Estimation of Wind Characteristics and Energy Yield at Different Towns in Libya

Farag Ahwide, Souhel Bousheha

***Abstract*—**A technical assessment has been made of electricity generation, considering wind turbines ranging between Vestas (V80-2.0 MW and V112-3.0 MW) and the air density is equal to 1.225 Kg/m3, at different towns in Libya. Wind speed might have been measured each 3 hours during 10 m stature at a time for 10 quite sometime between 2000 Furthermore 2009, these towns which are spotted on the bank from claiming Mediterranean ocean also how in the desert, which need aid Derna 1, Derna 2, Shahat, Benghazi, Ajdabya, Sirte, Misurata, Tripoli-Airport, Al-Zawya, Al-Kofra, Sabha, Nalut. The work presented long term "wind data analysis in terms of annual, seasonal, monthly and diurnal variations at these sites. Wind power density with different heights has been studied. Excel sheet program was used to calculate the values of wind power density and the values of wind speed frequency for the stations; their seasonally values have been estimated. Limit variable with rated wind pace to 10 different wind turbines need to be been estimated, which is used to focus those required yearly vitality yield of a wind vitality change framework (WECS), acknowledging wind turbines extending between 600 kW and 3000 kW).

***Keywords*—**Energy yield, wind turbines, wind speed, wind power density.

I. Introduction

WIND is an abundant resource available in nature that could be utilized by mechanically converting wind power to electricity using wind turbines. Libya can have a rich start with a traditional fossil fuel reserve, as well as a rich of a renewable vitality assets for example, such that sun based What's more wind. Of these, the wind seems to be the most suitable renewable energy resource for electricity production. At the meteorological stations in Derna and Benghazi, wind data have been recorded over 10 years, so the seasonal variation of the measured and calculated frequency distribution of the wind speed at this site could be analyzed. The main aim of this paper is to present an analytical method to choose suitable large wind turbines with low rated wind speed and high capacity factor at this site [1].

II. Wind Characteristics and Data Analysis

Those exhibits contemplate will make clinched alongside light for estimations over each three hours wind velocity to ten town picked stations along the individuals to float from guaranteeing Mediterranean sea zone Furthermore. Sahara zone in Libya was made toward tallness starting with asserting 10 m in ground level. Meteorological control Previously, Tripoli provided for the majority of the data to a period of more than 10 quite some time [2]. Fig. 1 indicates the imply wind velocity variety in the least sites; twelve-month wind pace might have been inside the cutoff points of 6. 0 m/s did both Benghazi and Derna towns, same time equivalent to 5 m/s to each of the destinations Misurata, Sabha and al Kofrah Also short of what 5. 0 m/s Previously, Nalut site, same time again, it diminished to 4. 0 m/s over every of the locales Zuarah, Tripoli, Sert, Ajdabya, Shahat. Fig. 2 shows the average monthly wind speed for all stations, the wind speed has a maximum value of 6.8 m/s at Benghazi in February and a minimum value of 1.7 m/s at Ejdabya in November. This zone is characterized by sea-land winds. From Fig. 3, it might be made that high-water speeds happen in the winter Furthermore spring seasons, that's in light might be an aftereffect of the Mediterranean ocean optional depressions. Fig. 4 shows the average monthly wind speeds for different seasons. During a winter season, the wind speed level at three stations Benghazi, Derna, and Misrata reaches high values of 5.3–6.8 m/s, these stations are located on the coast of Mediterranean Sea zone. Benghazi town recorded the best average wind speed during February with 6.8 m/s at 10-meter height. While in Sabha, Al-Kofrah and Benghazi towns which are located on the coast of Mediterranean Sea zone and Sahara zone have high values of average wind speed in the spring season with 5.8–6.8 m/s, where the maximum value is recorded in Benghazi during April with 6.8 m/s. Over a sunny season, the wind velocity level achieves 6. 0 m/s In Benghazi Throughout July.

A. Wind Speed and Wind Power Density with Height

1. Wind Speed Variation

In this study, the annual behavior of the wind speed, averages of three hours values of wind speed were used to get yearly mean values for an all towns. The case study of Derna–Libya, wind speed data measured every 3 hours for 10 years from used in order to indicate the variation in the importance of changes in height, as shown in Figs. 4-6. The variation in wind speed with elevation influences both the assessment of wind resources and the design of wind turbines. While, the data direction and wind speed with heights up to 80 meters, were estimated in the same manner used in the previous research published and submitted by F. Ahwide and A. Spena [3]. Monthly and annually variations of wind speed have been estimated for Derna site (as shown in Figs. 4 and 5), the mean speed values at 10 m height are shown in Fig. 4. It's frequency from 5.1 m/s to 6.4 m/s, for years, 2006,2004 respectively. This mean wind speed for 10 years was 5.67 m/s, also this figure shows mean wind speeds at certain heights 20, 40, 60, 70, 100 and 125m, it can be seen that the marked changes in

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the mean wind velocity at different heights.

