10th ANKARA INTERNATIONAL AEROSPACE CONFERENCE AIAC-2019-116
18-20 September 2019 - METU, Ankara TURKEY

AN ANALYSIS OF WIND SPEED DISTRIBUTION AND ECONOMICAL EVALUATION AT MISURATA CITY, LIBYA

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ABSTRACT

The statistical wind data obtained from measurements for the period of 5 years (2012-2016) were collected from the meteorological station of Misurata - Libya. The site coordinates are: latitude 32.3256° N and 15.0993° longitude. The elevation of the site is 18 m above mean sea level (AMSL). The wind speed has been measured at height of 10 m above the ground level using 3 cup anemometers. Moreover wind speed has been estimated at height of (30 and 50) metres . Firstly the statistical wind data set was analyzed using the Weibull distribution function. The energy pattern factor (EPF) method was used to calculate shape and scale parameters at 10 m, 30 m, and 50 m height. Secondly the annual energy production (AEP), capacity factor (Cf) was estimated. In addition the present value cost (pvc) method was used to calculate the cost of energy output. Finally the cost of energy was compared with the cost of three types of wind turbines; namely V27-225, p15-50 at high 30 m and V39-500 at high 50m. Results showed the best capacity factor and price of kilowatt will be obtained if turbine type p15-50 at high 30m is used.

INTRODUCTION

Electricity production from fuel, fuel sources as a significant earth polluting activity, created researchers around the world to find different clean and Renewable sources of energy. Wind energy as a free and accessible renewable supply takes into consideration and attracts several researchers from whole around the world to enhance the technology and assess the wind the potential in specific areas. Within the last decade scores of studies have been developed in several countries everywhere the globe [Prasad, 2009].
With the increase in the demand for energy consumption annually in Libya, which led to shedding light on the alternative energy sector to benefit from it is available in Libya, including solar and wind energy, where it is one of the best alternatives, with record the average solar radiation in Libya is about 7.5 kWh/m^2/day with around 3000 to 3500 sunshine hours a year. The average wind speed is between 6 m/s and 7.5 m/s at 40m height. This enormous measure of sunshine and wind distribution over an area of 1,750,000 km^2 can contribute supply the future electricity needs of Libya and its countries around. Libya is relying on oil and gas to produce electricity and with the increase in demand for energy increases the need for larger quantities of oil and gas where negative effect to economy [Khalil, 2015].
The first for the growth plans in Libya is to connect lines electricity to all areas so that the average power consumption of each person is the rate to be one of the major factors to measure the

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growth scale in modern countries. The production of electricity is now expensive, specially for the agrarian applications, the cost of electricity in Libya in the agrarian and manufacturing take high value from government budget in the last thirty years. The value of plans to electricity delivery contractors or at the finally of construction nearly 17,144 million Libyan dinars the section of electrical power production, (1.420 LYD equal 1 USD) [Mohamed, 2016].

There were few important studies about wind energy carried out at different locations in Libya; [El- Osta,1995] have selected a small wind farm of 1.5MW to be a pilot wind project. They have investigated different sites in Tripoli. The average wind speed was found as 6.9m/s at 10m height with an available power of 399 W/m^2. Their results were promising for the wind farm project.
[Mohammed, 2013] have investigated the utilization of renewable energy in Libya.They concluded that Libya is rich in renewable energy including wind energy but needs more comprehensive energy strategy and more financial and educational investment.
[Elmnefi, 2014] have obtained wind speed measurements for 12 months period at Benina site in Libya. The results showed an average wind speed of about 11 m/s at 10m height which indicates the high wind energy potential in Benina site. Very recently [Elfarra, 2019] have selected four sites close to the Libyan coast and conducted the technical and economical assessment of wind power generation using real measured wind data. The results have shown the electricity cost of all the sites is below the world average electricity price.
Other studies for the wind potential in other centuries such as Turkey [Kaplan, 2016], Italy [Basile, 2015], Algeria [Charrouf, 2016], Iran [Hossieni, 2014] and India [Mohankumar, 2017] have also been performed.
The aim of this work is to study the possibility of generation electrical energy from the wind energy by analysis the information for wind speed obtained from the meteorological station of Misurata city. Knowing the wind energy potential within this location zone. Use of wind energy as additional source for power generation in the city of Misurata firstly, will contribute to electrical energy savings and secondly, will reduce the emission of greenhouse gases, such as carbon dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O), are the main factors of increasing the global warming.

METHOD

The meteorological station of Misrata city is located in the west of Libya, where it is characterized by its location near the sea, and available wind. To reduce the problem of pollution resulting from the power stations and the search for investments in alternatives to oil such as clean energy was resorted to the choice of this site, recorded data for the average wind speed per month "for five consecutive years (2012–2016) were used for the analysis. The wind speeds and measured at height of six meters.

Weibull function is a commonly used one in wind energy [Elmnefi, 2014;Oyedepo, 2012, and Mostafaeipour, 2014]. It is one of the most widely used method where a good description of speed distribution is given throughout the year probability distribution function Possibility be expressed as:

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

Where (k) and (C) are parameters the Weibull shape and scale parameter, density function is recognized as cumulative distribution function and Possibility be expressed as:

$$F(v) = 1 - e^{-(\frac{v}{c})^k} \qquad (2)$$

In order to obtain the Weipull variables we can obtain them in a number of methods, including Energy pattern factor (EPF) [Gaddada,2016] can be expressed as:

$$\mathrm{EPF} = \frac{1}{(\overline{v})3} \sum_{k=1}^{n} \frac{vi^3}{n} \qquad (3)$$

where $\overline{v}$ is the main wind speed

$$K=3.957\ EPF^{-0.898} \qquad (4)$$

$$C = \frac{\overline{v}\ k^{2.6774}}{0.184+0.816k^{2.78855}} \qquad (5)$$

Wind speed changes with altitude and for predicts speed we can apply this function:

$$(V_2/V_1) = (h_2/h_1)^m \qquad (6)$$

Where h_1 and h_2 are highs and V_1 and V_2 are mean speeds and (m) it is dependent on several factors and usually takes 0.14.

