International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 6 (2019), pp. 784-792

Evaluation of the Wind Energy Potential in Lebanon's Coastal Regions using Weibull Distribution Function

Youssef Kassem[1, 2,*], Hüseyin Gökçekuş[1], Moaad M. Mizran[2], Salah M. Alsayas [2]

[1]*Department of Civil Engineering, Civil and Environmental Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus.*

[2]*Department of Mechanical Engineering, Engineering Faculty, Near East University, 99138 Nicosia (via Mersin 10, Turkey), Cyprus.*

*****Correspondence Author*

Abstract

In the present paper, the wind potential at some selected regions in Lebanon using Two-Parameter Weibull distribution function is investigated. In addition, two methods called maximum likelihood (MLM) and moment (MM) methods are used to estimate the parameters of Weibull function. The Kolmogorov–Smirnov (KS) statistic and Chi-Square (CS) statistic are calculated in order to assess the reliability of the method. It is found that the MM method is provided a good fit to the actual wind speed data. In addition, the wind power densities are determined at different hub height using power law method. The result showed that the wind speeds at the selected study are within the range of 2.627 m/s and 3.56 m/s. Furthermore, the wind speed densities are varied between 14.634W/m2 and 25.280W/m2, which classified as poor wind power. Consequently, the result demonstrated that the small-scale wind turbines are suitable to be used for producing electricity in the studied regions.

Keywords: Lebanese coastal regions; Weibull statistical distribution; wind speed characteristics; wind power density

1. INTRODUCTION

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

Wind energy is recognized as a significant source for reducing and consumption of fossil fuel [3, 4]. Additionally, wind energy is a clean, environmentally friendly and inexhaustible energy source [5-7]. An alternative source such as wind is needed to reduce GHG emissions [7]. Wind energy can be used as a power generator for home, businesses and so on [7-10]. The wind turbine is used to convert the wind speed into electricity [11].

Several researchers have studied wind and solar potential of various locations in the world. For instance, Alayat et al. [12] evaluated the wind potential at an eight-selected location in Northern Cyprus. They concluded that small-scale wind turbine could be used for generating electricity in these locations. Kassem et al. [13] 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 potential of wind energy 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 the Weibull distribution function. The results indicated 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 wind farm project could be feasible at some certain location in Malaysia.

The main purpose of this paper is to evaluate the wind potential in three regions, namely, Beirut, Sidon, and Tripoli, in Lebanon. The data consist of daily, monthly and yearly wind speed data during seven years period (2010-2016) and measured at 10m height. The Weibull distribution function is used to analyze the wind speed characteristics of the selected regions. Two methods (maximum likelihood (MLM) and moment (MM)) methods are utilized to determine the parameters (shape and scale parameters). In order to estimate the wind speed and wind power density at different hub heights, the power law model is used.

2. RENEWABLE ENERGY IN LEBANON

The clean power source is the power that generated using natural energy such as hydro, solar, and wind and so on. These natural sources are free and known as renewable energy sources. Currently, the electrical energy in Lebanon is generated by oil product, hydro-power, and importation as shown in Figure 1. It is observed that approximately 95% of the energy generated by oil product and 0.3% by renewable sources. In addition, according to the global atlas map, the wind power density at the top of the mountains area is about 1500MW, but the total wind power investment in these areas may be very expensive [17]. Generally, the wind energy potential is depended on the measurement of wind speed at specific regions and it can be collected from meteorological stations. Several researchers have studied the wind potential at several locations in Lebanon [18-24].