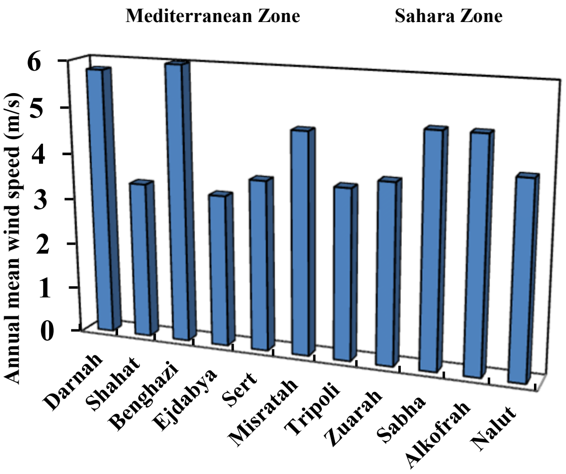

Fig. 1 Annual average wind speed for selected stations

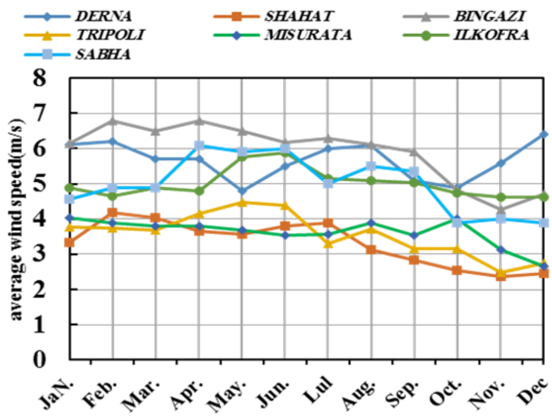

Fig. 2 Average monthly wind speeds for selected stations

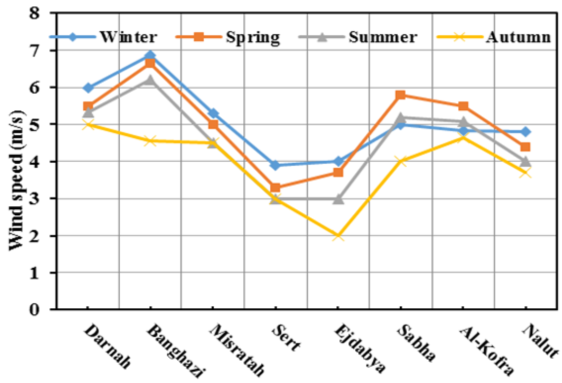

Fig. 3 Average monthly wind speed at different seasons

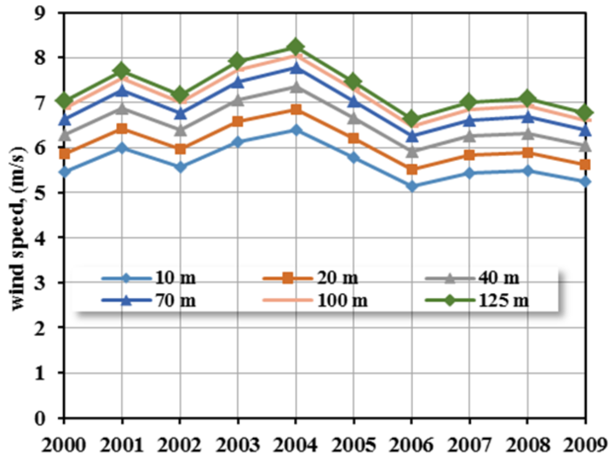

Fig. 4 Average wind speed with different heights at Derna

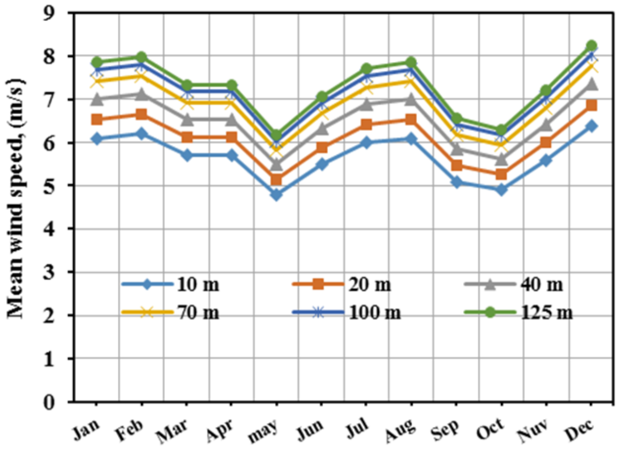

Fig. 5 Monthly wind speed with different heights at Derna

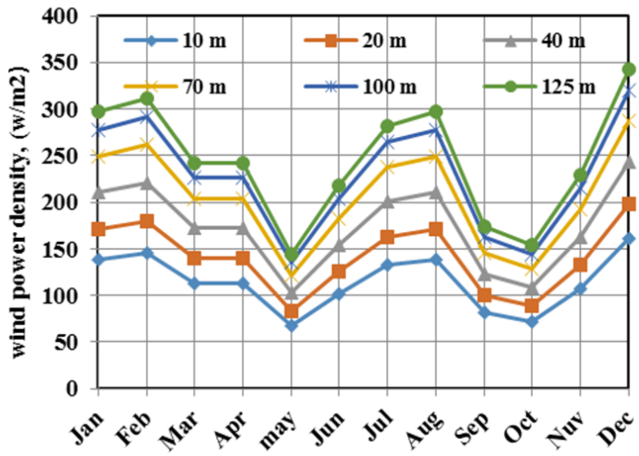

Fig. 6 Monthly of wind power density with heights at Derna

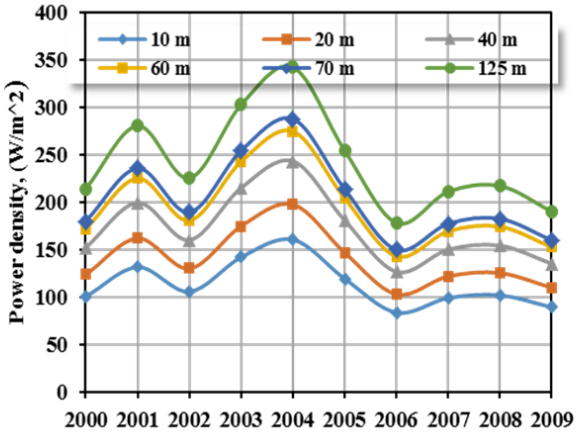

Fig. 7 Annual wind power density with heights at Derna

2. Frequency Distribution of Mean Wind Speed

Annual mean wind speed has been estimated from the histogram of the frequency distribution of mean wind speed for a period of 10 years, these sites are on the coast of Libya and others in the desert (Derna1, Derna2, Shahat, Benghazi, Ajdabya, Sirte, Misurata, Tripoli-Airport, Al-Zawya, Al Kofrah, Nalut, Sabha), and the wind characteristics have been analyzed based on long-term measured data of daily wind speeds, 3-hourly measured wind data at 10 m height, which are obtained from meteorological station. The analysis of wind data included wind data, each 3-hour, which has been recalculated to represent the mean wind speed (as shown in Fig. 1). The mean wind speed is the most commonly used indicator of wind production potential were defined as [4]:

$$V = \frac{1}{N}\sum_{i=1}^{N} V_i$$

where N is the sample size and Vi is the observation value, the case study of Derna town with heights, by taking a summation of multiple each wind speed in its probability, the mean wind speed was 5.67 m/s in Derna, as shown in Figs. 8-10.

B. Wind Power Density Variation

Monthly and annually of average wind power density, PA, is the average available wind power per unit area has been calculated at different heights from the equation, as shown in Fig. 6 and 7, these figures indicate that the maximum power density is 350 W/m² in 2004 and the overall mean power density is 300 W/m² at 125 m height. Also, these figures show the change of power density at various heights. The wind power density was calculated from equation PA=12ρ1Ni=1NVi3[W/m2], this has rendered to design the diagrams of average wind speed duration (V) (as shown in Fig. 8) and of the specific power (P'), (as shown in Fig. 9) according to a coefficient of the conventional use of time u = h/8760 % [3]. The results obtained by using the same mechanism calculations of our previous article [5].