The mean wind power density of the region can be obtain as:

$$P = \frac{1}{2} \rho\ (EPF)\ V^3 \qquad (7)$$

To find the capacity factor (Cf), power and energy per year out applied these functions:

$$(P)OUT = (P)eR\ \{ \frac{e^{-\left(\frac{Qc}{c}\right)k} - e^{-\left(\frac{Qr}{c}\right)k}}{\left(\frac{Qr}{c}\right)k - \left(\frac{Qc}{c}\right)k} - e^{-\left(\frac{Qf}{c}\right)k} \} \qquad (8)$$

Where QC, Qr and Qf are the cut in wind speed, rated wind speed and cut off wind speed, PeR Rated electrical power and (E rated) of energy.

$$\text{Capacity factor } (C_f) = P_{out} / P_{eR} \qquad (9)$$

$$\text{Energy output } E_{out} = C_f * E_{rated} \qquad (10)$$

Analysis of the cost wind energy:

To obtain the cost of electricity per kWh, the cost can be obtained by expressing this formula[Gaddada,2016]:

$$PVC = I + Comr\left[\frac{1+i}{r-i}\right]x\left[1-\left(\frac{1+i}{1+r}\right)t\right] - S\left(\frac{1+i}{1+r}\right)t \qquad (11)$$

Where I is the investment cost, Comr is the operation, maintenance and repair cost, i is the inflation rate, r is the Interest rate, t is the lifetime of the machine (in years) and S is the scrap value.

Table1 shows information on the turbines used in the calculations and their characteristics. Table2 illustrate the value and price of kilowatt used in the accounts, which is variable over the years and its improving.

Table 1: characteristics of the selected turbines

Turbine specifications	Vestas V27-225 kw	Vestas V39-500 kw	Polaris p15-50 kw
Rated power p (kw)	225kw	500 kw	50 kw
Cut wind speed Q_c (m/s)	3.5	4	2.5
Cut off speed Q_f (m/s)	25	25	25
Rated wind speed Q_r (m/s)	14	15	10
Hub height (m)	30	50	30
Number of blades	3	3	3

Table 2: turbines cost band

Wind turbine Size (kw)	Min. specific Cost (s/kw)	Max. specific Cost (s/kw)	Average specific Cost (s/kw)
10-20	2200	3000	2600
20-200	1250	2300	1775
200 to up	700	1600	1150

RESULTS AND DISCUSSION

Figure (1) shows the varation of montly wind speed during the period from 2012 to 2016, noting that the minimum speed is fall between August and November the lowest value recorded in 2015 (V =4.8 m/s) and the maximum value was also recorded in March 2015 (V= 9.3 m/s) .

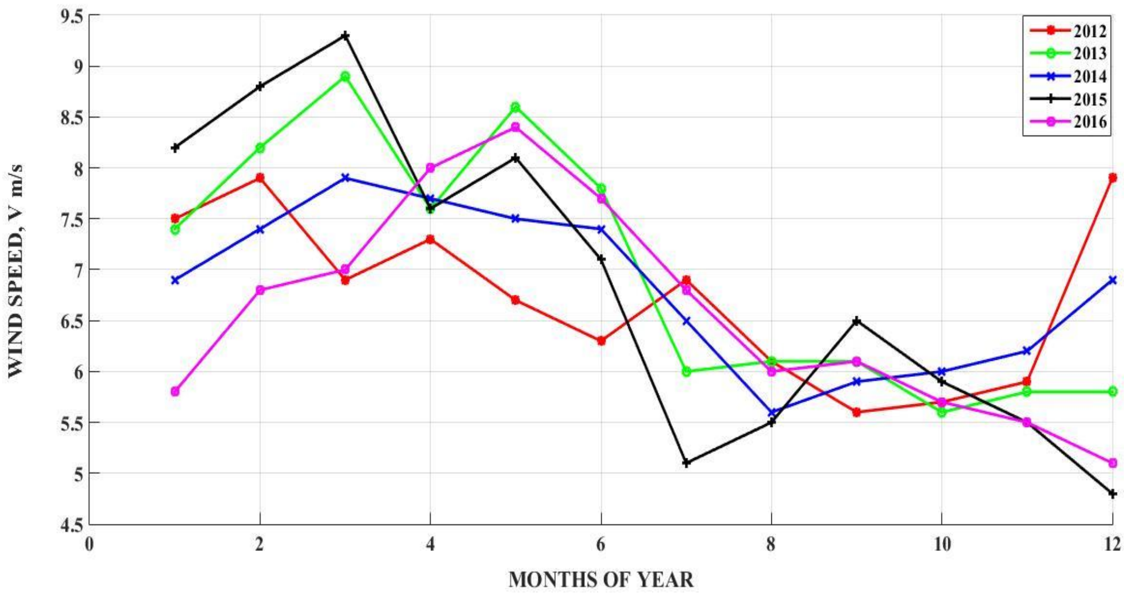

Figure 1: Monthly wind speed variation at 10 m height

Table (3) shows obtained values of Weibull shape and scale parameter (k) and (C) and mean speed V_m for years 2012-2016 used by Energy pattern factor method at high 10 m.
Figure(2) showed that as the value of C increases for a given value of K the shape of the distribution gets wider. Because of this C is called the scale parameter; it has dimensions of velocity. The plot also shows that as K increases to 3.8 for a given value of C to 7.5 m/s , the maximum of the (pdf)increases. Because of this K is called the shape parameter; it is dimensionless. But it is less when used k=3.5 and uses C= 7.6 m/s.

