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# An Investigation on Wind Energy Potential in Nalut, Libya, using Weibull Distribution

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## Abstract

The objective of the present paper is to analyze the wind speed characteristics of mountain area (Nalut) in Libya. In the present paper, monthly wind speed is used, taken from the meteorological service during a 30-year period (1981-2010) and measured at 10m height. Weibull probability density function is used to analyze the wind speed characteristics and wind potential of the selected area. The results indicated that the mean monthly wind speeds in the studied area are within the range of 3.66-4.84m/s. Moreover, the results showed that the annual wind speed and wind power density are 4.35m/s and 50.90 W/m2, respectively. In this study, three wind turbine with various power rated (Bonus 300kW/33, Bonus 1MW/54 and Vestas 2MW/80) is used. Because of this study; the annual energy generated and capacity factor were ranged from 28.33-199.74kWh and 25.87-31.02%. It is found that the highest capacity factor and maximum annual generated energy were obtained from Bonus 1MW/54 and Vestas 2MW/80, respectively. Furthermore, energy cost per kWh (EC) of the selected is determined. It was revealed that the EC is obtained in the range of 0.850-1.867$/kWh for Bonus 300kW/33, 0.723-1.484$/kWh for Bonus 1MW/54 and 0.787-1.866$/kWh for Vestas 2MW/80, respectively. It concluded that Bonus model with a power rated of 1000kW could be strongly recommended for installation in the studied area.

**Keywords:** Electricity-generated cost per kWh; Libya; mountain area; Nalut; Weibull distribution; wind speed

## 1. INTRODUCTION

The global energy demand is rapidly increased because the growth of the population, consumption of fossil fuel [1, 2]. Therefore, the increases of populations and energy demand have increased in recent years the significance of renewable energy as alternative source especially wind energy for electricity generating in Libya to reduce greenhouse gas emissions (GHG).

Wind energy is recognized as significant source for reducing and consumption of fossil fuel [3, 4]. Additionally, wind energy is clean, environmental friendly and inexhaustible energy source [5-7]. An alternative source such as wind is needed to reduce the GHG emissions [7]. Wind energy is the world's fastest-growing energy source and it can power industry, businesses, and homes with clean, renewable electricity for many years to come [7-8]. Wind turbine is used to convert the wind speed into electricity [10]. It is considerable power source for meeting electricity demand in many countries [11].

Several researchers have studied wind and solar potential of various locations in the world. For an instance, Alayat et al. [12] studied techno-economic assessment of the wind power potential for eight locations, namely, Lefkoşa, Ercan, Girne, Güzelyurt, Gazimağusa, Dipkarpaz, Yeni Boğaziçi, and Salamis, distributed over the Northern part of Cyprus. The results showed that small-scale wind turbine use could be suitable for generating electricity in the studied locations. Kassem et al. [2] evaluated the economic feasibility of 12MW grid-connected wind farms and PV plants for producing electricity at Girne and Lefkoşa in Northern Cyprus. The authors concluded that PV plants are the most economical option compared to wind farms for generating electricity in the selected studied. Kassem et al. [13] analyzed the wind power potential at Salamis region in Northern Cyprus. They found that high capacity wind turbine (MW) could not be suitable for electricity production in the region based on the value of wind power density. Solyali et al. [14] studied wind power potential for Selvili-Tepe location in Northern Cyprus. The authors found that wind energy sources in this site are classified to be marginal (wind power class is 2). Azad et al. [15] investigated the wind energy assessment at different hub heights in desired locations using Weibull distribution function. The results showed that wind power sources in the site are categorized to be poor. Albani and Ibrahim [16] analyzed the wind energy potential at three coastal locations in Malaysia. They concluded that production of wind energy is feasible and practical only at certain locations in Malaysia. Soulouknga et al. [17] evaluate the wind potential at Faya-Largeau in Chad. They found that the wind power density is 343.31 W/m$^2$.

To the best of author's knowledge, this is the first study to carry out such an analysis the wind speed of Nalut, Libya. This work is divided into two objectives. First objective, the wind speed characteristics, and wind potential are analyzed at mountain area (Nalut) in Libya for a period of 30 years (1981-2010). The data are collected from the meteorological service of Libya. The second objective of this current work is to estimate the electricity generated cost of three different wind turbine models using present value of costs (PVC) method. To achieve these objectives, Weibull distribution function with a two parameters and power law method are used to evaluate the wind potential at the selected region.

## 2. DATA MEASUREMENT

In this work, monthly wind speed data for 30-year period (1981-2010) are used. The average monthly wind speed data is calculated using a simple statistical method. The data is measured at a height of 10m using a cup anemometer. The location and area specific information are shown in Figure 1 and Table 1, respectively.