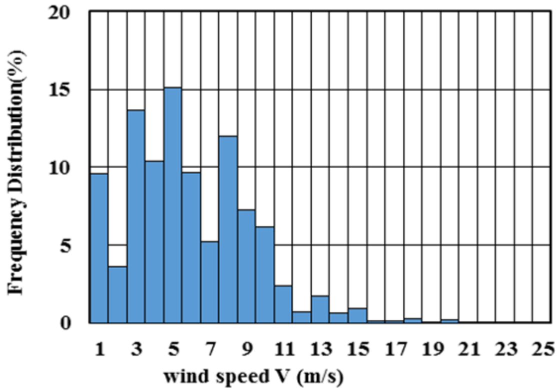

Fig. 8 Histogram of frequency distribution at Derna, 10 m height

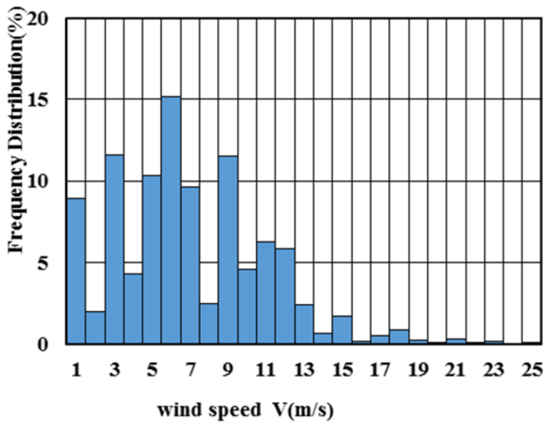

Fig. 9 Histogram of frequency distribution at Derna, 40 m height

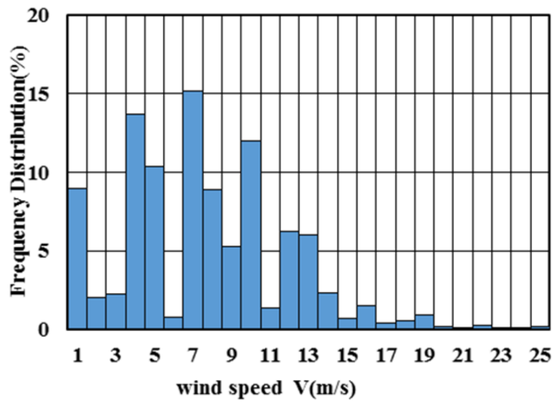

Fig. 10 Histogram of frequency distribution at Derna, 80m height

C. Estimated Power Curve of Used Wind Turbines

The power curve for a wind turbine shows this net power output as a function of wind speed. As shown in Figs. 13 and 14, (for an 80 m and 112 m diameters of wind turbines), these curves feature three key wind speeds:

a) Cut- in wind speed: This is the wind speed at which the wind turbine will start generating power- typical cut- in wind speeds are 3 to 5m/s.
b) Nominal wind speed: This is the lowest speed at which the wind turbine reaches its noumenal power output. As

shown in Fig. 10, no useful power output can be produced from Vestas (V 80 – 2 MW) at the wind speed below 4m/s due to the mechanical losses, while for wind speed between 5-13 m/s the power output has increased by increasing wind speed rapidly. As for as, the wind speed equal the cut-out velocity - the wind speed at which the wind turbine will be close down to keep loads What's more generator force starting with arriving at harming levels [6]. This applies to most of the wind turbines used with minor differences in the characteristics of each turbine are shown in Table I.

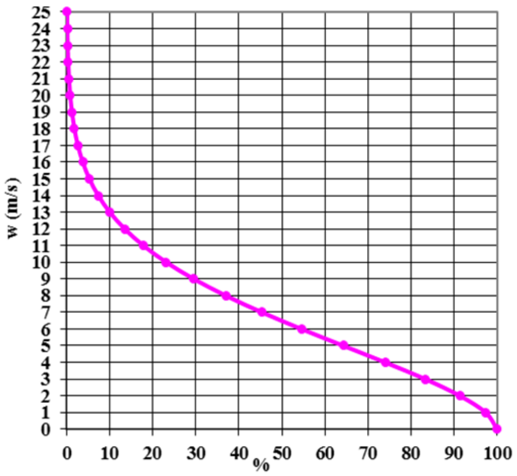

Fig. 11 Average wind speed duration, Derna-Libya, (2000 to 2009)

