ISSN:1533-9211
SEYBOLD REPORT
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# Analysis of Wind Speed and Energy Potential Using Weibull and Rayleigh

**Elvy Sahnur Nasution**[1,*]
[1]Universitas Muhammadiyah Sumatera Utara, St. Mukhtar Basri No 217, Medan, Indonesia.

**Catra Indra Cahyadi**[2]
[2]Politeknik Penerbangan Medan, Indonesia.

**Sukarwoto**[2]
[2]Politeknik Penerbangan Medan, Indonesia.

**Suwarno**[3]
[3]Universitas Muhammadiyah Sumatera Utara, St. Denai No 217, Medan, Indonesia.

**Doni Pinayungan**[4]
[4]Institut Teknologi dan Sain Padang Lawas Utara, Indonesia.

## Abstract

Wind speed analysis in Medan is very important to determine future energy potential. Research that has been carried out has found that wind speeds in Medan range from 3.5-7.5m/s, but the energy potential has not been analyzed and evaluated. This research proposes an analysis of the shape factor (k) and scale (c) for wind speed with the Weibull and Rayleigh distribution models using the correlation coefficient ($R^2$), Chi-Square ($\chi^2$), and Root mean square error (RMSE). For this analysis, wind speed data was obtained from the Meteorology, Climatology, and Geophysics Agency for three years, from 2019 to 2021 in Medan. The probability density distribution function (Pdf) is shown in the shape (k) and scale (c) parameters obtained from the data analysis above. These *k* and *c* parameters are very important to observe about the potential for electrical energy produced in Medan. The research results show that the Weibull distribution is better than the Pdf-based Rayleigh distribution. Meanwhile, the results of statistical analysis show that the Weibull distribution is better than the Rayleigh distribution based on $R^2$. However, on the other hand, the Rayleigh distribution is better than the Weibull distribution based on Chi-Square and RMSE.

ISSN:1533-9211
SEYBOLD REPORT
www.seybold-report.com

ISSN: 1533 - 9211

CORRESPONDING AUTHOR:

**Elvy Sahnur Nasution**
elvysahnur@umsu.ac.id

KEYWORDS:

Wind speed, Weibull and Rayleigh distribution, wind energy potential, $R^2$, $\chi^2$, and RMSE

Received: 14 January 2024
Accepted: 06 February 2024
Published: 17 February 2024

TO CITE THIS ARTICLE:

Nasution, E. S., Cahyadi, C. I., Sukarwoto, & Suwarno, D., Pinayungan, D. (2024). Analysis of Wind Speed and Energy Potential Using Weibull and Rayleigh. *Seybold Report Journal*, *19*(2), 96-108. DOI: 10.5110/77. 1111

## INTRODUCTION

The wind is a renewable energy source that can be used as an alternative energy source. Energy supply-demand is increasing throughout the world resulting in the depletion of the global energy supply, so it is necessary to find alternative energy as a source of energy reserves. This energy limitation has the potential to produce energy that is not used is clean from air pollution and does not pollute the environment. Public awareness of environmental problems is increasing due to the energy crisis, climate change, and environmental problems (Crescenza Calculli, Angela Maria D'Uggento, Angela Labarile, Nunziata Ribecco., 2021). These last few years, the company has been considering the condition of the environment to use energy consumption ecologically clean and not pollute the surrounding environment (Ioannis Manisalidis, Elisavet Stavropoulou, Agathangelos Stavropoulos, Eugenia Bezirtzoglou., 2020), (Urban, J; Bahnik, D; Demczuk, R; Souto Maior, C; Vilasanti, 2019). Environmental problems can be overcome effectively by buying environmentally friendly products in daily consumption (Nguyen, T.T.T; Yang, Z; Nguyen, N; Johnson, L.W; Cao, 2019), (Sheng, G; Xie, F; Gong, S; Pan, 2019), (Beibei Yue, Guanghua Sheng, Shengxiang She, Jiaqi Xu., 2020). Wind speed probability distribution has been widely used for offshore wind farm planning and is used to estimate various amounts of power output and load (Cihangir Kan, Yilser Devrim, Serkan Erylmaz., 2020), (Davi Ribeiro Lins, Kevin Santos Guedes, Anselmo Ramalho Pitombeira-Neto, Paulo Alexandre Costa Rocha, Carla Freitas de Andrade., 2023).

Wind speed information be useful to researchers involved in the study of renewable energy and wind energy use can reduce the things that are caused by fossil fuels and carbon dioxide emissions. Statistical analysis can help to predict the renewable energy conversion from wind energy and several attempts to model it, to obtain energy estimates by the facts on the ground (Suwarno et al., 2023), (Zambak, Cahyadi, Helmi, Sofie, & Suwarno, 2023). In its application, the wind speed distribution is used to represent the distribution function (Suwarno et al., 2021). The statisticians are interested in using Weibull models in the modeling and analysis of wind energy, as it can be approached by the measurement data (Suwarno. Leong Jenn Hwai. Muhammad Fitra Zambak. & Indra Nisja. and Rohana., 2016). Mathematically, the two-parameter Weibull distribution function has been widely used compared to the three parameters (Wenxin Wang, Kexin Chen, Yang Bai, Yu Chen, Jianwen Wang., 2021).