## 3. METHODOLOGY

The statistical functions such as Weibull and Rayleigh distribution functions are widley used for studied the wind speed charaestictics of specific region [18]. The propbabilty function of Wibull distribution with two parameters proved stistically and experimentally and gavea good agreement with actual wind speed data [18-21]. In the presnt study, probability and the cumulative density function of Weibull distributionwith two parameters are used to study the variation characteristics of the wind speed. The probability density ($f(v)$) and cumulative distribution ($F(v)$) functions for Weibull distribution are expressed in Eq. (1) and (2) [21-25]:

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

**Figure 1.** Presentation of the map of L[illegible] represented the selected area).

**Table 1.** Nalut, Libya information

| Region location | |
|---|---|
| Latitude (°N) | 31.874 |
| Longitude (°E) | 10.979 |
| Elevation (m) | 568 |

$$F(v)1-exp\left[-\left(\frac{v}{c}\right)^k\right] \tag{2}$$

where $c$ is the scale parameter in m/s and $k$ is the shape factor of distribution.

In this study, mean wind speed data is used, therefore, the Energy pattern factor ($\mathrm{E_{pf}}$) method was used to determine the Weibull distribution parameters. it can be expressed as following equations [22, 23].

$$E_{pf}=\frac{\overline{V^3}}{\bar{V}^3}=\frac{\left(\frac{1}{n}\sum_{i=1}^{n}v_i^3\right)}{\left(\frac{1}{n}\sum_{i=1}^{n}\bar{v}_i\right)^2} \tag{3}$$

Furthermore, Eq. (4) is used to estimate the shape factor after calculating the $E_{pf}$.

$$k=\frac{1+3.69}{\left(E_{pf}\right)^2} \tag{4}$$

The averaged wind speed ( $\bar{V}$ ) and standard deviation of the wind speed ($\sigma$) are calcuated using Eqs. (5) and (7), respectively [24].

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

$$c=\frac{\bar{V}}{\Gamma\left(1+\frac{1}{k}\right)} \tag{6}$$

$$\sigma=c\left[\Gamma\left(1+\frac{2}{k}\right)-\Gamma^2\left(1+\frac{1}{k}\right)\right]^{1/2} \tag{7}$$

### 3.1 Wind power and energy density

The theoretically available kinetic energy that wind possesses at a certain location can be expressed as the mean wind power density (WPD). In other words, it is the maximum available wind power at each unit area. The mathematical expression for wind power density is given with the following relation [25]:

$$\frac{\bar{P}}{A}=\frac{1}{2}\rho\bar{v}^3 \tag{8}$$

where $\bar{P}$ is the available power for wind per unit area in W/m$^2$ and $\rho$ is the density of air in kg/m$^3$.

Periodic wind power density per unit area (Monthly or annually) is given with the following expression [26]:

$$\bar{P}=\frac{1}{2}\rho c^3\Gamma\left(1+\frac{3}{k}\right) \tag{9}$$

The total amount of wind energy density (Wh/m$^2$) for a specific period can be calculated with the following equation [25]:

$$E=\bar{P}T \tag{10}$$

where T is the period in hours (8760h).

### 3.2 Wind speed and Weibull paramters at different hub height

Power law model is widely used to estimate the wind speed ($v$) at different hub height of wind turbine ($z$) [25, 27]. It is expressed as

$$\frac{v}{v_{10}}=\left(\frac{z}{z_{10}}\right)^\alpha \tag{11}$$

where $v_{10}$ is the wind speed at original height $z_{10}$, and α is the surface roughness coefficient (Eq. (12)).

$$\alpha=\frac{0.37-0.088ln(v_{10})}{1-0.088ln(z_{10}/10)} \tag{12}$$

The Weibull parameters at measurement height of 10m as [28]:

$$c(z)=\mathrm{c_0}\left(\frac{z}{z_{10}}\right)^n \tag{13}$$

$$k(z)=\frac{\mathrm{k_0}\left[1-0.088\ln\left(\frac{z_{10}}{10}\right)\right]}{\left[1-0.088\ln\left(\frac{z_{10}}{10}\right)\right]} \tag{14}$$

where $\mathrm{c_0}$ and $\mathrm{k_0}$ are the scale and shape factors determined for the measured height, $z_{10}$ is the height of the wind speed measurements and $z$ is extrapolation height. The exponent $n$ can be calculated by the relation given below [28].

$$n=\frac{[0.37-0.088ln(\mathrm{c_0})]}{1-0.088\ln\left(\frac{z}{10}\right)} \tag{15}$$

### 3.3 Most probable wind speed and wind speed carrying maximum energy

The wind speed that is most possible or probable ($v_{mp}$ ) and that carrying the highest (maximum) energy ( $v_{\max E}$ ) are necessary for approximating wind power. The two wind speeds are obtained from the scale and shapes factors as expressed in Eqs. (16) and (17) [17] .