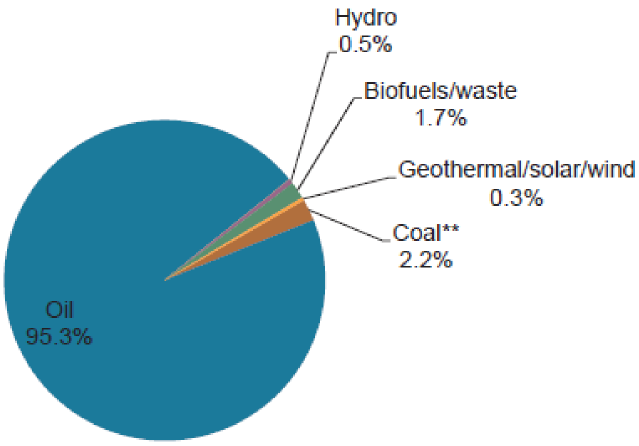


Figure 1. Share of total primary energy supply in 2015 [25]

3. ANALYSIS PROCEDURE

3.1. Wind speed probability distribution

In the present study, probability and the cumulative density function of Weibull distribution with two parameters are used to study the 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) [26-30]:

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

$$F(v) = 1 - e \quad (2)$$

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

Based on the previous scientific researches, several methods have been used to determine the parameters of Weibull distribution function [31]. In this study, two methods are used to estimate the parameters of the distribution function.

3.1.1 Maximum likelihood method (MLM)

The MLM is a mathematical technique used to estimate the Weibull parameters through a numerical iteration. The Weibull parameters k and c values are calculated by the following equations

$$k = \left(\frac{\sum_1^n v_i^k ln(v_i)}{\sum_1^n v_i^k} - \frac{\sum_1^n ln(v_i)}{n}\right)^{-1} \quad (3)$$

$$c = \left(\frac{1}{n}\sum_1^n v_i^k\right)^{1/k} \quad (4)$$

3.1.2 Moment method (MM)

The oldest method used to determine the parameters of the Weibull distribution function is MM. The Weibull distribution can be estimated through an iterative resolution of Eqs. (5) and (6).

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

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

where $\bar{v}$ and σ are the mean wind speed and the standard deviation of the observed data of the wind speed, respectively.

3.2 Variation of Weibull parameters with height

Power law model is widely used to estimate the wind speed (v) at a different hub height of wind turbine (z) [32]. It is expressed as

$$\frac{v}{v_{10}} = \left(\frac{z}{z_{10}}\right)^{\alpha} \quad (7)$$

where v_{10} is the wind speed measured at 10m height (z_{10}), and α is the surface roughness coefficient (Eq. (8)).

$$\alpha = \frac{0.37 - 0.088ln(v_{10})}{1 - 0.088ln(z_{10}/10)} \quad (8)$$

The Weibull parameters at measurement height of 10m as [33]:

$$c(z) = \mathrm{c}_0\left(\frac{z}{z_{10}}\right)^n \quad (9)$$

$$k(z) = \frac{\mathrm{k}_0\left[1 - 0.088\ln\left(\frac{z_{10}}{10}\right)\right]}{\left[1 - 0.088\ln\left(\frac{z_{10}}{10}\right)\right]} \quad (10)$$

where c_0 and 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 [33].

$$n = \frac{[0.37 - 0.088ln(\mathrm{c}_0)]}{1 - 0.088\ln\left(\frac{z}{10}\right)} \quad (11)$$

3.4 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 [32]:

$$\frac{\bar{P}}{A} = \frac{1}{2}\rho\bar{v}^3 \quad (12)$$

where $\bar{P}$ is the available power for wind per unit area in W/m^2 and ρ 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 [34]:

$$\bar{P} = \frac{1}{2}\rho c^3 \Gamma\left(1 + \frac{3}{k}\right) \quad (13)$$

The annual wind energy density (E) inWh/m^2 can be estimated with the following equation [32]:

$$E = \bar{P}T \quad (14)$$

where T is period (T = 8760h).

4. WIND DATA MEASUREMENT

In this work, wind speed data for the 7-year period (2010-2016) are used. The data is measured at a height of 10m. The location and regions specific information is shown in Figure 2 and Table 1, respectively.

Figure 2. Location of the sites used in this study

Table 1. Description of the locations

Station	Longitude (°E)	Latitude (°N)	Period records	Height [m]	Year
Beirut	35° 30'	33° 53'	2010-2016	10	7
Sidon	35° 22'	33° 33'	2010-2016	10	7
Tripoli	35° 50'	34° 26'	2010-2016	10	7

5. ASSESSMENT ANALYSIS OF MEASURED WIND SPEED DATA

The measured wind speed data are the most critical key to evaluate the characteristics of wind energy in specific regions. The evaluation of wind potential can be analyzed using hourly, daily or monthly wind speed data using distributions function. Power law model is also utilized to evaluate the wind potential at a specific location in order to estimate the wind speed and wind power density at various heights. In this section, the characteristics of wind speed at three selected regions are discussed in details.