Characteristics of wind are one of the most important parameters in the design and performance analysis system to determine the potential energy conversion. Many researchers have developed statistical models to model the frequency distribution of wind speed. To determine the probability density function of wind speed using the Rayleigh and Weibull Model (Suwarno, 2021). Geographically, Medan has daily and monthly wind speeds with varying duration and speed. The availability of wind speed data can help to analyze more accurately the distribution and also can help in constructing wind power sources (Zambak, Cahyadi, Helmi, Sofie, & Suwarno., 2023). Wind speed characteristics in Medan are assessed from the amount of potential wind energy generally, these characteristics use PDF and other functions. PDF has been studied and applied in all regions of the world, but selecting PDF is very important in analyzing wind energy because wind energy is formulated as an explicit function of several parameters of wind speed distribution.

Pdf is suitable for evaluating the wind speed that will be used to estimate the power output. Rayleigh and Weibull distribution is most used in the analysis of wind speeds, and the most common way to study wind energy estimation (Zuzana Sedliackova, Ivana Pobocikova, Maria Michalkova, 2020). So far, the Weibull distribution is the most widely used to analyze the characterization of the wind speed and the most common among models (Sadiah M A Aljeddani and M A Mohammed, 2023). In previous research, the analysis of the characteristics of wind speed using Weibull and Rayleigh distribution, but not many studies that relate to the evaluation of the feasibility of using the model data used correlation coefficient, Chi-square, and RMSE. Therefore, this study proposes PDF analysis with the Weibull and Rayleigh distribution and evaluates it with statistical analysis models, namely $R^2$, $\chi^2$, and RMSE.

## RESEARCH METHOD

This research analyzes using two models of Weibull and Rayleigh. Then analyzed using a statistical probability density function (Pdf), then the results were compared to two models to find the most appropriate model to use in analyzing the characteristics of wind speed and potential electrical energy. The research step is to analyze the wind speed with PDF using the Weibull and Rayleigh distribution, and then evaluate it with three models ($R^2$, $\chi^2$, and RMSE) to see the suitability of the data studied and the results compared to select the best model proposed and to be applied, then calculate the energy potential electricity generated from the conditions of wind speed is being investigated (Hicham Bidaoui. Ikram El Abbasi. Abdelmajid El Bouardi. Abdelmoumen Darcherif. & Hicham Bidaoui, Ikram El Abbassi, Abdelmajid El Bouardi, Abdelmoumen Darcherif., 2019), (Huanyu Shi, Zhibao Dong, Nan Xiao, Qinni Huang., 2021).

This research was carried out according to the proposal using two models, namely the Weibull and Rayleigh distribution models. The analysis is performed using probability density function statistics, and then the results of the two models are compared to find the most suitable model to be used to analyze wind speed and energy potential (Zhiming Wang and Weimin Liu, 2021).

### A. Wind speed distribution

Pdf function and other functions form an important aspect of analyzing wind speed. The use of a probability density function for a variety of applications, including identification and analysis of the parameters of the distribution function of wind speed data (Geletaw B and Gebregziabher K, 2022). The Rayleigh and Weibull distributions are used to adjust the Pdf of the measured wind speed at the site over a specified period and the Weibull Pdf distribution is expressed as (Agbassou Guenoukpati, Adekunle Akim Salami, Mawugno Koffi Kadjo, Kossi Napo., 2020), (Yusuf Alper KAPLAN and Gulizar Gizem UNALDI, 2020):

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{1}$$

here, *f(v)* is the incremental probability, and *c* and *k* represent scale and shape parameters, respectively.

The following equation to estimate the shape (*k*) and the scale (*c*) factor is expressed by (Prem Kumar Chaurasiya, Siraj Ahme, Vilas Warudkar., 2018).

$$k = \left(\frac{\sigma}{v}\right)^{-1.086} \text{and} \quad c = \left(\frac{\bar{v}}{\Gamma\left(1+\frac{1}{k}\right)}\right) \tag{2}$$

The distribution for the Cdf is given by (Alamgir Khalil, Abdullah Ali H Ahmadini, Muhammad Ali, Wali Khan Mashwani, Shokrya S Alshqaq, Zabidin Salleh., 2021), (Kevin Maritato and Stan Uryasev, 2023).

$$F(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{3}$$

The shape factor equal to 2, substituted for equation (1), will give the Pdf of the Rayleigh and is represented by (Suwarno et al., 2023).

$$f(v) = \left(\frac{2v}{c^2}\right)\exp\left[\left(-\frac{v}{c}\right)^{k}\right] \tag{4}$$

The average value ($v_m$) and standard deviation ($\sigma$) can be calculated, respectively (N Balpetek and E Kavak Akpinar, 2019).

$$v_m = c\Gamma\left(1+\frac{1}{k}\right) \tag{5}$$

$$\sigma = c\left[\Gamma\left(1+\frac{2}{k}\right)-\Gamma^2\left(1+\frac{1}{k}\right)\right]^{1/2} \tag{6}$$

here, $\Gamma$ is the gamma function.