$$v_{mp}=c\left(1-\frac{1}{k}\right)^{1/k} \tag{16}$$

$$v_{\max E}=c\left(1+\frac{2}{k}\right)^{1/k} \tag{17}$$

### 3.4 Wind turbine energy output and capacity factor

The wind turbine can produce a useful power when the wind speed reaches to cut-in wind speed ($v_{ci}$) of the turbine. After that the power starts to increase until the wind speed achieves the rated wind speed ($v_r$), at this speed the power is equal to rated power of wind turbine ($P_r$). The power generation is stop when the wind speed greater than the wind cut-off wind speed ($v_{co}$) in order to prevent damage on the wind turbine. Consequently, the power generation of wind turbine ($P_{wt}$) and the total power generated ($E_{wt}$) over a period ($t$) can be expressed as

$$P_{wt(i)} = \begin{cases} \mathrm{P_r}\dfrac{v_i^2 - v_{ci}^2}{v_r^2 - v_{ci}^2} & v_{ci} \le v_i \le v_r \\ \dfrac{1}{2}\rho A C_p v_r^2 & v_r \le v_i \le v_{co} \\ 0 & 0 \le v_i \le v_{ci} \; and \; v_{co} \le v_i \le \infty \end{cases} \tag{18}$$

$$E_{wt} = \sum_{i=1}^{n} P_{wt(i)} \times t \tag{19}$$

where $C_p$ is the performance coefficient, which can be estimated as

$$C_p = 2\frac{P_r}{\rho A v_r^3} \tag{20}$$

Finally, the capacity factor (CF) of a wind turbine can be estimated as [29]:

$$CF = \frac{E_{wt}}{P_r . t} \tag{21}$$

### 3.5 Economic analysis of wind turbines

The wind power project cost depends on three main factors: capital cost ($I$), operation and maintenance system cost ($C_{omr}$) and the turbine life ($n$) [30, 31]. Several methods are used to estimate the cost of wind power project. The most common method used to calculate the wind energy cost is present value of costs (PVC) method [32]. It is expressed as

$$PVC = \left[I + C_{omr}\left(\frac{1+i}{r-i}\right) \times \left[1 - \left(\frac{1+i}{1+r}\right)^n\right] - S\left(\frac{1+i}{1+r}\right)^n\right] \tag{22}$$

where r is the discount rate, $i$ is the inflation rate and $S$ is the scrap value of the turbine price and civil work.

The cost energy cost per kWh (CE) can be estimated as [32]:

$$CE = \frac{PVC}{t \times P_r \times CF} \tag{23}$$

## 4. STATISTICAL ANALYSIS

In this study, the statistical anlysis is used to obtain the mean result of wind speed data from 1981 to 2010, which described as follows:

### 4.1. Wind speed characteristics at 10m height

The variation of wind speed data over the 30 years is illustrated in Figure 2. it is observed that the maximum and minimum wind speed values are recorded in May and August with a value of 4.84 m/s and 3. 66m/s , respectivily.

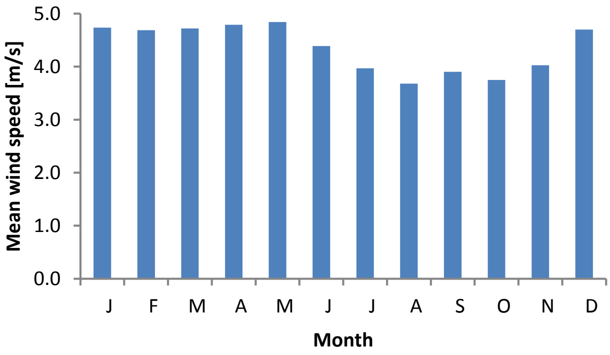

**Figure 2.** Monthly variation of mean wind speed in Nalut, Libya

In order to know if the area is suitable for insullation of a wind turbine, the most probable wind speed (Vmp) and the maximum energy carrying wind speed (VmaxE) were calculated using Eqs. (16) and (17). Figure 3 shows the monthly variation of mean, Vmp and VmaxE. It is observed that monthly varition of Vmp and VmaxE are varied between 3.84-5.05 m/s and 4.05-5.70 m/s, respectively.