5.1 Daily, seasonally and yearly wind speed data at 10m height

Figure 3 illustrates the variation of mean daily and yearly wind speed at three selected regions in Lebanon. It is observed that the maximum and minimum daily wind speeds are recorded in 2015 and 2016 with a value of 3.241 m/s and 2.083m/s, respectively at Beirut. For Sidon, it is found that the minimum daily wind speed is achieved in 2016 i.e., 2.250m/s, while the maximum daily wind speed is recorded in 2011 (4.050 m/s). In addition, it is noticed that the highest and lowest daily wind speed is recorded in 2011 (4.500 m/s) and 2016 (2.500m/s), respectively. It is can concluded that Tripoli has the highest annual wind speed (3.450 m/s) compared to Sidon (3.11m/s) and Beirut (2.88 m/s).

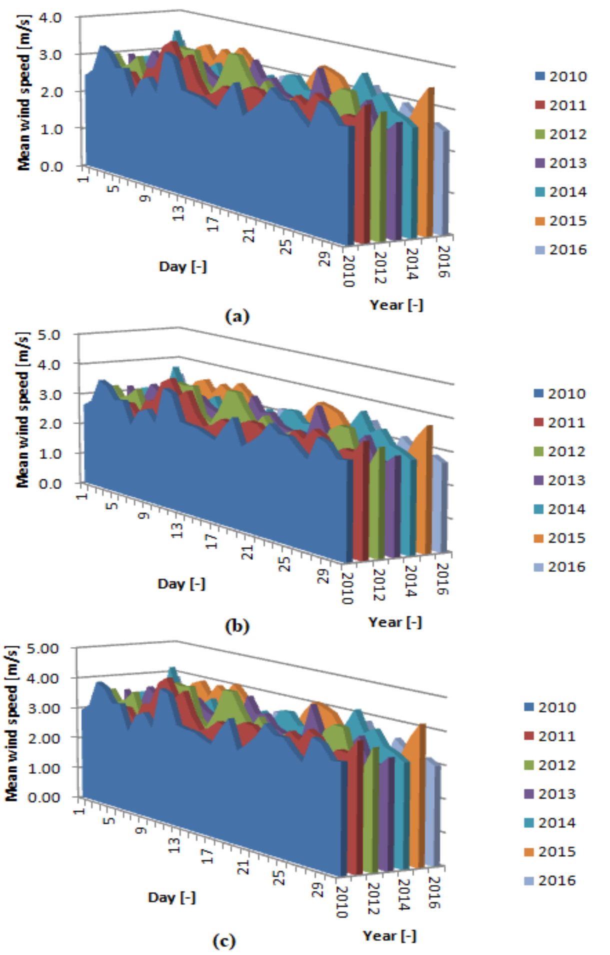
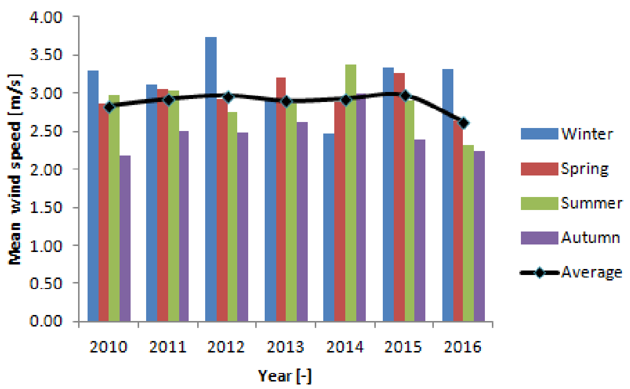


Figure 3. Mean wind speed data for three selected regions; (a) Beirut, (b) Sidon and (c) Tripoli at 10m height