The Rayleigh scale (Cr) parameter is obtained from equation (7) which is represented by

$$C_r = \sqrt{\frac{1}{2N}\sum_{i=1}^{N} v_i^2} \tag{7}$$

here, $v_i$ is the $i^{th}$ wind speed, the average Rayleigh value is determined by the equation (8), given by;

$$\bar{v}_r = C_r\sqrt{\frac{\pi}{2}} \tag{8}$$

## B. Wind Power density function

The magnitude of the wind speed is directly proportional to three times the wind speed ($v$) through a blade sweep area *(A)* so its magnitude is as follows; (Shigang Qin and Deshun Liu, 2023).

$$P(v) = \frac{1}{2}\rho A v^3 \tag{9}$$

here, $\rho$ is the average air density.

The power for the monthly or annual wind speed per unit area at a location can be expressed as:

$$P_w = \frac{1}{2}\rho v^3 \Gamma\left(1+\frac{1}{k}\right) \tag{10}$$

here, $c$ is expressed as follows;

$$c = \frac{v_m}{\Gamma\left(1+\frac{1}{k}\right)} \tag{11}$$

The parameters will affect the shape and scale of the average wind speed $m_v$. Model Rayleigh obtained by adjusting the shape parameter ($k$) is equal to 2 in the equation (8), then the parameters Rayleigh scale model can be expressed by (Pilar A Rivera, Inmaculada Barranco-Chamorro, Diego I Gallardo, Hector W Gomez., 2020).

$$P_R = \frac{3}{\pi}\rho v_m^3 \tag{12}$$

## C. Modeling of wind data

The wind speed modeling will depend on the height of the installed instruments. Based on empirical, the wind speed model can be approached empirically in the following equation (13);

$$\bar{v} = \frac{1}{n}\sum_{i=1}^{n} v_i$$

(13)

here, $\bar{v}$ is the wind speed average;

$v_i$ is the measured wind speed;

$n$ is the number of measurement data.

## D. Analysis of the distribution function

The analysis model uses Weibull and Rayleigh and is evaluated using the correlation coefficient ($R^2$), Chi-Square, and root mean square error (RMSE) which is stated by the following equation;

$$R^2 = \frac{\sum_{i=1}^{N}(y_i - z_i)^2 - \sum_{i=1}^{N}(x_i - y_i)^2}{\sum_{i=1}^{N}(y_i - z_i)^2} \tag{14}$$

$$\chi^2 = \frac{\sum_{i=1}^{n}(y_i - x_i)^2}{N - n} \tag{15}$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(y_i - x_i)^2\right]^{1/2} \tag{16}$$

here, $y_i$ is the $i^{th}$ measured data, $z_i$ is the average value, $x_i$ is the $i^{th}$ predictive data with the Weibull or Rayleigh, and $N$ and $n$ are the number of observations, and the number of constants, respectively (Zambak, Cahyadi, Helmi, Sofie, & Suwarno, 2023).

# RESULTS AND DISCUSSION

## 1. Shape and Scale Parameters

Variable wind speed is usually described using the density function of two parameters, ie the shape (k) and scale (c) factor. The shape and scale parameters for the three years are shown in Table 1.

**Table 1. Shape and scale parameters for three years**

| Years | 2017 | | 2018 | | 2019 | |
|---|---|---|---|---|---|---|
| Parameters | k | c | k | c | k | c |
| January | 4.90 | 4.85 | 4.90 | 4.85 | 4.89 | 5.02 |
| February | 4.67 | 5.34 | 4.74 | 5.32 | 4.05 | 5.39 |
| March | 4.93 | 5.55 | 4.96 | 5.57 | 3.83 | 5.05 |
| April | 5.73 | 5.05 | 5.72 | 5.03 | 5.30 | 5.23 |
| May | 5.82 | 5.72 | 5.86 | 5.76 | 4.81 | 5.30 |
| June | 4.78 | 5.83 | 4.75 | 5.86 | 5.12 | 5.87 |
| July | 4.37 | 5.85 | 4.34 | 5.87 | 6.95 | 5.10 |
| August | 5.06 | 5.85 | 5.19 | 5.46 | 5.25 | 5.74 |
| September | 4.31 | 5.54 | 4.16 | 5.35 | 6.71 | 5.70 |
| October | 4.63 | 5.26 | 4.83 | 5.10 | 5.73 | 5.83 |
| November | 4.57 | 5.45 | 4.54 | 5.49 | 5.69 | 5.60 |
| December | 4.56 | 4.59 | 4.46 | 4.61 | 6.05 | 6.11 |
| Years | 4.56 | 5.37 | 4.92 | 5.35 | 5.27 | 5.50 |

The results were calculated approach to these two parameters, each year is shown in Table 1, wherein the shape parameter ranges from **4.56** to **5.27**, the scale parameter ranges from **5.35** to **5.50**, and the average shape parameter is **4.91**, the scale parameter around **5.41**. A comparison PDF each year for the Weibull distribution is shown in Figure 1.