Table 3: Results obtained of values K, C, Epf and Vm for years 2012-2016 used byEnergy Pattern Factor method at 10 m height

year	2012	2013	2014	2015	2016
C	7.5	7.9	7.6	7.6	7.3
K	3.8	3.7	3.8	3.5	3.7
EPf	1.040	1.084	1.038	1.038	1.071
Vm data	6.7	7	6.8	6.9	6.6
Vm plot	6.9	7.2	7	6.9	6.7

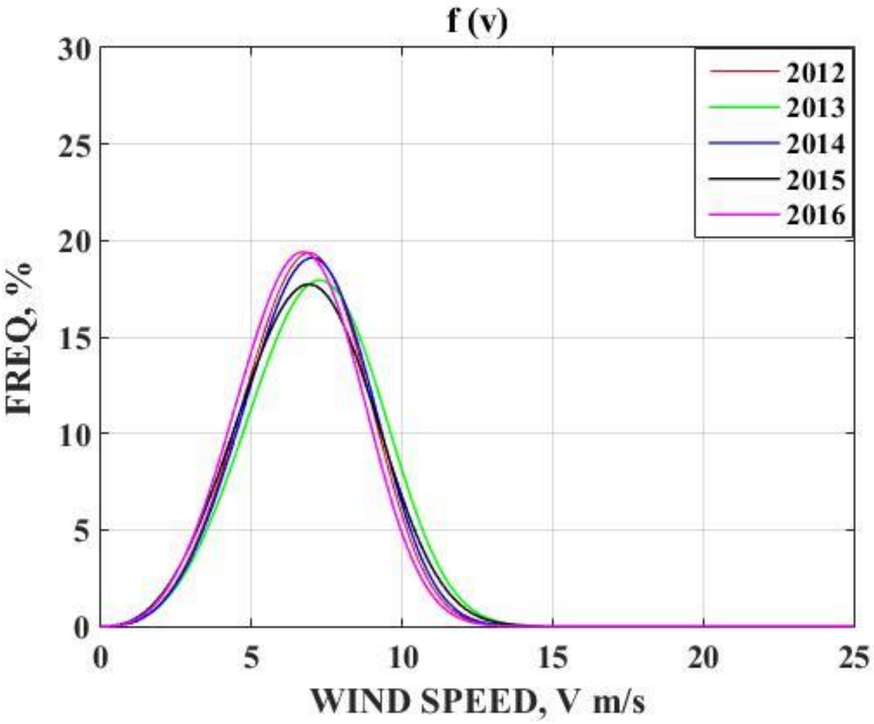

Figure 2: Probability wind speed density at 10 m height period 2012-2016

Figure (3) shows the cumulative density function of the Weibull distribution rises, the curve covers much more area under it. Also, the figure shows that the cdf for years 2012 V = 6.9 m/s , cdf = 51.73 % rises than the cdf for others, where is 2013 V=7.2 m/s , cdf = 50.81 % is the lowest value . Based on this observation, we consider understand the validity of the wind speed measure for that turbine. The table (4) shows the value of parameters over the years at height 30 m. Figures (4 & 7) the Wind speeds were taken at different altitudes(30-50) meters which increased wind speed .

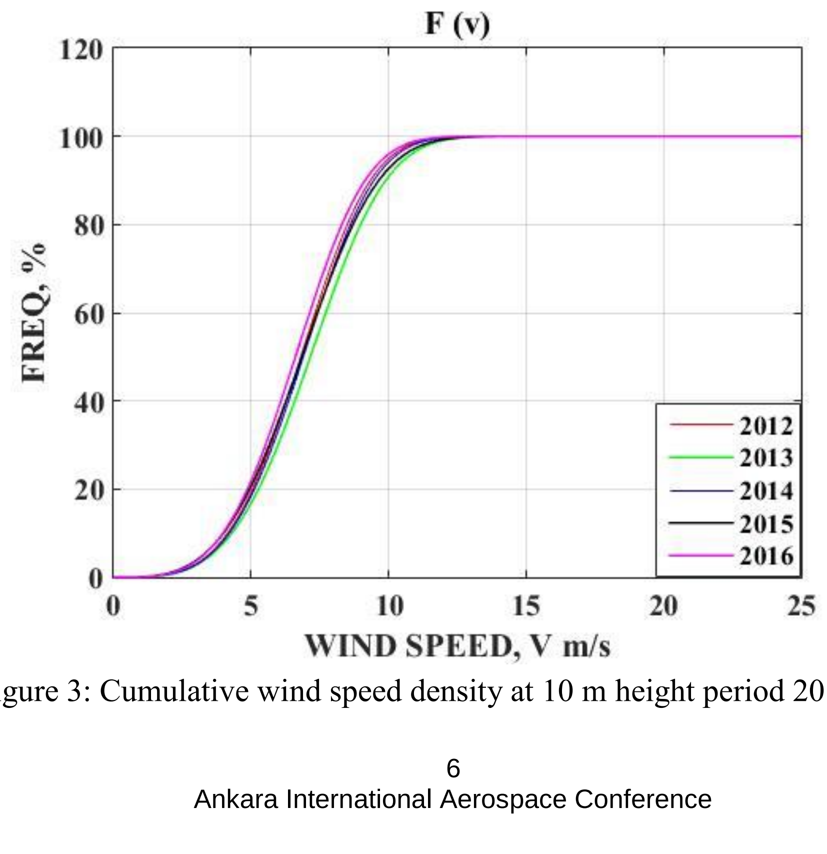

Figure 3: Cumulative wind speed density at 10 m height period 2012-2016

Table 4: The value of parameters over the years at height 30 m

Year	2012	2013	2014	2015	2016
K	3.8	3.7	3.8	3.5	3.7
C m/s	8.8	9.2	9.0	9.0	8.7
Epf	1.040	1.084	1.038	1.138	1.071
V Mean m/s	8.4	8.8	8.5	8.6	8.2
V plot m/s	8.1	8.5	8.3	8.2	8
Freq (pdf) %	16.5	15.4	16.14	14.97	16.29
Freq (cdf) %	51.8	52.58	52.06	51.42	51.96
P w/m^2	338.5	407.8	362.3	384.3	335.9

To find the cost of energy for each Kw applied this function and using V27-225 wind turbine:

Cost = 258750 $ I =310.500 $ comr = 3234.375 $ S = 310500*0.1 = 31050 $
r = 0.15 i = 0.12 civil cost = 20% of cost = 51750 $ t=20 y

$$PVC = I + Comr\left[\frac{1+i}{r-i}\right]x\left[1-\left(\frac{1+i}{1+r}\right)t\right] - S\left(\frac{1+i}{1+r}\right)t$$

Pvc = 341702.1297 / 20 (y) * E (kw)