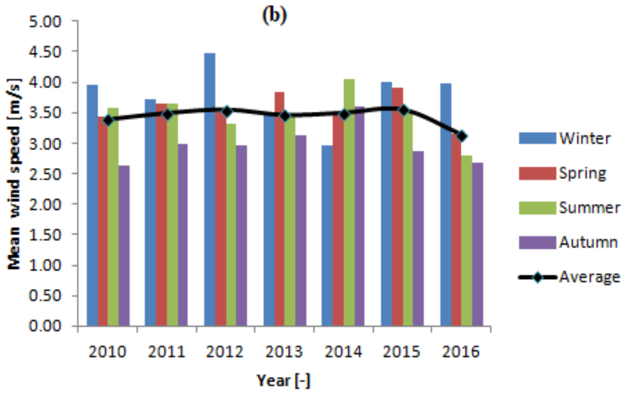
The monthly wind speed data were calculated using a simple statistical method. Figure 4 shows the variation monthly wind speed at three studied regions in Lebanon. It is found that the wind speed values in 2016 in the selected regions were decreased with a percentage of about 11% compared to the previous years. This may be due to the increase in the number of a large building, which increased surface drag and wake turbulence, and decrease wind speed as reported in Ref. [35]. Moreover, it is found that the highest wind speed is obtained in January 2012 (winter season) with a value of 5.38m/s at Tripoli, 4.84m/s at Sidon and 4.48m/s at Beirut. In addition, it noticed that the maximum wind speeds are recorded in 2014 and 2013 summer and spring season, respectively as shown in Figure 4.

5.2 Wind speed distribution function

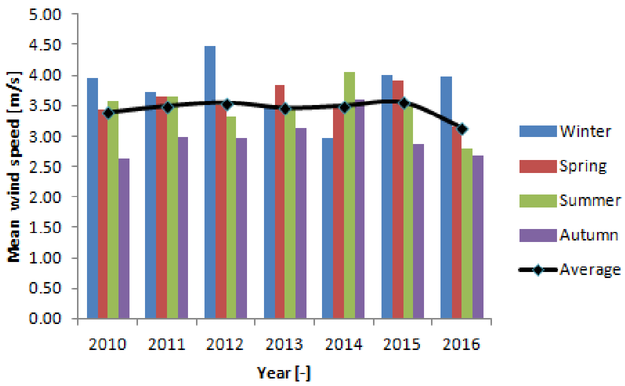
In order to calculate the wind power density at each region, the air density was assumed to be 1.23 kg/m^2 for 10m height and other heights in this study. Figure 5 compares the observed data and probability density calculated using MLM and MM methods for three selected regions. Kolmogorov-Smirnov (KS) and Chi-square (CS) are calculated in order to choose the accuracy method. The method (MLM or MM) with a minimum value of KS and CS will be selected to be the best model for the wind speed distribution at each station. Moreover, the wind power density at 10m height is presented in Tables 2. It is observed that the highest power density value was observed in Tripoli.



(a)



(b)



(c)

Figure 4. Seasonally wind speed data for three selected regions; (a) Beirut, (b) Sidon and (c) Tripoli at 10m height

Table 5. Weibull parameters and the selected method (in bold) for each station at 10m height (2010-2016)

Regions	Method	k	c [m/s]	Mean [m/s]	PWD [W/m^2]	Kolmogorov-Smirnov	Chi-square
Beirut	**MLM**	25.646	2.934	2.872	14.614	0.505	0.414
	MM	35.44	2.922	2.877	14.634	**0.440**	**<0.0001**
	Actual data	-	-	2.876	14.570	-	-
Sidon	**MLM**	25.645	3.168	3.101	18.397	0.504	0.396
	MM	35.44	3.155	3.106	18.422	**0.440**	**<0.0001**
	Actual data	-	-	3.106	18.353	-	-
Tripoli	**MLM**	25.646	3.52	3.446	25.236	0.506	0.402
	MM	35.44	3.506	3.452	25.280	**0.440**	**<0.0001**
	Actual data	-	-	3.452	25.195	-	-

International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 6 (2019), pp. 784-792