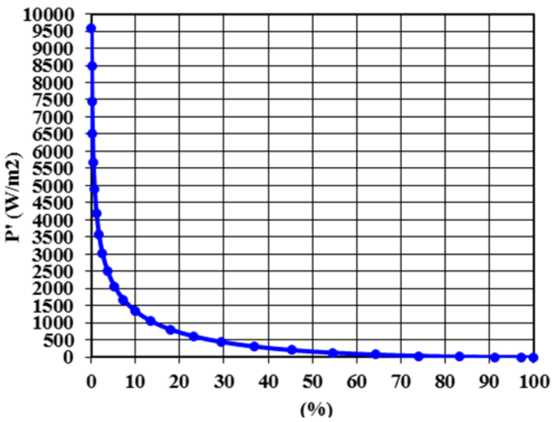

Fig. 12 Specific power durations Derna- Libya, 10 years

TABLE I
MAIN CHARACTERISTICS OF WIND TURBINES USED

Vestas Wind Turbines (V80-2MW) & (V112-3MW)		
Turbine model	Vestas V80-2.0MW	Vestas V112-3MW
Rated power	2000 kW	3000 KW
Swept area	5027 m^2	9852 m^2
Rotor diameter	80 m	112 m
Number of blades	3	2
Cut-in wind speed	4 m/s	3 m/s
Rated wind speed	16 m/s	12 m/s
Cut-out wind speed	25 m/s	20 m/s
Hub hight	80m	84 m

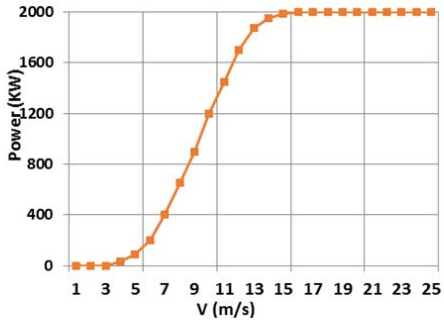

Fig. 13 Power curve of Vestas 112–3 MW wind turbine

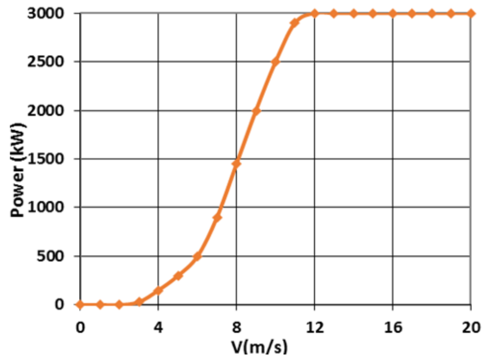

Fig. 14 Power curve of Vestas 112 – 3 MW wind turbine

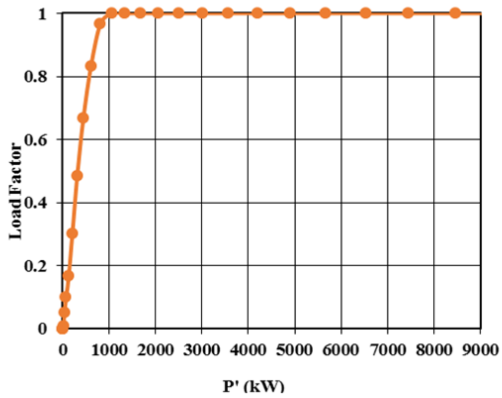

Fig. 15 Load Factor curve of Vestas (V 112 – 3 MW)