To find the cost of energy for each Kw applied this function and using P15-50 wind turbine:

Cost = 88750 $ I =106.500 $ comr = 3234.375 $ S = 106500*0.1 = 10650 $
r = 0.15 i = 0.12 civil cost = 20% of cost = 17750 $ t = 20 y

$$PVC = I + Comr\left[\frac{1+i}{r-i}\right]x\left[1-\left(\frac{1+i}{1+r}\right)t\right] - S\left(\frac{1+i}{1+r}\right)t$$

Pvc = 93233.079 / 20 (y) * E (kw)

Table (5) shows the value of parameters over the years at height 30 m Using V27-225 wind turbine, Observed The higher the capacity factor present the lower the cost per kilowatt with the increased rate of annual energy production. Table (6) shows the value of parameters over the years at height 30 m using p15-50 wind turbine, observed . The higher the capacity factor present the lower the cost per kilowatt and also increased than used Using V27-225 wind turbine The tables (7,8) showed the value of parameters over the years at wind speed at height 50 m using V 39-500 wind turbine observer the value of power , energy and cost are best than used V27 -225.

Table 5: The value of parameters over the years at height 30 m Using V27-225 wind turbine

year	2012	2013	2014	2015	2016
C f	0.17	0.23	0.19	0.21	0.17
P Out KW	19.55	30	23.8	25.2	18.7
E Mwh	137	202.12	161.47	175.44	137.1
Cost $ (kw)	0.12	0.08	0.10	0.10	0.12

Table 6: The value of parameters over the years at height 30 m using p15-50 wind turbine

year	2012	2013	2014	2015	2016
Cf	0.49	0.54	0.52	0.53	0.48
Pout kw	8.9	10.26	9.65	9.35	8.6
E Mwh	99.97	117.54	109.64	109.94	96.30
Cost $ (kw)	0.047	0.039	0.042	0.043	0.049

Figure (5) shows the maximum pdf in 2012 when mean speed V = 8.1 m/s equal 16.5 and observer the minimum pdf at 2015 when mean speed V= 8.2 equal 14.97.

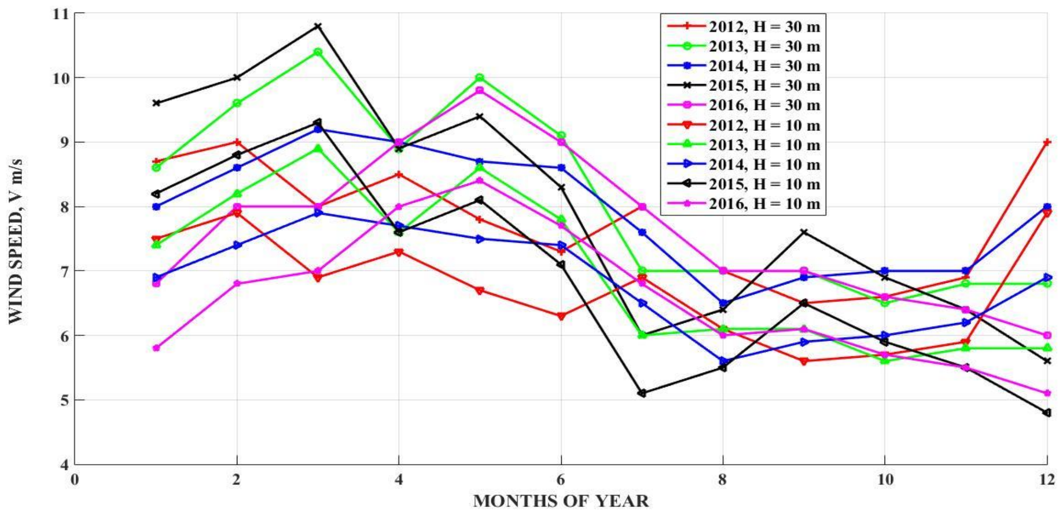

Figure 4: Comparison of wind speed m/s at height of 10 meters and height of 30 meters

Figure (6) shows maximum cdf reached in 2016 when V= 8m/s equal 51.6. Fig (8) showed the maximum pdf at 2012 when mean speed V = 8.8 m/s equal 15.29 and observer the minimum pdf at 2015 when mean speed V= 8.9 equal 13.75. Fig (9) shows maximum cdf reached in 2014 when V= 8.9m/s equal 52.76.the plots (10,11,12,13,14) showed the comparison for parameters of energy , capacity factor and cost when using V27-225, p15-50, V 39-500 wind turbine.