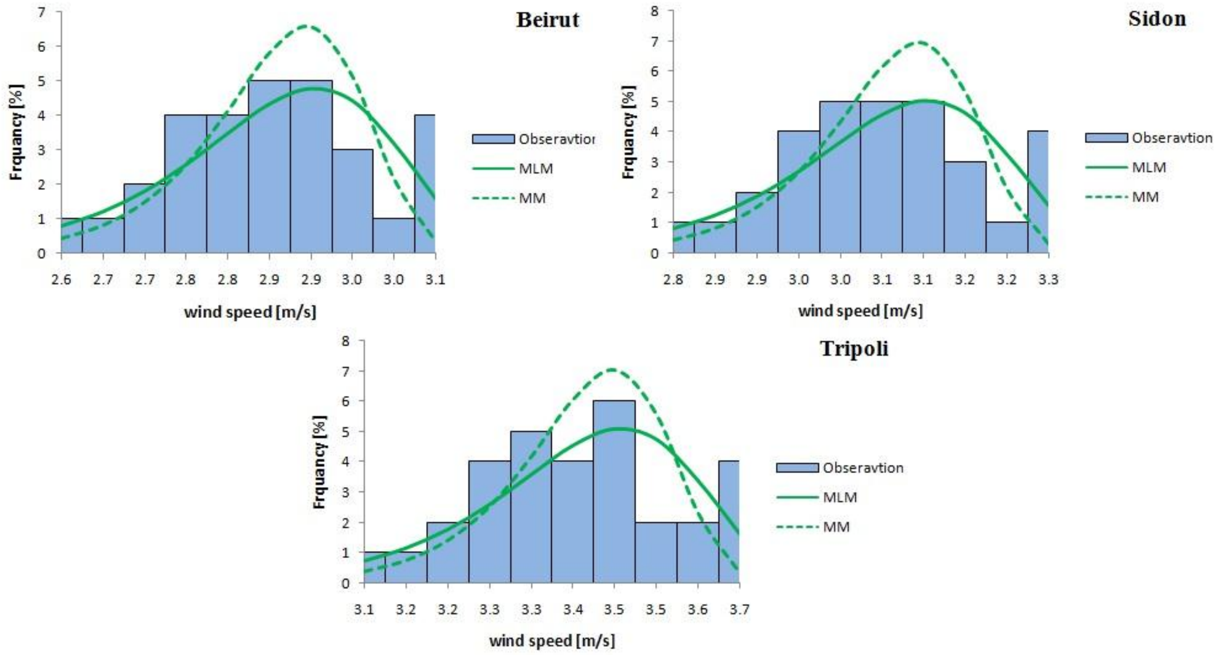


Figure 5. Wind speed probability frequency for the year 2010-2016 at 10m height

5.3 Wind speed information at various heights

The best wind speed to establish a wind turbine should be within the range of 6.7 and 11m/s [36]. Therefore, in this study, the power law model has been used to calculate the wind power density at different heights. The surface roughness (α), have been determined using Eq. (8), values for different locations of Lebanon's coastal regions are shown in Table 3.

Table 3. Roughness value for different regions in Lebanon

Regions	Roughness value (α)
Beirut	0.277
Sidon	0.270
Tripoli	0.261

In this paper, annual mean wind speed has been calculated using the value for α at various heights various from 20 to 130m. Figure 6 presents the vertical wind shear profile at six studied sites for various heights.