A comparison PDF each year for the Weibull distribution (WD) is shown in Figure 1. The amount of Pdf of the Weibull distribution is influenced by two parameters related to the wind speed, the wind speed of about 5.34 m/s can be seen as the highest Pdf occurred in 2021, followed by 2020 and 2019.

Comparison Pdf each year for Rayleigh distribution is affected by the scale parameter related to the wind speed, the wind speed of about 3.73 m/s is obtained Pdf highest in 2019, followed by 2020 and 2021, as shown in Figure 2.

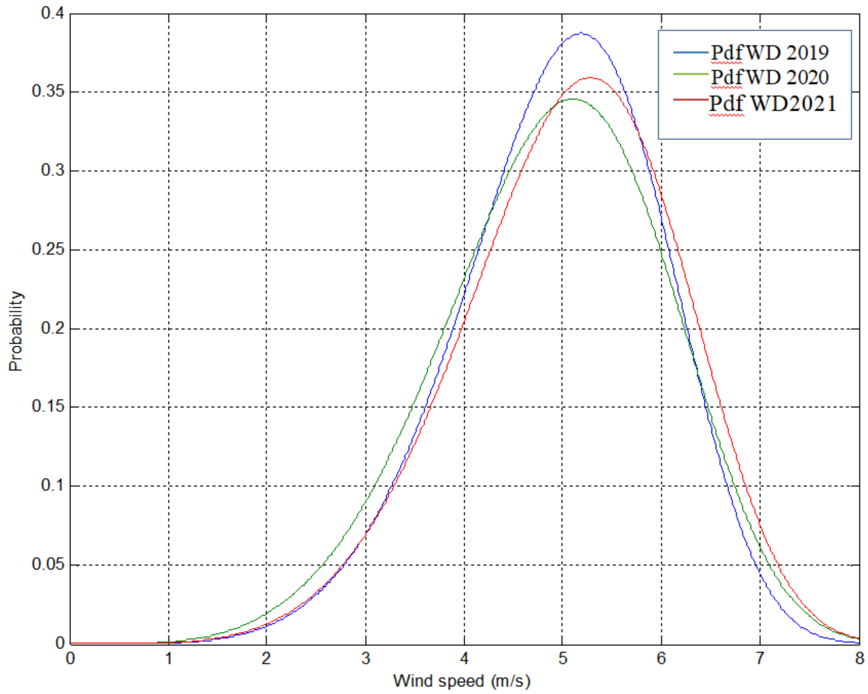


Figure 1. Weibull Pdf three years

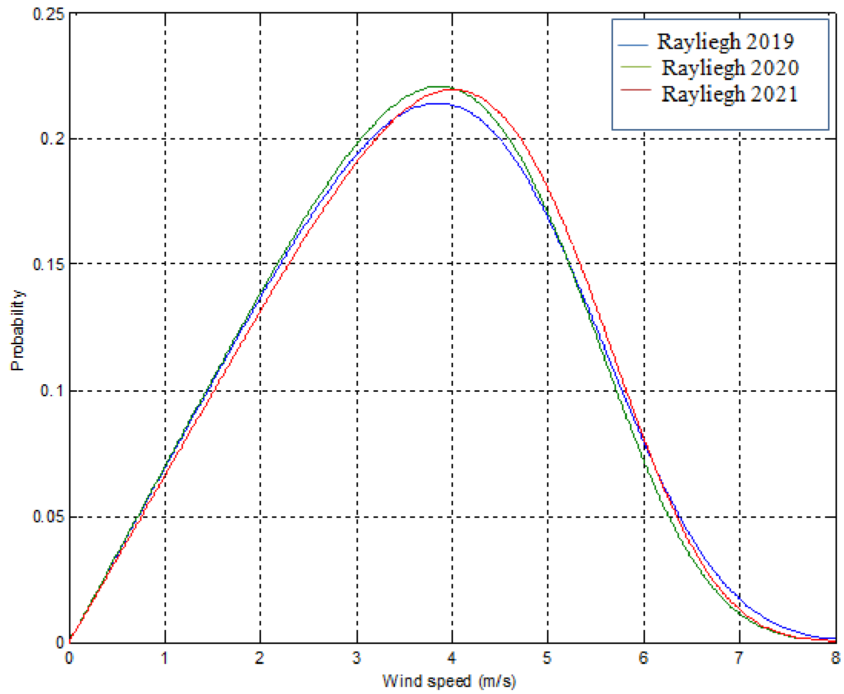


Figure 2. Rayleigh Pdf three years

The comparison between the Weibull and Rayleigh models for each year is shown in Figure 3, Figure 4, and Figure 5.