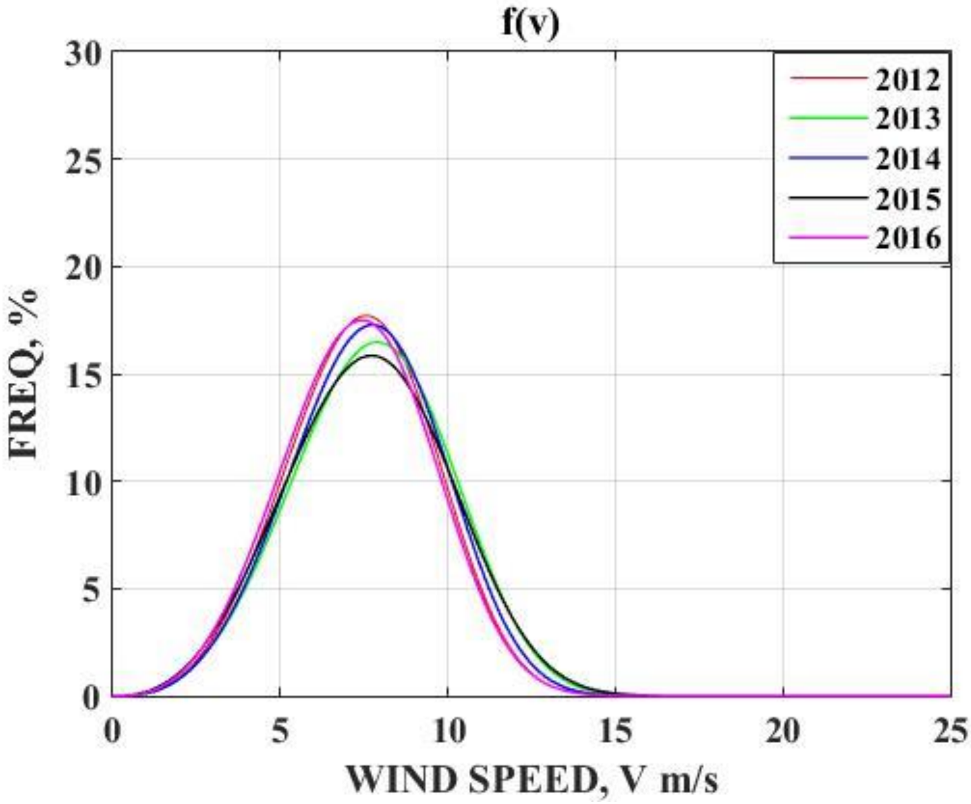

Figure 5: Probability wind speed density at 30m high period 2012-2016

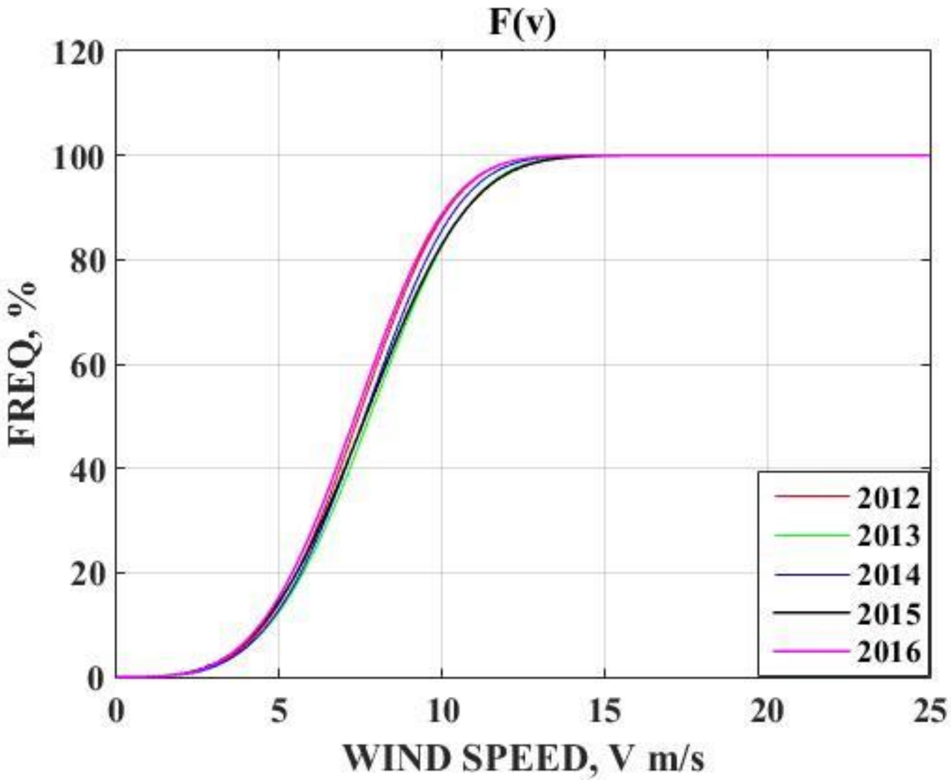

Figure 6: cumulative wind speed density at 30 m high period 2012-2016

Table 7: The value of parameters over the years at wind speed at height 50 m

Year	2012	2013	2014	2015	2016
K	3.8	3.7	3.8	3.5	3.7
C	9.5	9.9	9.6	9.8	9.3
Epf	1.040	1.084	1.035	1.138	1.071
V Mean m/s	9	9.4	9.2	9.2	9
V plot m/s	8.8	9.1	8.9	8.9	8.5
Freq (pdf)	15.29	14.32	15.13	13.75	15.24
Freq (cdf)	52.29	51.91	52.76	51.02	51.17
P W/m^2	434.4	500.5	447	491.4	403

To find the cost of energy for each Kw applied this function and using V39-500 wind turbine:
Cost = 575,000 $ I =690,000 $ comr = (575,000/20) * 0.25 = 7187.5 $
S = 690,000*0.1 = 69000 $ t= 20 y r = 0.15 i = 0.12 civil work = 20% of cost = 115,000 $

$$PVC = I + Comr\left[\frac{1+i}{r-i}\right]x\left[1-\left(\frac{1+i}{1+r}\right)t\right] - S\left(\frac{1+i}{1+r}\right)t$$

PVC = 759338.85 / 20 (y) * E (kW)

Table 8: The value of parameters over the years at height 50 m using V 39-500 wind turbine

year	2012	2013	2014	2015	2016
C f %	0.17	0.21	0.18	0.22	0.17
POut kw	69.7	92.4	75.6	92.4	64.6
E Mwh	384.81	493.92	413.15	504.96	368.64
Cost $ (kw)	0.10	0.076	0. 09	0.075	0.10

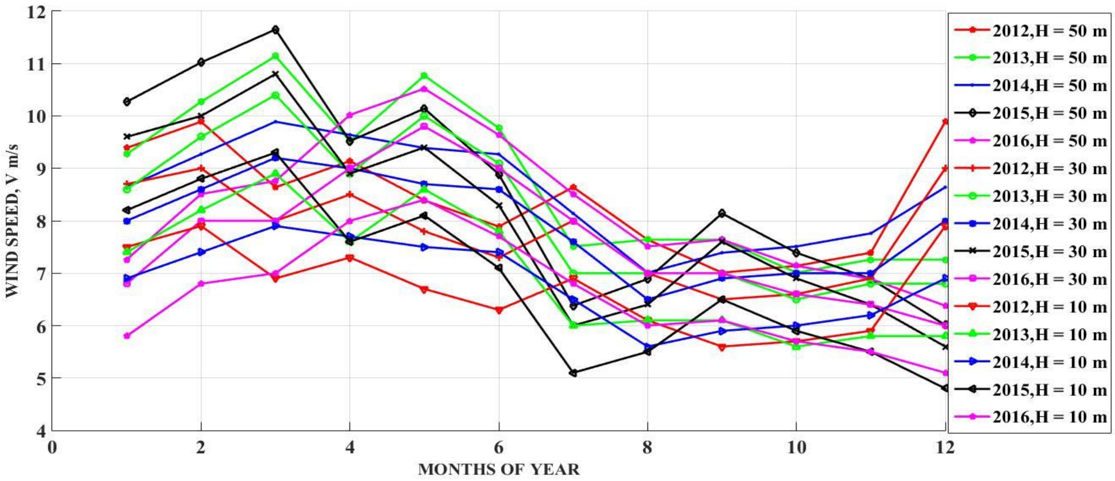

Figure 7: Comparison of wind speed m/s at height of 10 meters, 30 m and 50 m height