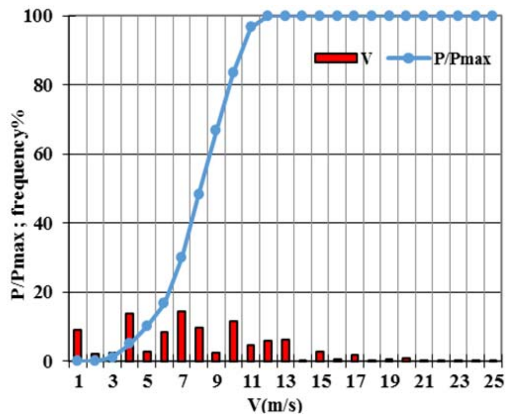

Fig. 16 Load Factor Distribution and wind speeds frequency

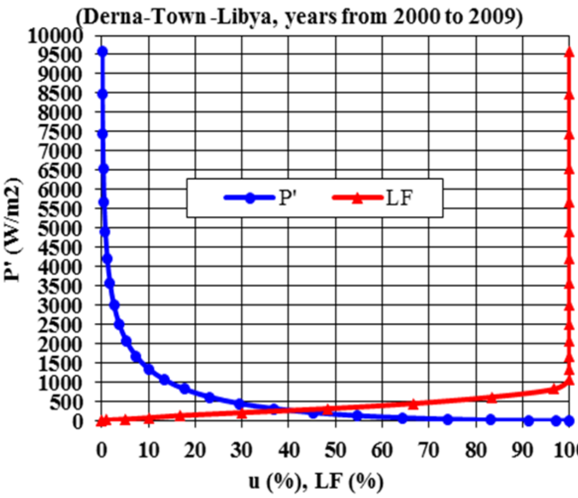

Fig. 17 Specific power (P') and load factor (L.F.) durations

III. Energy Yield and Load Factor

The calculation of the annual energy yield of a wind turbine is of a fundamental importance in the evaluation of any project. The future wind speed distribution is combined with the facility curve of the rotary engine to provide the energy generated at every wind speed and therefore the whole energy generated throughout the year. It is usual to perform the calculation using 1m/s wind speed bins as this gives acceptable accuracy. The annual energy expressed mathematically as:

$$\text{Energy Yield} = \sum_{i=1}^{i=n} H(i) * P(i) \text{ (GWh)}$$

where H(i) is the number of hours in wind speed bin i and P(i) is the power output at that wind speed [5]. The capacity factor Cf, is a very significant index of productivity of a wind turbine. It speaks to the portion of the aggregate vitality conveyed over a period, Eout, isolated by the greatest vitality that could have been conveyed if the turbine was utilized at most extreme limit over the whole-time frame, Er ¼ 8760Pr. The capacity factor (C.f) is the annual capacity factor of a wind turbine can be calculated as [6]:

$$\text{C. F}=\frac{\text{Eout(KWh)}}{\text{Er}} \text{ C. F} = \frac{\text{Eout(KWh)}}{\text{Er}}$$

From the curve of Fig. 13, the load factor (L.F) was calculated (as shown in Fig. 15), which is defined as the ratio between the instantaneous power and the maximum load of wind turbine, in relation the specific power P' is corresponding to each wind speed (V) according to equation, $\overline{P}/A = (1/2)\,\rho \frac{1}{N}\sum_{i=1}^{N} V_i^3$ [W/m2], [7]. From the curve of Fig. 15 the load factor (L.F) was calculated and designed its diagram as in Fig. 16, which is defined as the ratio between the instantaneous power and the maximum load of wind turbine, in relation of specific power (P'), corresponding to each wind speed (V) according to an equation of wind power density. Fig. 16 shows the curve of load factor superimposed on the frequency distribution of wind speeds of Derna location at 80 m height. The Proportionality between the power output and the relative frequency distribution also has been noted.

A. Energy Yield Using (V80-2MW& V112-3MW)

The annual energy yield was evaluated using the Excel work sheet and Ahwide's method at different towns in Libya, considering wind turbines ranging between 0.6 MW and 3.0 MW). The performance of the load factor (L.F) according to the conventional time use coefficient (Fig. 17) has been associated with corresponding diagram of local duration of P'(u). By multiplying each value of LF (u) for the duration (u) of the corresponding specific power P'(u) we can obtain an energy yield function of time of the wind turbine (Fig. 18) product of a quantity characteristic of the machine (L.F) for a quantity characteristic of the site (u (P')):

$$\text{Energy Yield} = \text{L.F*u(P')} \text{ [7]}$$

It is proposed to adopt the integral yield as an indicator of the viability of the choice and the dimensioning without taking into account the value of power coefficient (Cp) of a wind turbine which need those real execution for figure 14. Those most extreme of variety energy attained through the vitality yield and the best possibility of the site and identifies at the same occasion when those particular energy to be made for the undertaking to Derna town, the function of the energy yield assumes values less than 20%, insignificant for the purposes of a power installation [8]. The annual energy yield was evaluated using Ahwide's method and Excel work sheet, as shown in Figs. 18, 19, and 24. In Benghazi and Derna towns recorded the highest values, equaling, compared to the rest of towns studied. As for an estimation of annual energy yield, considering wind turbine (V80- 2 MW) (as shown in Table II).