Figure 3 shows a comparison between the Weibull and Rayleigh models for 2019, the difference between the two models for 2019 is indicated by the red line in the amount of about 1.325%.

Figure 4 shows a comparison between the Weibull and Rayleigh models for 2020, the difference between the two models is indicated by the red line in the amount of about 0.736%.

Figure 5 shows the comparison between the Weibull and Rayleigh models for 2021, the difference between the two models is shown by the red line which is about 0.328%.

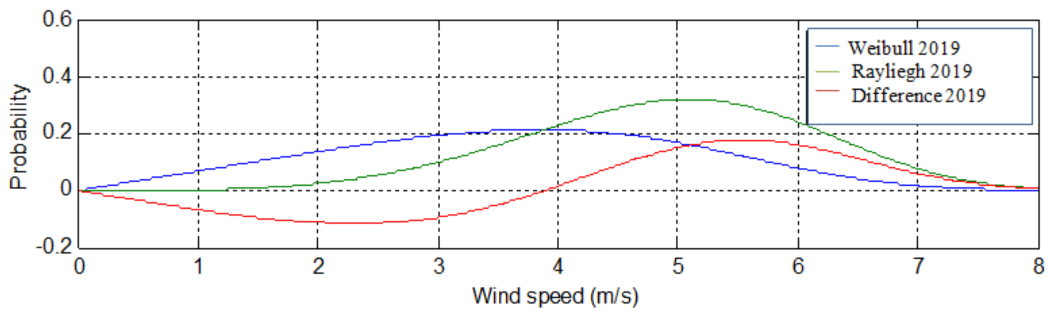


Figure 3. Comparison of Weibull and Rayleigh in 2019

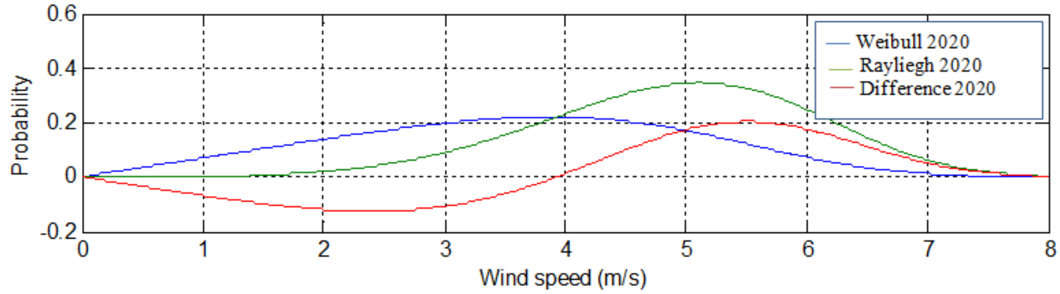


Figure 4. Comparison of Weibull and Rayleigh in 2020

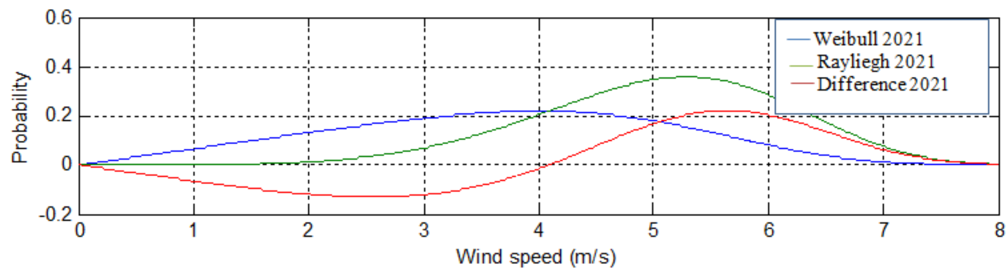


Figure 5. Comparison of Weibull and Rayleigh in 2021

The difference in average for the third year was about 0.796%, and the difference in average for three years was quite good, this shows that the two models are proposed to be well received by a probability density function and statistical tests.

## 2. Distribution Function Analysis

They analyze the potential of wind energy using the correlation coefficient ($R^2$), Chi-Square ($\chi^2$), and RMSE are shown in Table 2.