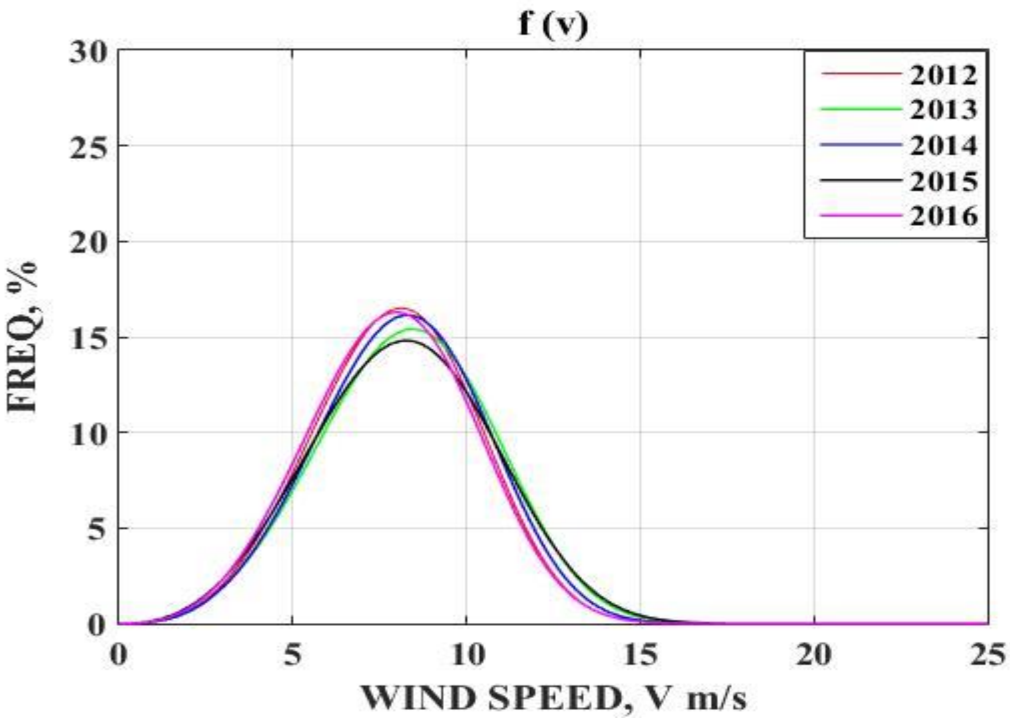

Figure 8: Probability wind speed density at 50 m height period 2012-2016

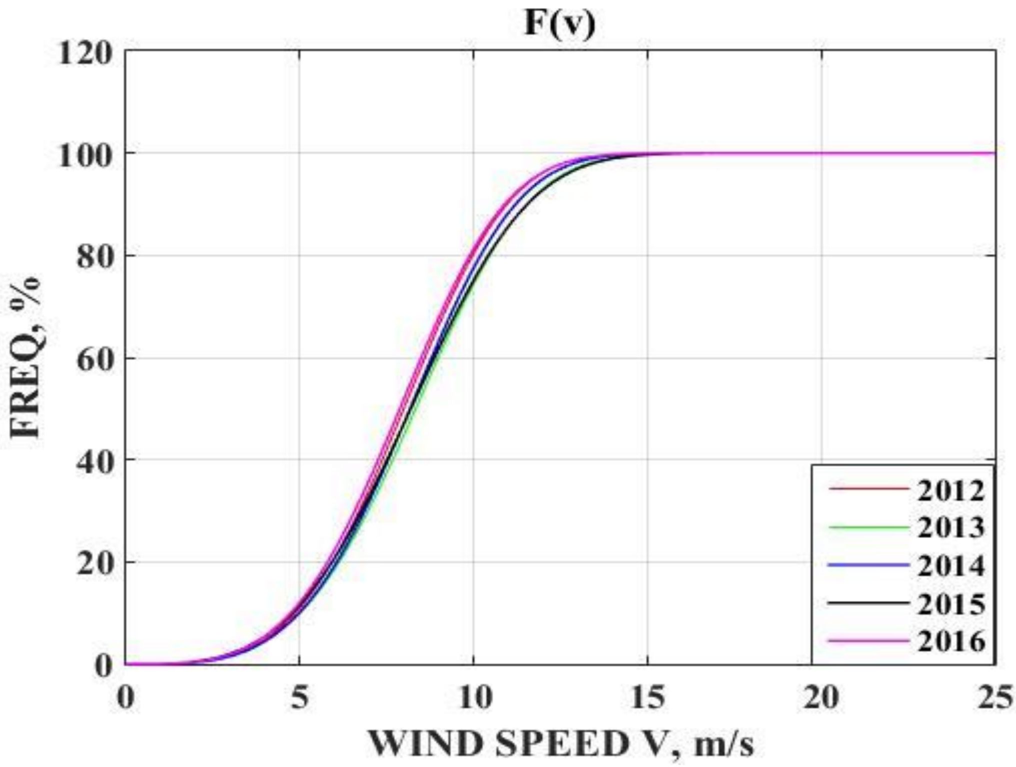

Figure 9: Cumulative wind speed density at 50 m height period 2012-2016

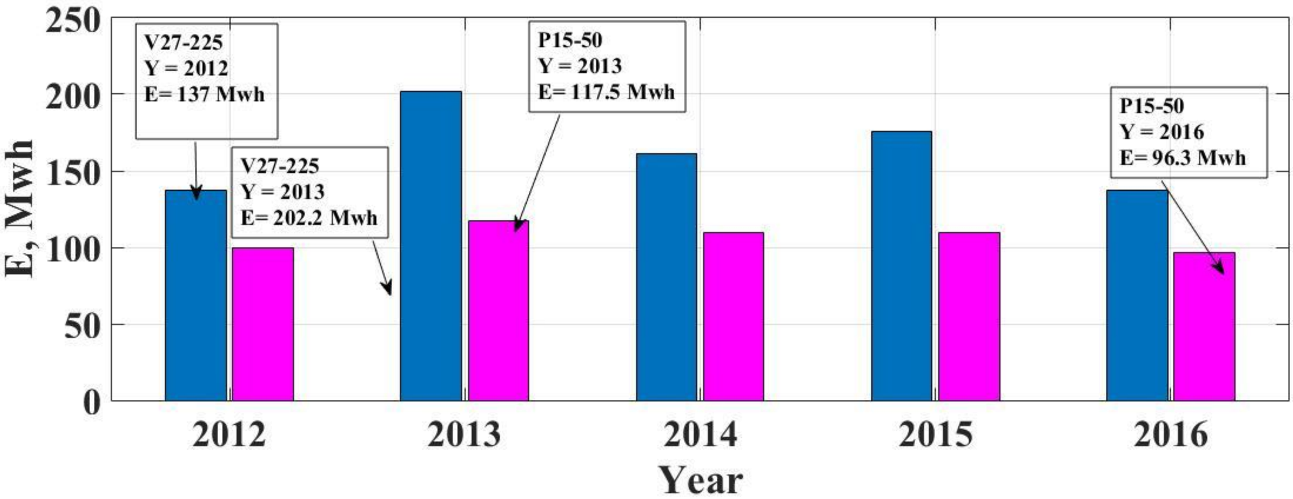