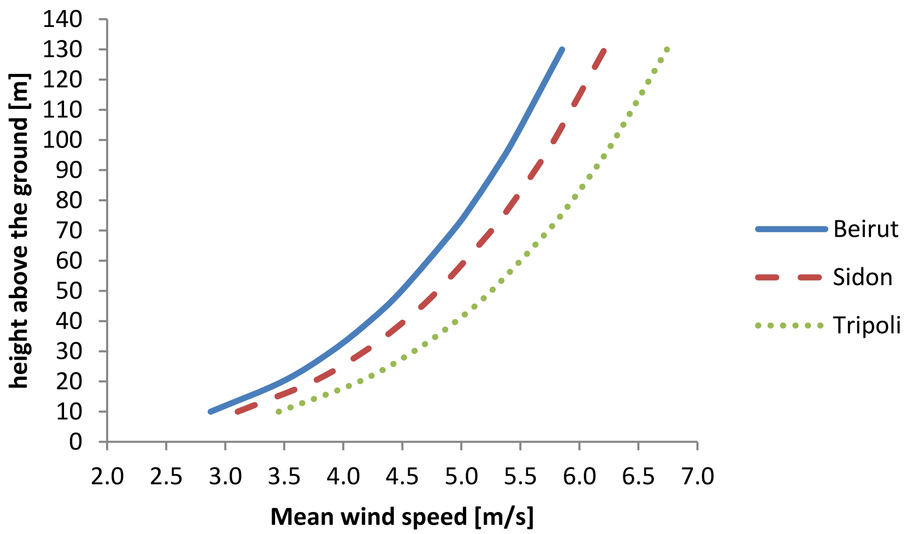


Figure 6. Vertical wind shear profile at studied sits

Using the power law model, the actual data collected at the height of 10 m is synthesized to the height of 1300 m at which wind speed will be above 6.7m/s. The 130 m synthesized data is presented in Figure 7. As per the actual data at 130 m, the synthesized data is also matched with using MLM and MM.

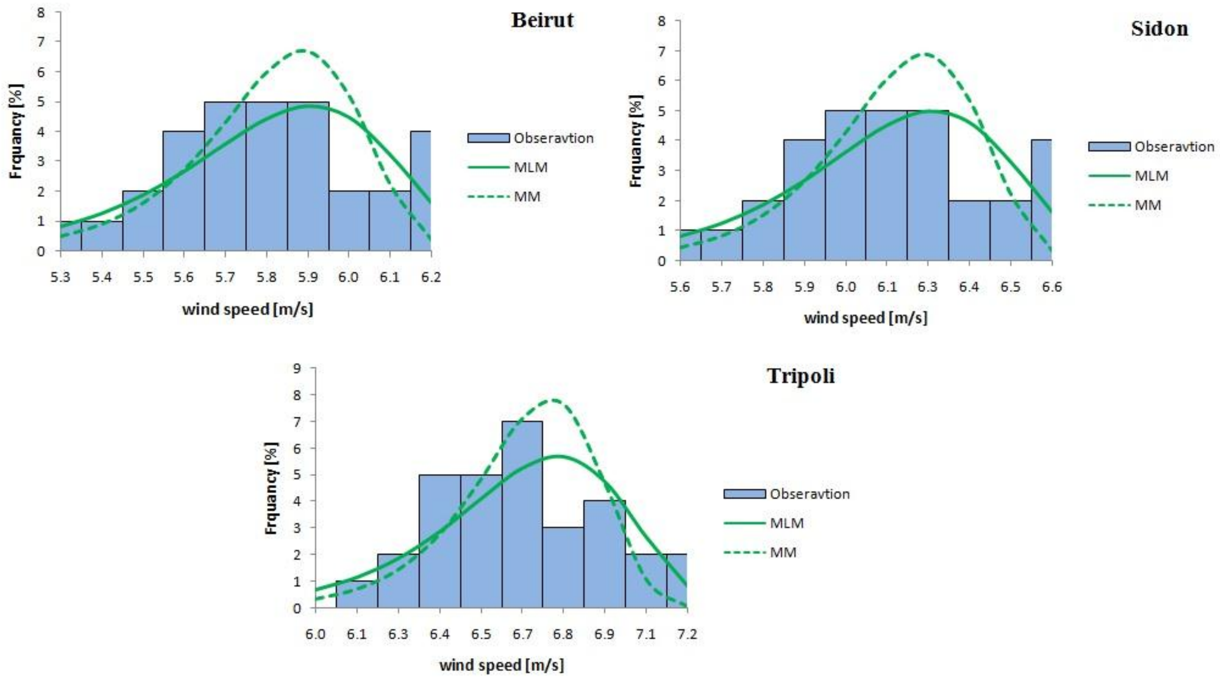


Figure 7. Wind speed probability frequency for the year 2010-2016 at 130m height

Moreover, the WPD was obtained at various heights and is tabulated in Table 4. Lebanese coastal regions have been found to have a maximum wind power density value of 59.743 and 90.330 W/m^2 at 30 and 50m heights at Tripoli. According to wind power classification [37], the WPD is considered as poor wind power at the selected study. Therefore, a small-scale wind turbine could be suitable to generate wind power at the studied regions.