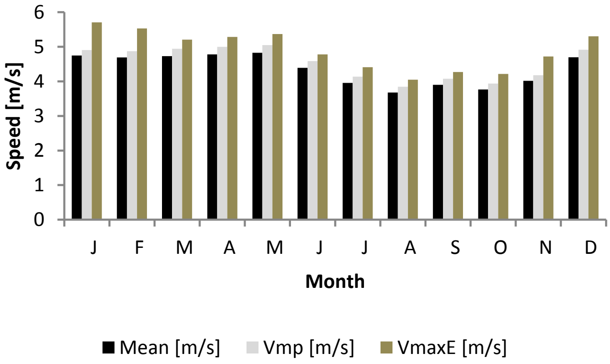

**Figure 3.** Monthly variation of Vmp and V maxE in Nalut, Libya

### 4.2 Mean air density of Nalut

Table 2 is tabulated the average air temperature and atmospheric pressure of the studied area. Assuming that air is an ideal gas, average yearly air density ($\rho$) values were calculated using Eq. (24) [33] or Eq. (25) [. Therefore, the averaged monthly air density was also tabulated in Table 2. In the current study, the air density at 10m height is assumed constant for other heights as there will be no significant difference.

$$\rho(z) = \frac{353.049}{T} e^{\left(-0.034\frac{z}{T}\right)} \tag{24}$$

$$\rho(z) = \frac{P}{RT} e^{\left(-\frac{gh}{RT}\right)} \tag{25}$$

$P$ is the atmospheric pressure (hPa), $R$ is the molar gas constant (287.05 J/(K mol)), $T$ is the air temperature (K), $g$ is the gravitational constant (9.81 m/s$^2$), and $z$ is the considered height(s)

**Table 2.** Mean monthly air temperature, atomospheric pressure and air density at 10m height

| Month | Air temperature [K] | Atomospheric pressure [hPa] | Air density [kg/m$^3$] |
|---|---|---|---|
| J | 282.9 | 1021 | 1.246 |
| F | 284.6 | 1019 | 1.239 |
| M | 287.7 | 1017 | 1.226 |
| A | 291.6 | 1014 | 1.209 |
| M | 295.8 | 1014 | 1.192 |
| J | 299.5 | 1014 | 1.177 |
| J | 301.4 | 1014 | 1.170 |
| A | 301.8 | 1014 | 1.169 |
| S | 299.1 | 1015 | 1.179 |
| O | 294.9 | 1017 | 1.196 |
| N | 289.0 | 1018 | 1.220 |
| D | 284.2 | 1020 | 1.241 |
| Averaged | 292.7 | 1016.4 | 1.205 |

### 4.3 Analysis of Weibull parameters, power and energy densities

The monthly values of the Weibull distribution parameters are presented in Table 3. The distribution paramters values were calculated using Eqs. (4) and (6). In addition, the wind power dnesity and energy are determined using Eqs. (9) and (10), respectively. It is found that the monthly shape paramters are ranged between 4.29 and 8.31. In addition, the scale paramters are with the rang of 3.92-5.22m/s. Moreover, it is found that the hightest wind power density is achived in May (67.737 W/m$^2$) and the lowest value is obtained in August (29.961 W/m$^2$) as shown in Table 3.

**Table 3.** Monthly Weibull parameters, power density and energy density.

| Month | k | c [m/s] | WPD [W/m$^2$] | E [kWh/m$^2$] |
|---|---|---|---|---|
| J | 4.293 | 5.218 | 64.526 | 565.250 |
| F | 4.698 | 5.126 | 62.146 | 544.400 |
| M | 7.412 | 5.039 | 63.661 | 557.674 |
| A | 7.106 | 5.105 | 65.773 | 576.175 |
| M | 6.778 | 5.168 | 67.737 | 593.376 |
| J | 8.314 | 4.655 | 51.044 | 447.142 |
| J | 6.64 | 4.238 | 37.222 | 326.069 |
| A | 7.396 | 3.92 | 29.961 | 262.462 |
| S | 7.782 | 4.147 | 35.747 | 313.141 |
| O | 6.412 | 4.041 | 32.093 | 281.136 |
| N | 4.776 | 4.387 | 39.059 | 342.156 |
| D | 6.08 | 5.059 | 62.425 | 546.840 |

### 4.4 Extrapolation of wind speed and parameters Weibull at different hub height

During the investigation period, the mean annual wind speed at Nalut area is 4.34m/s at 10m height. The monthly averaged wind speed at various heights is estimated using Eq. (11) and presented in Figure 4. It is observed that the maximum and minimum wind speeds occurred in May and August, respectively. In addition, it is observed that the monthly variations of wind speed at various heights share a similar pattern as shown in Figure 4.