Figure 10: Comparison the value of energy using wind turbine p15-50 m and Using V27-225 wind turbine at 30 m height

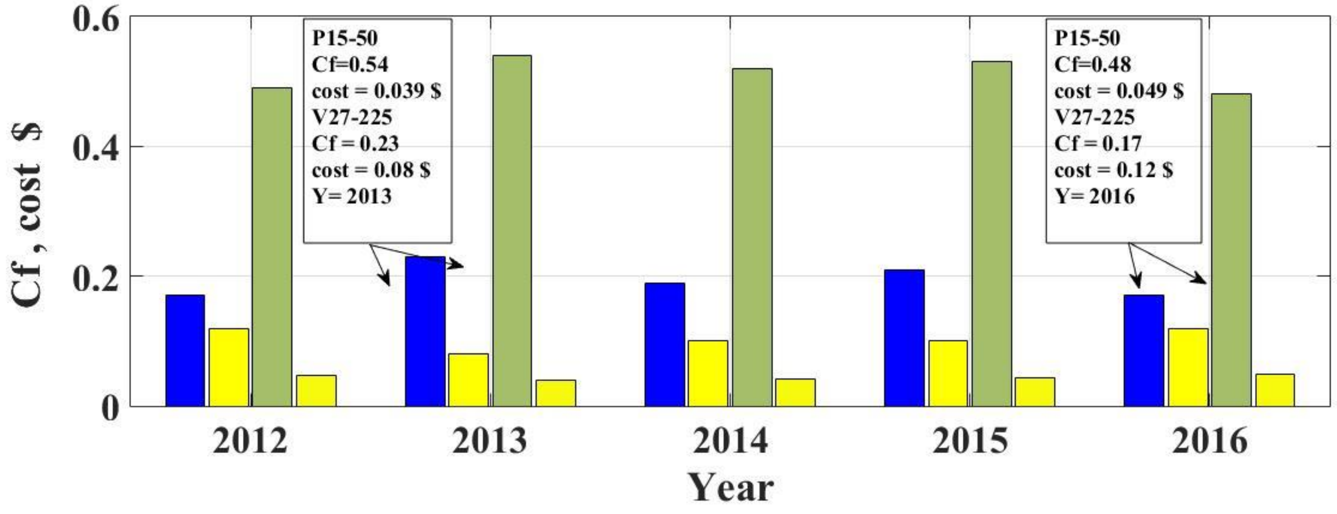

Figure 11: Comparison between the value of capacity factor (Cf) and coast using wind turbine p15-50 and Using V27-225 wind turbine at 30 m height