Table 4. The wind power density of Lebanon's coastal regions (2010-2016)

Height	Region	Method	k	c [m/s]	Mean [m/s]	PWD [W/m^2]	Kolmogorov-Smirnov	Chi-square
30 m	**Beirut**	**MLM**	25.646	4.006	3.921	37.199	0.505	0.183
		MM	35.440	3.961	3.900	36.454	0.440	<0.0001
		Calculated	-	-	3.899	36.309	-	-
	Sidon	**MLM**	25.645	4.262	4.172	44.796	0.505	0.285
		MM	35.440	4.245	4.179	44.871	0.440	<0.0001
		Calculated	-	-	4.180	44.726	-	-
	Tripoli	**MLM**	25.637	4.689	4.590	59.654	0.507	0.195
		MM	35.440	4.670	4.598	59.743	0.440	<0.0001
		Calculated	-	-	4.598	59.548	-	-
50	**Beirut**	**MLM**	25.646	4.562	4.466	54.937	0.505	0.183
		MM	35.440	4.563	4.492	55.730	0.440	<0.0001
		Calculated	-	-	4.492	55.513	-	-
	Sidon	**MLM**	25.645	4.893	4.790	67.784	0.506	0.171
		MM	35.344	4.873	4.797	67.877	0.440	<0.0001
		Calculated	-	-	4.799	67.676	-	-

Height	Region	Method	k	c [m/s]	Mean [m/s]	PWD [W/m²]	Kolmogorov-Smirnov	Chi-square
		MLM	25.647	5.358	5.245	89.004	0.505	0.185
	Tripoli	**MM**	35.440	5.360	5.277	90.330	0.440	<0.0001
		Calculated	-	-	5.254	88.829	-	-
70	**Beirut**	**MLM**	25.647	5.219	5.109	82.255	0.505	0.190
		MM	35.440	5.009	4.931	73.721	0.440	<0.0001
		Calculated	-	-	4.931	73.425	-	-
	Sidon	**MLM**	25.647	5.358	5.245	89.004	0.505	0.185
		MM	35.440	5.336	5.253	89.122	0.440	<0.0001
		Calculated	-	-	5.255	88.903	-	-
	Tripoli	**MLM**	25.643	5.850	5.727	115.842	0.506	0.410
		MM	35.440	5.826	5.736	115.997	0.440	<0.0001
		Calculated	-	-	5.736	115.600	-	-
90	**Beirut**	**MLM**	25.646	5.392	5.278	90.714	0.505	0.460
		MM	35.440	5.370	5.287	90.836	0.440	<0.0001
		Calculated	-	-	5.286	90.480	-	-
	Sidon	**MLM**	25.646	5.734	5.613	109.087	0.506	0.261
		MM	35.440	5.771	5.682	112.743	0.440	<0.0001
		Calculated	-	-	5.625	108.996	-	-
	Tripoli	**MLM**	25.644	6.246	6.114	140.996	0.506	0.266
		MM	35.440	6.221	6.125	141.226	0.440	<0.0001
		Calculated	-	-	6.125	140.738	-	-
130	**Beirut**	**MLM**	25.646	5.970	5.844	123.118	0.505	0.470
		MM	35.440	5.945	5.853	123.251	0.440	<0.0001
		Calculated	-	-	5.853	122.824	-	-
	Sidon	**MLM**	25.642	6.333	6.199	146.970	0.506	0.438
		MM	35.440	6.307	6.209	147.165	0.440	<0.0001
		Calculated	-	-	6.212	146.857	-	-
	Tripoli	**MLM**	25.648	6.876	6.731	188.108	0.506	0.511
		MM	35.440	6.848	6.742	188.377	0.440	<0.0001
		Calculated	-	-	6.742	187.691	-	-