**Table 2. The statistic analysis parameters for monthly wind speed distribution in Medan**

| | | January | February | March | April | May | June |
|---|---|---|---|---|---|---|---|
| $R^2$ | Weibull | 0.965 | 0.970 | 0.967 | 0.946 | **0.934** | **0.978** |
| | Rayleigh | 0.311 | 0.663 | 0.630 | 0.309 | 0.641 | **0.788** |
| $\chi^2$ | Weibull | 0.041 | 0.041 | 0.045 | 0.048 | 0.072 | 0.046 |
| | Rayleigh | 0.807 | 0.459 | 0.501 | 0.611 | 0.391 | 0.438 |
| RMSE | Weibull | 0.198 | 0.190 | 0.208 | 0.211 | 0.264 | 0.208 |
| | Rayleigh | 0.884 | 0.665 | 0.696 | 0.769 | 0.615 | 0.651 |
| | | July | August | September | October | November | December |
| $R^2$ | Weibull | 0.971 | 0.964 | 0.974 | 0.970 | 0.970 | 0.974 |
| | Rayleigh | 0.726 | 0.610 | 0.609 | 0.502 | 0.646 | **0.195** |
| $\chi^2$ | Weibull | 0.049 | 0.044 | 0.040 | 0.039 | 0.043 | 0.031 |
| | Rayleigh | 0.463 | 0.473 | 0.599 | 0.640 | 0.507 | 0.957 |
| RMSE | Weibull | 0.218 | 0.207 | 0.193 | 0.193 | 0.120 | 0.173 |
| | Rayleigh | 0.669 | 0.677 | 0.761 | 0.787 | 0.700 | 0.962 |

Table 2 shows the results of the evaluation using the correlation coefficient (**$R^2$**), Chi-Square (**$\chi^2$**) and, root mean square error (**RMSE**). The correlation coefficient (**$R^2$**) for the **Weibull** distribution ranges from **0.934** to **0.978**, while for the **Rayleigh** distribution, it ranges from **0.195** and **0.788**. Weibull models maintain the correlation coefficient (**$R^2$**) is best for all distribution functions. However, for statistical analysis based on

**Chi-square** ($\chi^2$) and **RMSE**, the Weibull distribution has the lowest value compared to the Rayleigh distribution.

## 3. Energy Density and Power Density Potential

The power density of the monthly wind speed is shown in Figure 6. Wind speed for three years (2019-2021) has a minimum, maximum, and average speed between 2.33 to 2.71 m/s, 7.35 to 7.71 m/s, and 4.91 to 5.06 m/s, respectively. Meanwhile, the annual power density is shown in Table 3, with the power density between **74.77, 72.21** and **79.46** W/m$^2$. This power density is only capable of producing a maximum power per square meter of 79.4618 Watts.

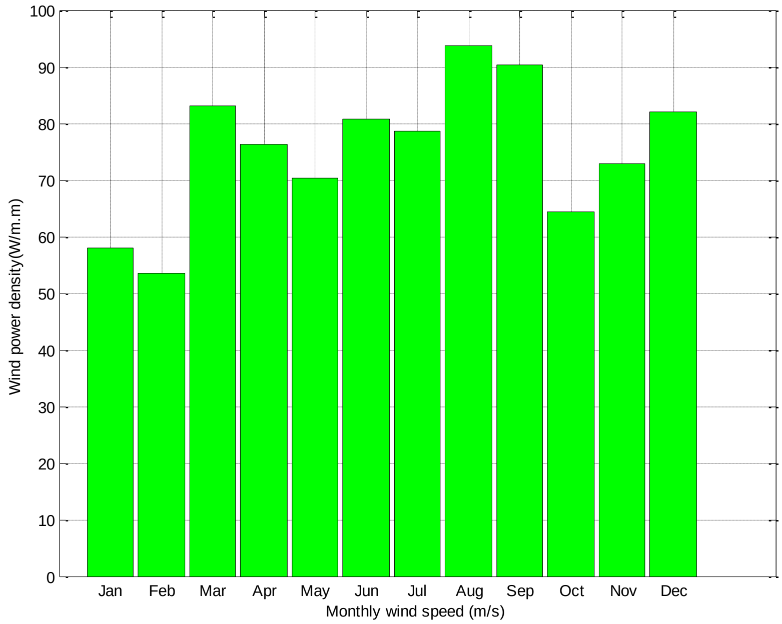


Figure 6. Power density (W/m$^2$)

The potential wind speed converted to energy and power density in Medan based on actual wind speed data is shown in Table 3.

Table 3. Wind energy in Medan

| tential | Years | | |
|---|---|---|---|
| | 2019 | 2020 | 2021 |
| wer density (W/m$^2$) | 74.77 | 72.21 | 79.46 |

# CONCLUSION

Wind speed characteristics in Medan were statistically analyzed and wind speed data collected for three years (2019-2021) were used for analysis. The results of the analysis and evaluation show that; Pdf comparison between Weibull and Reyleigh models shows that the Weibull model is better than Rayleigh. For statistical analysis using the correlation coefficient ($R^2$), where the Weibull distribution is the best against the Rayleigh distribution. However, if you use Chi-Square and RMSE, the Rayleigh distribution model is the best compared to the Weibull distribution. Meanwhile, the power density is only able to produce a small amount of power for street lighting, amounting to 79.51 watts/$m^2$.

## ACKNOWLEDGEMENTS

Thank you to researchers and all parties who have supported and provided motivation in completing this journal.

## COMPETING INTERESTS

The authors have no compting interest to declare.