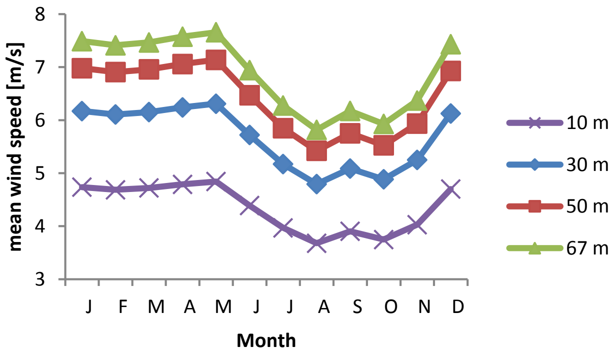

**Figure 4.** Monthly averaged wind speed at various heights

The Weibull parameters values at various heights are calculated at various heights using Eqs. (13)-(15) and tabulated in Table 4. It is observed that the Weibull paramters (k and c) are increased with the hub heights, which indicated that the wind speed of Nalut is constant. The wind power density and the wind speed at various height are shown in Figure 6. It is noticed that the wind power density is increased with the increased of altitude.

It can be concluded that there is a good correlations between wind speed and Weibull parameters because they are function of heights as shown in Figure 5 and Table 4.

**Table 4.** Weibull parameters extrapolated at various heights

| Month | 30 m | | 50 m | | 67 m | |
|---|---|---|---|---|---|---|
| | k | c [m/s] | k | c [m/s] | k | c [m/s] |
| J | 4.29 | 6.80 | 4.31 | 7.69 | 4.32 | 8.25 |
| F | 4.70 | 6.68 | 4.71 | 7.56 | 4.72 | 8.11 |
| M | 7.41 | 6.57 | 7.43 | 7.43 | 7.43 | 7.97 |
| A | 7.11 | 6.65 | 7.13 | 7.52 | 7.14 | 8.07 |
| M | 6.78 | 6.73 | 6.80 | 7.62 | 6.81 | 8.17 |
| J | 8.31 | 6.07 | 8.33 | 6.86 | 8.34 | 7.36 |
| J | 6.64 | 5.52 | 6.66 | 6.25 | 6.67 | 6.70 |
| A | 7.40 | 5.11 | 7.42 | 5.78 | 7.43 | 6.20 |
| S | 7.78 | 5.40 | 7.79 | 6.11 | 7.80 | 6.56 |
| O | 6.41 | 5.27 | 6.43 | 5.96 | 6.44 | 6.39 |
| N | 4.78 | 5.72 | 4.80 | 6.47 | 4.81 | 6.94 |
| D | 6.08 | 6.59 | 6.10 | 7.46 | 6.11 | 8.00 |

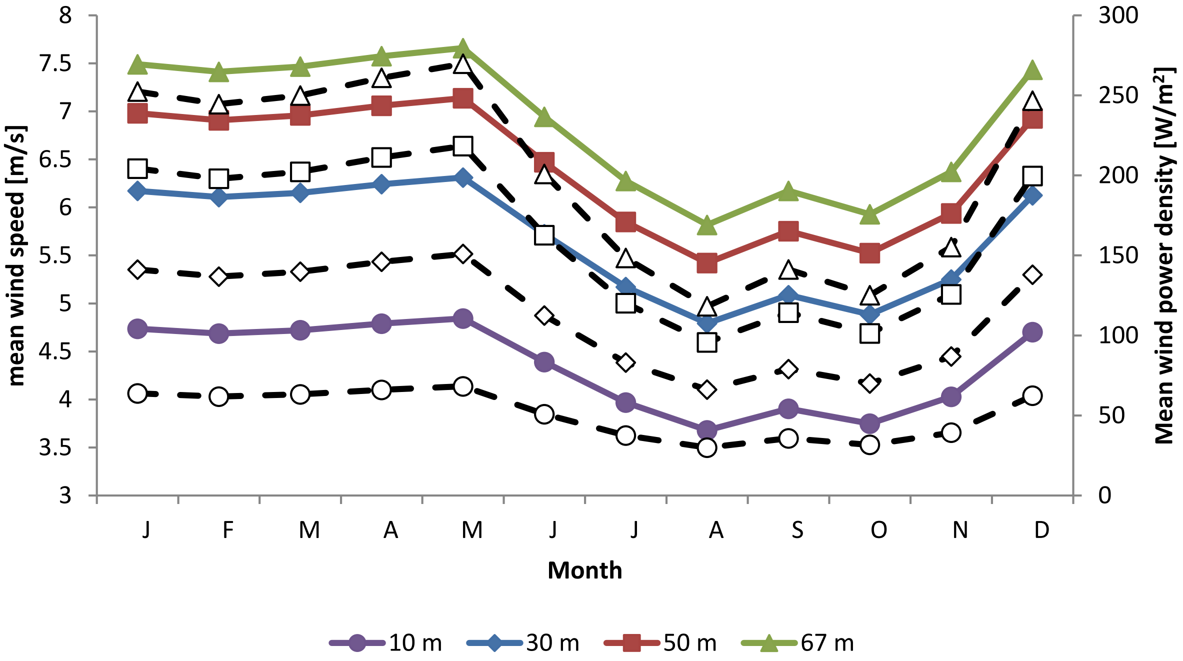

**Figure 5.** Monthly variation of wind power density and wind speed in Nalut, Libya at verious height (wind speed: solid line; wind power density: dashed line)

### 4.5 Performance selected wind turbines

The selected wind turbines that satisfy the estimated annual energy for the selected location are shown in Table 5. In this study, three-wind turbine models with the different are used in the present work. Selection of these wind turbines were made after an overall comparison between different types of wind turbines.