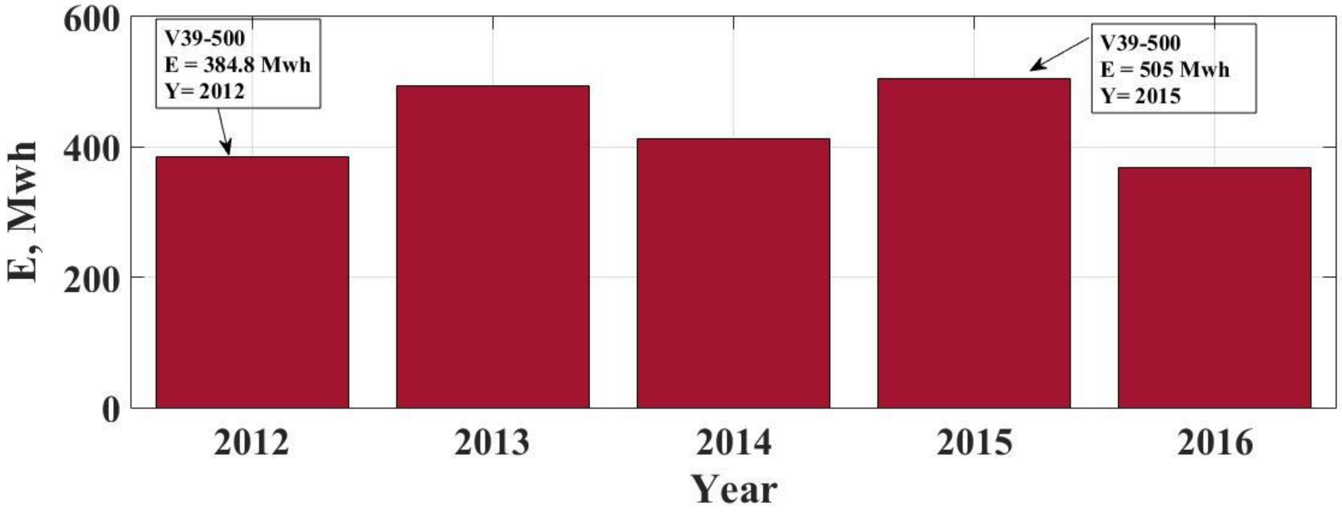

Figure 12: The value of energy using wind turbine V 39-500 At 50 m height

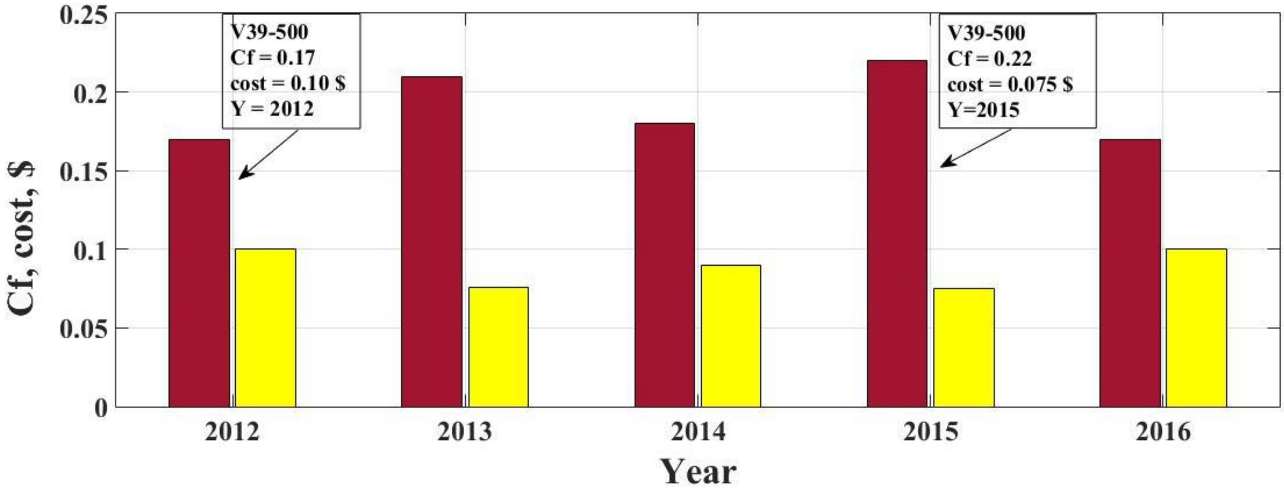

Figure 13: Comparison the value of capacity factor (Cf) and coast using wind turbine V 39-500 At 50 m height

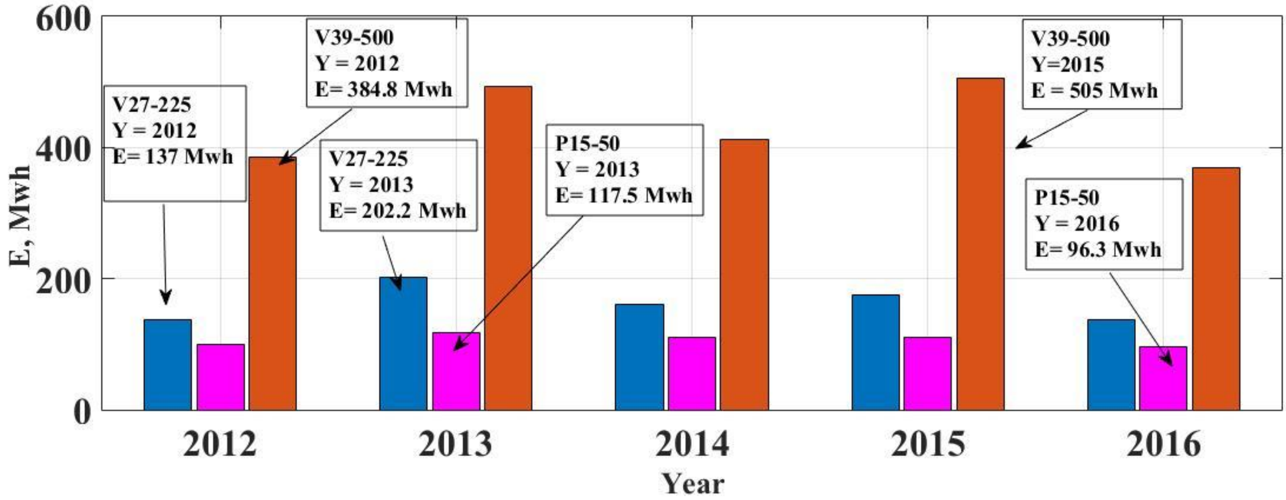

Figure 14: Comparison the value of energy using wind turbine p15-50 m and Using V27-225 wind turbine at 30 m height and using V 39-500 wind turbine at 50 m height

CONCLUSION

It is concluded that the Weibull distribution using the energy pattern factor (EPF) method is a useful technique to conduct wind speed analysis from observed wind speed data at, Misurata in western Libya. From the observed wind speed data during for five years (2012-2016), the maximum values of Weibull shape parameters were 3.7 and 3.8 at 30 m and 50 m height respectively and the maximum Weibull scale parameters were 9.2 and 9.6 m/s at 30 and 50 m height respectively.

As a result of this study Misurata city area is considered a good location to generate energy from the wind where it reaches wind speed to 8.5 m / s at a height of 30 m and up to 9.1 m / s at a height of 50 m/s. It was found addition the annual energy rates of cost obtained at a height of 30 m using the turbine type P15-50 are better than turbine type 27- 225. In addition the average annual energy obtained by V 39-500 at a height of 50 m is considered to be best compared to turbines V27- 225, and p15-50.Finally by increasing the capacity factor the lower price cost (kilowatt) of the output energy production will be obtained.

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