## Author's Affiliation

**Elvy Sahnur Nasution[1,*]**
[1]Universitas Muhammadiyah Sumatera Utara, St. Mukhtar Basri No 217, Medan, Indonesia.

[*,1]Corresponding Author E-mail: elvysahnur@umsu.ac.id

**Catra Indra Cahyadi[2]**
[2]Politeknik Penerbangan Medan, Indonesia.

E-mail: catraindracahyadi@gmail.com

**Sukarwoto[2]**
[2]Politeknik Penerbangan Medan, Indonesia.
E-mail: wotocahbara@gmail.com

**Suwarno[3]**
[3]Universitas Muhammadiyah Sumatera Utara, St. Denai No 217, Medan, Indonesia.
E-mail: suwarno@umsu.ac.id

**Doni Pinayungan[4]**
[4]Institut Teknologi dan Sain Padang Lawas Utara, Indonesia.
E-mail: donipinayungan@gmail.com

**HOW TO CITE THIS ARTICLE:**

Nasution, E. S., Cahyadi, C. I., Sukarwoto, & Suwarno, D., Pinayungan, D. (2024). Analysis of Wind Speed and Energy Potential Using Weibull and Rayleigh. *Seybold Report Journal, 19*(2), 96-108. DOI: 10.5110/77. 1111

## REFERENCES

Agbassou Guenoukpati, Adekunle Akim Salami, Mawugno Koffi Kadjo, Kossi Napo. (2020). Estimating Weibull Parameters for Wind Energy Applications Using Seven Numerical Methods: Case studies of Three Coastal Sites in West Africa. *Int. Journal of Renewable Energy Development (IJRED)*, *9*(2), 217–226. http://ejournal.undip.ac.id/index.php/ijred

Alamgir Khalil, Abdullah Ali H Ahmadini, Muhammad Ali, Wali Khan Mashwani, Shokrya S Alshqaq, Zabidin Salleh. (2021). A Novel Method for Developing Efficient Probability Distributions with Applications to Engineering and Life Science Data. *Ournal of Mathematics*, *1–13*. https://doi.org/10.1155/2021/4479270

Beibei Yue, Guanghua Sheng, Shengxiang She, Jiaqi Xu. (2020). Impact of Consumer Environmental Responsibility on Green Consumption Behavior in China: The Role of Environmental Concern and Price Sensitivity. *Sustainability*, *15*(5), 1–16. https://doi.org/10.3390/su12052074

Cihangir Kan, Yilser Devrim, Serkan Erylmaz. (2020). On the theoretical distribution of the wind farm power when there is a correlation between wind speed and wind turbine availability. *Reliability Engineering & System Safety*, *203*.

Crescenza Calculli, Angela Maria D'Uggento, Angela Labarile, Nunziata Ribecco. (2021). Evaluating people's awareness about climate changes and environmental issues: A case study. *Journal of Cleaner Production*, *324*. https://doi.org/10.1016/j.jclepro.2021.129244

Davi Ribeiro Lins, Kevin Santos Guedes, Anselmo Ramalho Pitombeira-Neto, Paulo Alexandre Costa Rocha, Carla Freitas de Andrade. (2023). Comparison of the performance of different wind speed distribution models applied to onshore and offshore wind speed data in the Northeast Brazil. *Energy*, *278*(Part A).

Geletaw B and Gebregziabher K. (2022). Statistical Analysis of Wind Speed for Energy Potential estimation in Bahir Dar, Ethiopia using Weibull. *Lat. Am. J. Phys. Educ.*, *16*(4), 1–8.

Hicham Bidaoui. Ikram El Abbasi. Abdelmajid El Bouardi. Abdelmoumen Darcherif., & Hicham Bidaoui, Ikram El Abbassi, Abdelmajid El Bouardi, Abdelmoumen Darcherif. (2019). *Wind Speed Data Analysis Using Weibull and Rayleigh Distribution Functions, Case Study: Five Cities Northern Morocco*. *32*, 786–793.

Huanyu Shi, Zhibao Dong, Nan Xiao, Qinni Huang. (2021). Wind Speed Distributions Used in Wind Energy Assessment: A Review. *Frontiers in Energy Research*, 1–14.

Ioannis Manisalidis, Elisavet Stavropoulou, Agathangelos Stavropoulos, Eugenia Bezirtzoglou. (2020). Environmental and Health Impacts of Air Pollution: A Review. *Frontiers*, *8*, 1–13. https://doi.org/10.3389/fpubh.2020.00014

Kevin Maritato and Stan Uryasev. (2023). Derivative of Reduced Cumulative Distribution Function and Applications. *J. Risk Financial Manag*, *16*(10), 1–24. https://doi.org/10.3390/jrfm16100450

N Balpetek and E Kavak Akpinar. (2019). STATISTICAL ANALYSIS OF WIND SPEED DISTRIBUTION WITH SINOPTURKEY APPLICATION. *Journal of Thermal Engineering*, *5*(4), 277–292.