In order to evaluate the cost of kWh of the energy produced by the turbine at the selected area, the following assumption had been taken.

1). The interest rate ($r$) and inflation rate ($i$) were taken to be 8% and 6%, respectively [35].
2). Machine life ($n$) is 20 years [36].
3). Operation and maintenance cost $C_{omr}$ is assumed 7% of the initial capital cost of the wind turbine installation system (system price/life time) [37].
4). Scrap value (S) was assumed 10% of the turbine price and civil work.
5). Investment (I) is the summation of the turbine price and other initial cost which varied from country to other country [37, 38]. In the present study, Investment (I) is assumed to be 68%.

**Table 5.** Characteristics of the selected wind turbines

| Characteristics | Bonus 300kW/33 | Bonus 1MW/54 | Vestas 2MW/80 |
|---|---|---|---|
| **Hub height [m]** | 30 | 50 | 67 |
| **Rated power [kW]** | 300 | 1000 | 2000 |
| **Rotor diameter [m]** | 33.4 | 54.2 | 80 |
| **Cut-in wind speed [m/s]** | 3 | 3 | 40 |
| **Rated wind speed [m/s]** | 14 | 15 | 16 |
| **Cut-off wind speed [m/s]** | 25 | 25 | 25 |

The monthly capacity factor of the selected wind turbine is shown in Figure 6. It is found that Bonus 1MW/54 has the maximum capacity factor compared to other models. In addition, it is observed that the maximum monthly capacity factor is recorded in May with a approximately value of 41%. In addition, the electricity-generated cost per kWh of wind turbine with capacity of 1MW is the lowest compared to other models as shown in Figure 7. The annual capacity factor and the electricity-generated cost per kWh of three selected wind turbine is tabulated in Table 6.

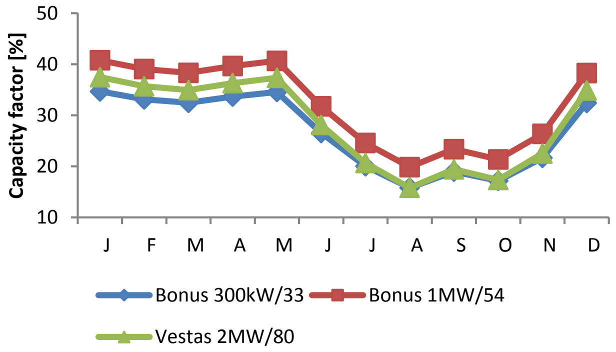

**Figure 6.** Monthly variation of capacity factor for for Nalut, Libya

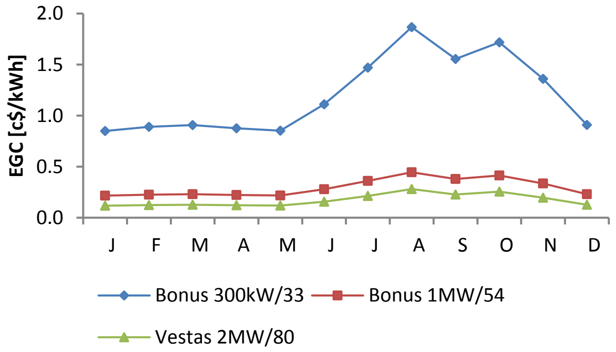

**Figure 7.** Monthly variation of electricity generated cost per kWh (EGC) for for Nalut, Libya

**Table 6.** Annual energy production for studied area

| Models | Total energy power [kWh] | Capacity factor [%] | EGC [c$/kWh] |
|---|---|---|---|
| **Bonus 300kW/33** | 28.33 | 25.87 | 1.13926 |
| **Bonus 1MW/54** | 113.23 | 31.02 | 0.28503 |
| **Vestas 2MW/80** | 199.74 | 27.36 | 0.16158 |

## 5. CONCLUSIONS

In this study, the evaluation of wind potential at Nalut in Libya was investigated. Moreover, the capabilities of three selected wind tuebine to generate power at the selected area were examined and compared. It is found that the mean wind speed was ranged from 3.66 to 4.84 m/s at 10 m height. Moreover, the values of wind power density were ranged from 29.961W/m$^2$ to 67.737W/m$^2$. The result demonstrated that the win potential at the selected area could be considered as poor according to wind power classification. In comparison, it was found that Bonus 1MW/54 has the lowest energy cost per KWh compared to Bonus 300kW/33 and Vestas 2MW/80, while Vestas 2MW/80 has maximum energy power.