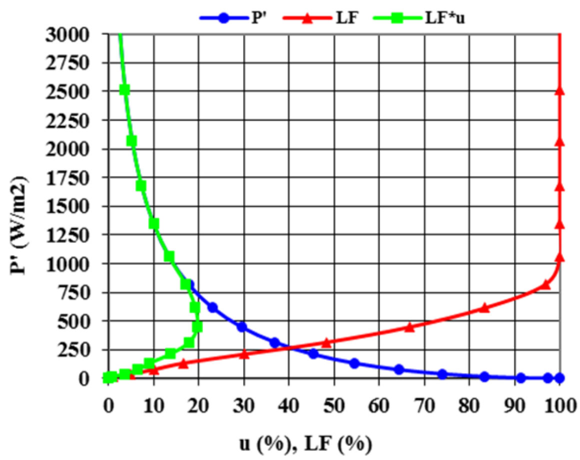

Fig. 18 Specific Power and Moment of (L.F*u), Derna-Town

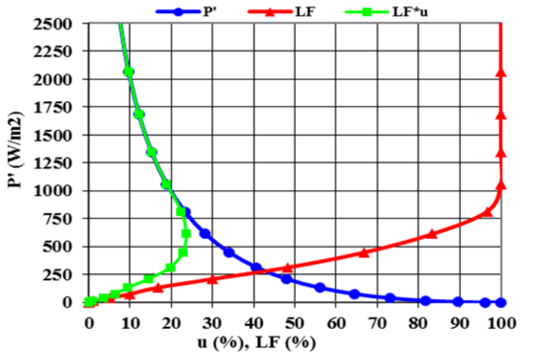

Fig. 19 Specific Power and Moment of (L.F*u), Benghazi-Town

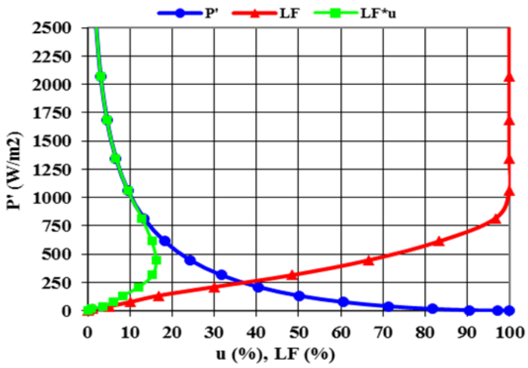

Fig. 20 Specific Power and Moment of (L.F*u), Sabha-Town

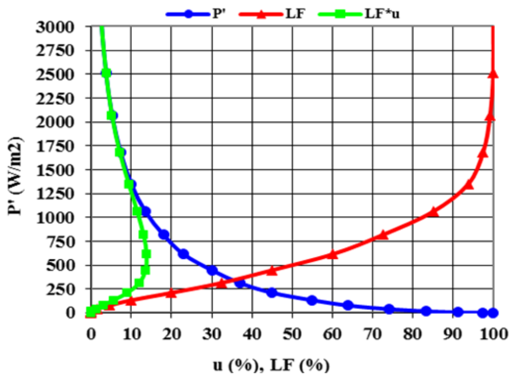

Fig. 21 Specific Power and Moment of (L.F*u), Derna-Town

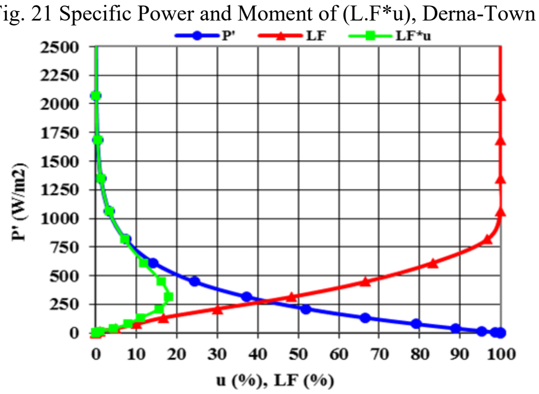

Fig. 22 Specific Power and Moment of (L.F*u), Benghazi-Town

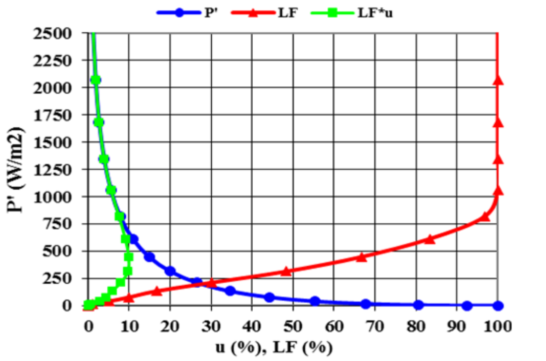

Fig. 23 Specific Power and Moment of (L.F*u), Misratah –Town

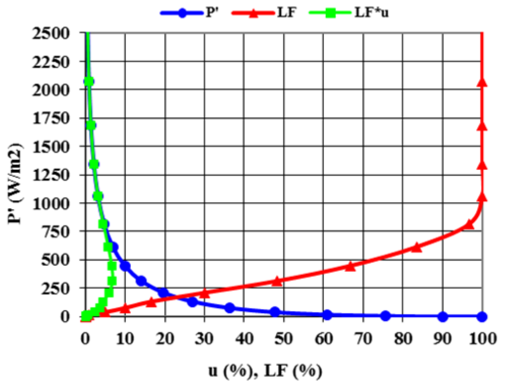

Fig. 24 Specific Power and Moment of (L.F*u), Tripoli-Town

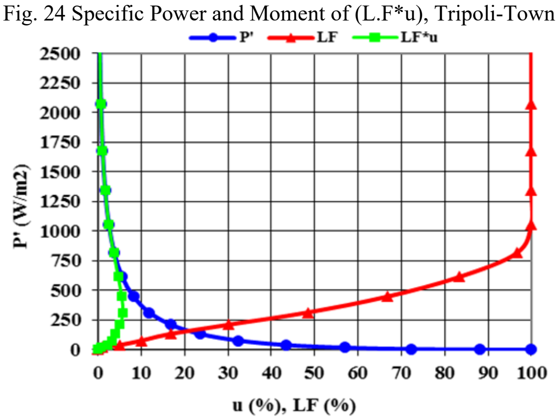

Fig. 25 Specific Power and Moment of (L.F*u), Shahat-Town

IV. Conclusions and Recommendations

Electricity generation was evaluated using Ahwide's method and Excel worksheet, at different towns, which are Derna 1, Derna 2, Shahat, Benghazi, Ajdabya, Sirte, Misurata, Tripoli-Airport, Al-Zawya, Al-Kofra, Sabha, Nalut. Considering wind turbines ranging between (0.6 MW and 3 MW) and the air, density is equal to 1.225 Kg/m3. Two turbines were evaluated to assess their wind energy capacity in the study area. In Benghazi and Derna recorded the highest values, compared to the rest of turbines studied, equaling (16.30 GWh, 12.48 MW) for vestas' wind turbine (V112/3.0 MW) and equaling (8.36 GWh, 6.48 GWh) for V80-2.0MW). These