6. CONCLUSIONS

In the current study, the availability of wind energy in three coastal regions in Lebanon was evaluated using Weibull diestribution function. The time series of wind speed data has been collected at 10m height and analyzed using two-parameter Weibull distribution. Additionally, monthly average air density values were calculated using the collected pressure and temperature values and applying ideal gas law. Furthermore, time series of wind speed data that has been collected at 10m height above the ground were extrapolated to 30, 50, 70, 90 and 130m heights, which had been chosen as the wind turbine hub height, using power law model. Following conclusions can be drawn from this paper:

- Based on the analysis, it is found that the annual wind speed at the selected regions is higher than 2m/s.
- The MM is the best method used to fit actual wind speed data at 10m height for the three studied regions to identify and describe the wind.
- During the investigation period, it is found that the value of wind power densities at the selected regions was varied between 14.634 W/m^2 and 25.28 W/m^2 at 10 m height and 36.454 W/m^2 and 59.743 W/m^2 at 30m height. These values show that the wind potential is considered as class 1 (poor) according to wind power classification. It can be concluded that small-scale wind turbine is suitable to utilize wind 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]. Cantarello, E., & Newton, A. C. (2014). An Introduction to the Green Economy: Science, Systems and Sustainability. New York.

[11]. 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.

[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]. Garrad, H. (2011). *The National wind atlas of Lebanon: A report* (UNDP/CEDRO - 2011). Retrieved from CEDRO website: http://www.lb.undp.org/content/lebanon/en/home/library/environment_energy/the-national-wind-atlas-of-lebanon.html

[18]. Said, C. (2005). Electric Energy & Energy Policy in Lebanon. Global Network on Energy for Sustainable Development (GNESD)

[19]. El-Fadel, M., Chedid, R., Zeinati, M., & Hmaidan, W. (2003). Mitigating energy-related GHG emissions through renewable energy. *Renewable Energy*, *28*(8), 1257-1276. doi:10.1016/s0960-1481(02)00229-x

[20]. Rakha, S. (2013). *Renewable Energy in Lebanon: Economic, Technical and Environmental Feasibility*. Lebanese American University, Lebanon.

[21]. Ibrahim, O., Fardoun, F., Younes, R., & Louahlia-Gualous, H. (2013). Energy status in Lebanon and electricity generation reform plan based on cost and pollution optimization. *Renewable and Sustainable Energy Reviews*, *20*, 255-278. doi:10.1016/j.rser.2012.11.014

[22]. Moubayed, N., El-Ali, A., & Outbib, R. (2009). Renewable Energy in Lebanon. *Renewable Energy*. doi:10.5772/7362

[23]. Houri, A. (2005). Renewable Energy Resources in Lebanon: Practical Applications. *ISESCO Science and Technology Vision*, *1*, 65-68.

[24]. Beheshti, H. (2010). *Exploring Renewable Energy Policy in Lebanon: Feed-In Tariff As A Policy Tool In The Electricity Sector*. American University of Beirut, Lebanon.

[25]. IEA-International Energy Agency. Energy Balance for Lebanon 2015. Available at https://www.iea.org/statistics/

[26]. 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

[27]. 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

[28]. 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

[29]. 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

[30]. 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

[31]. Chaurasiya, P. K., Ahmed, S., & Warudkar, V. (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. doi:10.1016/j.aej.2017.08.008

[32]. 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

[33]. 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

[34]. 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

[35]. Collier, C. G. (2006). The impact of urban areas on weather. Quarterly Journal of the Royal Meteorological Society, 132(614), 1-25. doi:10.1256/qj.05.199

[36]. Mostafaeipour, A. (2010). Feasibility study of harnessing wind energy for turbine installation in province of Yazd in Iran. Renewable and Sustainable Energy Reviews, 14(1), 93-111. doi:10.1016/j.rser.2009.05.009

[37]. Bilir, L., Imir, M., Devrim, Y., & Albostan, A. (2015). An investigation on wind energy potential and small scale wind turbine performance at İncek region – Ankara, Turkey. Energy Conversion and Management, 103, 910-923. doi:10.1016/j.enconman.2015.07.017