7
6	LSM,GM	3.2001e-04	1	0.1916	5	0.7027	1	0.0352	5	0.3200	1
7	EPFM	0.0051	2	0.1383	1	0.7214	2	0.0318	4	5.1099	2

Table 10 Lists of Error Percentage for Checking more Accurate Numerical Methods for r 2022.

2022		Goodness of fit test for Lagoon Coastal area of Ikorodu 2022									
Numerical methods		Comparative Analysis									
		RMSE	Ranking	X^2	Ranking	IA	Ranking	MAPE	Ranking	RRMSE	Ranking
1	MM	0.0046	2	1.9073	6	0.6761	5	0.0323	1	6.4148	3
2	EM,STDM	0.0045	1	2.1563	5	0.6764	6	0.0323	1	6.3530	1
3	MLM	0.0048	3	1.3660	3	0.6751	4	0.0324	2	6.6635	4
4	MMLM	0.0056	4	0.5520	1	0.6723	3	0.0325	3	7.8650	5
5	SMMLM	0.0304	6	22.2735	7	0.6501	2	0.0347	4	42.6080	7
6	LSM,GM	0.0117	5	0.5048	2	0.6119	1	0.0389	5	16.3687	6
7	EPFM	0.0046	2	2.0717	4	0.6764	6	0.0323	1	6.3728	2

Table 11 Lists of Error Percentage for Checking more Accurate Numerical Methods for 2023.

2023		Goodness of fit test for Lagoon Coastal area of Ikorodu 2023									
Numerical methods		Comparative Analysis									
		RMSE	Ranking	X^2	Ranking	IA	Ranking	MAPE	Ranking	RRMSE	Ranking
1	MM	0.0098	2	0.2858	2	0.5991	3	0.0468	5	9.7861	2
2	EM,STDM	0.0097	1	0.2867	4	0.5997	4	0.0468	5	9.7396	1
3	MLM	0.0099	3	0.2838	1	0.5987	2	0.0467	4	9.9406	4
4	MMLM	0.0110	4	0.2863	3	0.5948	1	0.0466	3	11.0351	5
5	SMMLM	0.0384	6	0.3746	5	0.6035	5	0.0462	2	38.4354	7
6	LSM,GM	0.0137	5	0.4159	6	0.6040	6	0.0460	1	13.6533	6
7	EPFM	0.0098	2	0.2858	2	0.5991	3	0.0468	5	9.7892	3