## REFERENCES

[1]. Belgasim, B., Aldali, Y., Abdunnabi, M. J., Hashem, G., & Hossin, K. (2018). The potential of concentrating solar power (CSP) for electricity generation in Libya. Renewable and Sustainable Energy Reviews, 90, 1-15. doi:10.1016/j.rser.2018.03.045

[2]. El-Osta, W., & Kalifa, Y. (2003). Prospects of wind power plants in Libya: A case study. Renewable Energy, 28(3), 363-371. doi:10.1016/s0960-1481(02)00051-4

[3]. Li, C., Liu, Y., Li, G., Li, J., Zhu, D., Jia, W., … Zhai, X. (2016). Evaluation of wind energy resource and wind turbine characteristics at two locations in China. *Technology in Society*, *47*, 121-128.

[4]. Woldeyohannes, A. D., Woldemichael, D. E., & Baheta, A. T. (2016). Sustainable renewable energy resources utilization in rural areas. *Renewable and Sustainable Energy Reviews*, *66*, 1-9.

[5]. Irwanto, M., Gomesh, N., Mamat, M., & Yusoff, Y. (2014). Assessment of wind power generation potential in Perlis, Malaysia. Renewable and Sustainable Energy Reviews, 38, 296-308.

[6]. Biswas, P. P., Suganthan, P., & Amaratunga, G. A. (2017). Optimal power flow solutions incorporating stochastic wind and solar power. *Energy Conversion and Management*, *148*, 1194-1207.

[7]. Kabir, E., Kumar, P., Kumar, S., Adelodun, A., & Kim, K. (2018). Solar energy: Potential and future prospects. *Renewable and Sustainable Energy*

*Reviews*, *82*, 894-900

[8]. Razmjoo, A., Qolipour, M., Shirmohammadi, R., Heibati, S. M., & Faraji, I. (2017). Techno-economic evaluation of standalone hybrid solar-wind systems for small residential districts in the central desert of Iran. *Environmental Progress & Sustainable Energy*, *36*(4), 1194-1207.

[9]. Spellman, F. R., & Stoudt, M. L. (2013). Environmental Science: Principles and Practices. UK: Scarecrow Press Inc.

[10]. Al Zohbi, G., Hendrick, P., & Bouillard, P. (2015). Wind characteristics and wind energy potential analysis in five sites in Lebanon. *International Journal of Hydrogen Energy*, *40*(44), 15311-15319.

[11]. Cantarello, E., & Newton, A. C. (2014). An Introduction to the Green Economy: Science, Systems and Sustainability. New York.

[12]. Alayat, M., Kassem, Y., & Çamur, H. (2018). Assessment of Wind Energy Potential as a Power Generation Source: A Case Study of Eight Selected Locations in Northern Cyprus. Energies, 11(10), 2697

[13]. Kassem, Y., Gökçekuş, H., & Çamur, H. (2018). Effects of climate characteristics on wind power potential and economic evaluation in Salamis region, Northern Cyprus. International Journal of Applied Environmental Sciences (IJAES), 13(3), 287-307

[14]. Solyali, D., Altunç, M., Tolun, S., & Aslan, Z. (2016). Wind resource assessment of Northern Cyprus. *Renewable and Sustainable Energy Reviews*, *55*, 180-187.

[15]. Azad, A., Rasul, M., & Yusaf, T. (2014). Statistical Diagnosis of the Best Weibull Methods for Wind Power Assessment for Agricultural Applications. Energies, 7(5), 3056-3085.

[16]. Albani, A., & Ibrahim, M. (2017). Wind Energy Potential and Power Law Indexes Assessment for Selected Near-Coastal Sites in Malaysia. Energies, 10(3), 307.

[17]. Soulouknga, M., Doka, S., N.revanna, N.djongyang, & T.c.kofane. (2018). Analysis of wind speed data and wind energy potential in Faya-Largeau, Chad, using Weibull distribution. Renewable Energy, 121, 1-8. doi:10.1016/j.renene.2018.01.002

[18]. Akpinar, E. K., & Akpinar, S. (2005). An assessment on seasonal analysis of wind energy characteristics and wind turbine characteristics. Energy Conversion and Management, 46(11-12), 1848-1867. doi:10.1016/j.enconman.2004.08.012

[19]. Akdağ, S., Bagiorgas, H., & Mihalakakou, G. (2010). Use of two-component Weibull mixtures in the analysis of wind speed in the Eastern Mediterranean. Applied Energy, 87(8), 2566-2573. doi:10.1016/j.apenergy.2010.02.033