values encouraged us to take advantage of wind power to achieve economic benefits, it requires procedure an economic assessment, to know the cost of kilowatts of electricity generation produced from wind turbines studied. The capacity factor of wind turbines used has been calculated, considering wind turbines have the same hub height, rotor diameter, rated power and different rated wind speed. The capacity factor is greater than with wind turbines characterized by lower rated wind speeds, also the use of wind turbines with lower rated wind speeds will produce more energy in a year than wind turbines with higher rated wind speeds. The important result derived from this study encourages the construction of wind farms at Benghazi and Derna towns for electricity generation using large wind turbines each having a capacity of greater than 1000 kW and we recommend usage of the wind turbine model ‘‘Vestas V80-90/ 2.0 MW" (Gamesa 80-90/2.MW) at 80m hub height.

TABLE II
ENERGY YEALD OF WIND TURBINES USED

Vestas Wind Turbines (V80-2MW)& (V112-3MW)		
Towns	Vestas V80-2.0MW	Vestas V112-3MW
	Energy Yield (GWh)	Energy Yield (GWh)
Benghazi Town	8.314 GWh	16.3 GWh
Derna Town	6.480 GWh	12.48 GWh
Sabha Town	4.99 GWh	9.78 GWh
Al- Kofra Town	3.77 GWh	8.39 GWh
Misratah Town	-	6.04 GWh
Tripoli Town	-	5.18 GWh
Shahat Town	-	3.3 GWh

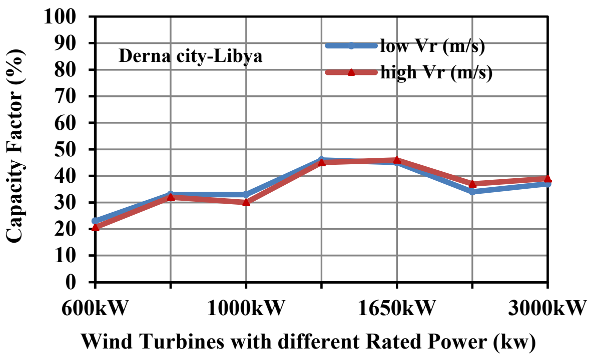

Fig. 26 Annual capacity factor for different wind turbines

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