Nguyen, T.T.T; Yang, Z; Nguyen, N; Johnson, L.W; Cao, T. . (2019). Greenwash and green purchase intention: The madiating role of green skepticism. *Sustainability*, *11*, 2653.

Pilar A Rivera, Inmaculada Barranco-Chamorro, Diego I Gallardo, Hector W Gomez. (2020). Scale Mixture of Rayleigh Distribution. *Mathenatics*, *8*(10), 1–22. https://doi.org/10.3390/math8101842

Prem Kumar Chaurasiya, Siraj Ahme, Vilas Warudkar. (2018). Study of different parameters estimation methods of Weibull distribution to determine wind power density using ground based Doppler SODAR instrument. *Alexandria Engineering Journal*, *57*(4), 2299–2311. https://doi.org/10.1016/j.aej.2017.08.008

Sadiah M A Aljeddani and M A Mohammed. (2023). A novel approach to Weibull distribution for the assessment of wind energy speed. *Alexandria Engineering Journal*, *78*, 56–64. https://doi.org/10.1016/j.aej.2023.07.027

Sheng, G; Xie, F; Gong, S; Pan, H. (2019). The role of cultural values in green purchasing intention: Empirical evidence from Chinese consumers. *Int. J. Comsum. Stud.*, *43*, 315–326.

Shigang Qin and Deshun Liu. (2023). Distribution Characteristics of Wind Speed Relative Volatility and Its Influence on Output Power. *Marine Science and Engineering*, *11*, 1–17.

Suwarno. Leong Jenn Hwai. Muhammad Fitra Zambak., & Indra Nisja. and Rohana. (2016). Assessment of Wind Energy Potential using Weibull Distribution Function as Wind Power Plant in Medan, North Sumatra. *International Journal of Simulation--Systems, Science & Technology*, *17*(41).

Suwarno, Cahyadi, C. I., Sukarwoto, Dewi, A. A., & Pinayungan, D. (2023). Comparative Analysis of Wind Speed and Energy Potential Assessment of Two Distribution Models in Medan, Indonesia. *International Review of Electrical Engineering*, *18*(4), 275–282. https://doi.org/10.15866/iree.v18i4.22725

Suwarno, D. (2021). Wind speed modeling based on measurement data to predict future wind speed with modified Rayleigh model. *International Journal of Power Electronics and Drive System (IJPEDS)*.

Suwarno, Yusuf, I., Irwanto, M., & Hiendro, A. (2021). Analysis of wind speed characteristics using different distribution models in Medan City, Indonesia. *International Journal of Power Electronics and Drive Systems*, *12*(2), 1102–1113. https://doi.org/10.11591/ijpeds.v12.i2.pp1102-1113

Urban, J; Bahnik, D; Demczuk, R; Souto Maior, C; Vilasanti, V. (2019). Green comsumption does not make people cheat: Three attempts to replicate moral licensing effect due to pro-enviromental behavior. *J. Environ. Psychol.*, *63*, 139–147.

Wenxin Wang, Kexin Chen, Yang Bai, Yu Chen, Jianwen Wang. (2021). New estimation method of wind power density with three-parameter Weibull distribution: A case on Central Inner Mongolia suburbs. *Wind Energy*, *25*(2), 368–386.

Yusuf Alper KAPLAN and Gulizar Gizem UNALDI. (2020). A COMPARISON OF WEIBULL AND RAYLEIGH DISTRIBUTION FUNCTIONS WITH MOMENT METHOD: A CASE STUDY OF OSMANİYE REGION IN TURKEY. *Eurasian Journal of Science Engineering and Technology*, *1*(1), 50–60.

Zambak, M. F., Cahyadi, C. I., Helmi, J., Sofie, T. M., & Suwarno. (2023). Evaluation and Analysis of Wind Speed with the Weibull and Rayleigh Distribution Models for Energy Potential Using Three Models. *International Journal of Energy Economics and Policy*, *13*(2), 427–432. https://doi.org/10.32479/ijeep.12775

Zambak, M. F., Cahyadi, C. I., Helmi, J., Sofie, T. M., & Suwarno. (2023). Evaluation and Analysis of Wind Speed with the Weibull and Rayleigh Distribution Models for Energy Potential Using Three Models. *International Journal of Energy Economics and Policy*, *13*(2), 427–432. https://doi.org/10.32479/ijeep.12775

Zhiming Wang and Weimin Liu. (2021). Wind energy potential assessment based on wind speed, its direction and power data. *Scitific Report*, *9*(2). https://doi.org/10.1038/s41598-021-96376-7

Zuzana Sedliackova, Ivana Pobocikova, Maria Michalkova, D. J. (2020). Wind speed modeling using Weibull distribution: A case of Liptovský Mikuláš, Slovakia. *MATEC Web of Conferences 357*, 1–10. https://doi.org/10.1051/matecconf/202235708005