[20]. Nor, K. M., Shaaban, M., & Rahman, H. A. (2014). Feasibility assessment of wind energy resources in Malaysia based on NWP models. Renewable Energy, 62, 147-154. doi:10.1016/j.renene.2013.07.001

[21]. Monahan, A. H., He, Y., Mcfarlane, N., & Dai, A. (2011). The Probability Distribution of Land Surface Wind Speeds. Journal of Climate, 24(15), 3892-3909. doi:10.1175/2011jcli4106.1

[22]. Mohammadi, K., & Mostafaeipour, A. (2013). Using different methods for comprehensive study of wind turbine utilization in Zarrineh, Iran. Energy Conversion and Management, 65, 463-470. doi:10.1016/j.enconman.2012.09.004

[23]. Azad, A., Rasul, M., Islam, R., & Shishir, I. R. (2015). Analysis of Wind Energy Prospect for Power Generation by Three Weibull Distribution Methods. Energy Procedia, 75, 722-727. doi:10.1016/j.egypro.2015.07.499

[24]. Fagbenle, R., Katende, J., Ajayi, O., & Okeniyi, J. (2011). Assessment of wind energy potential of two sites in North-East, Nigeria. Renewable Energy, 36(4), 1277-1283. doi:10.1016/j.renene.2010.10.003

[25]. Irwanto, M., Gomesh, N., Mamat, M., & Yusoff, Y. (2014). Assessment of wind power generation potential in Perlis, Malaysia. Renewable and Sustainable Energy Reviews, 38, 296-308. doi:10.1016/j.rser.2014.05.075

[26]. Yaniktepe, B., Koroglu, T., & Savrun, M. (2013). Investigation of wind characteristics and wind energy potential in Osmaniye, Turkey. Renewable and Sustainable Energy Reviews, 21, 703-711. doi:10.1016/j.rser.2013.01.005

[27]. Masseran N (2015) Evaluating wind power density models and their statistical properties. Energy, 84, 533-541. https://doi.org/10.1016/j.energy.2015.03.018

[28]. Safari, B., & Gasore, J. (2010). A statistical investigation of wind characteristics and wind energy potential based on the Weibull and Rayleigh models in Rwanda. Renewable Energy, 35(12), 2874-2880. doi:10.1016/j.renene.2010.04.032

[29]. Ayodele TR., Jimoh AA., Munda JL., Agee JT (2013) Viability and economic analysis of wind energy resource for power generation in Johannesburg, South Africa. International Journal of Sustainable Energy, 33(2), 284-303.https://doi.org/10.1080/14786451.2012.762777

[30]. Gökçek M., Genç MS (2009) Evaluation of electricity generation and energy cost of wind energy conversion systems (WECSs) in Central Turkey. Applied Energy, 86(12), 2731-2739. https://doi.org/10.1016/j.apenergy.2009.03.025

[31]. Gölçek M., Erdem HH., Bayülken A (2007) A Techno-Economical Evaluation for Installation of Suitable Wind Energy Plants in Western Marmara, Turkey. Energy Exploration & Exploitation, 25(6), 407-427.

[32]. Adaramola M., Paul S., Oyedepo S (2011) Assessment of electricity generation and energy cost of wind energy conversion systems in north-central Nigeria. Energy Conversion and Management, 52(12), 3363-3368.https://doi.org/10.1016/j.enconman.2011.07.007

[33]. Kidmo, D. K., Deli, K., Raidandi, D., & Yamigno, S. D. (2016). Wind Energy for Electricity Generation in the

Far North Region of Cameroon. Energy Procedia, 93, 66-73. doi:10.1016/j.egypro.2016.07.151

[34]. Olaofe, Z. O., & Folly, K. A. (2013). Wind energy analysis based on turbine and developed site power curves: A case-study of Darling City. Renewable Energy, 53, 306-318. doi:10.1016/j.renene.2012.11.003

[35]. Diaf, S., & Notton, G. (2013). Evaluation of electricity generation and energy cost of wind energy conversion systems in southern Algeria. Renewable and Sustainable Energy Reviews, 23, 379-390. doi:10.1016/j.rser.2013.03.002

[36]. Shata, A. A., & Hanitsch, R. (2006). Evaluation of wind energy potential and electricity generation on the coast of Mediterranean Sea in Egypt. Renewable Energy, 31(8), 1183-1202. doi:10.1016/j.renene.2005.06.015

[37]. Ohunakin, O. S., Oyewola, O. M., & Adaramola, M. S. (2013). Economic analysis of wind energy conversion systems using levelized cost of electricity and present value cost methods in Nigeria. International Journal of Energy and Environmental Engineering, 4(1), 2. doi:10.1186/2251-6832-4-2

[38]. Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2011). Wind energy explained: Theory, design and application. Chichester: John Wiley & Sons.