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Energy and power estimation for three different locations in Palestine

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ABSTRACT

In this paper power energy estimated based on wind speed records in three different areas in Palestine Nablus, Ramallah and Gaza. The main aims of this study to calculate the total amount of power and energy that can produce and to encourage investment in renewable energy in Palestine. Available meteorological data from local weather stations are used to study the wind energy potential in the West Bank (WB) for two sites and Gaza Strip (GS) for one site. The daily average wind speed data for three sites in Palestine analyzed, and fitted to the Weibull probability distribution function. The parameters of Weibull have been calculated by author using Graphical method. This study shed lights on the relationship between the wind energy and power versus the mean wind speed (MWS). The total gathered energy per unit area during 2006 in WB from Nablus site is 927.1 kwhr/m^2, whereas 2008.0141 kwhr/m^2 from Ramallah site.This significant study to assess the wind energy production in Palestine to encourage investment in renewable energy sectors.

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1. INTRODUCTION

Renewable energy market is strongly influenced by the political stability in the region, increasing demand on energy, availability of the indigenous resources and economic situation of the people [1]-[4]. The renewable wind power shows a cheap and feasible solution to spread power generators through large areas worldwide [5]-[9]. It turns into one of the most environmental and convenient friendly way of electricity generating. By the last 2007, global capacity of wind power generators was measured 94 GW (about 1% of global electricity useage) almost of the commercial wind turbines working nowadays are at locations with average of 6 m s-1wind speed. The major capacity of every wind turbines world widely installed by the last of 2017 was 539’291 Megawatt, in reference to preliminary statistics reported by WWEA today [10], [11].

In the year 2017, 52’552 Megawatt were added, a little higher than in 2016 when 51’402 Megawatt online went. That was the third greatest number ever installed through a year only, after the record years 2014 and 2015. However, the annual increase rate is the lowest growth ever of only 10,8 % since the wind turbines industrial deployment of the early end of the twentieth century [11]. Total installed capacity 2013-2017 [11] is shown in Figure 1.

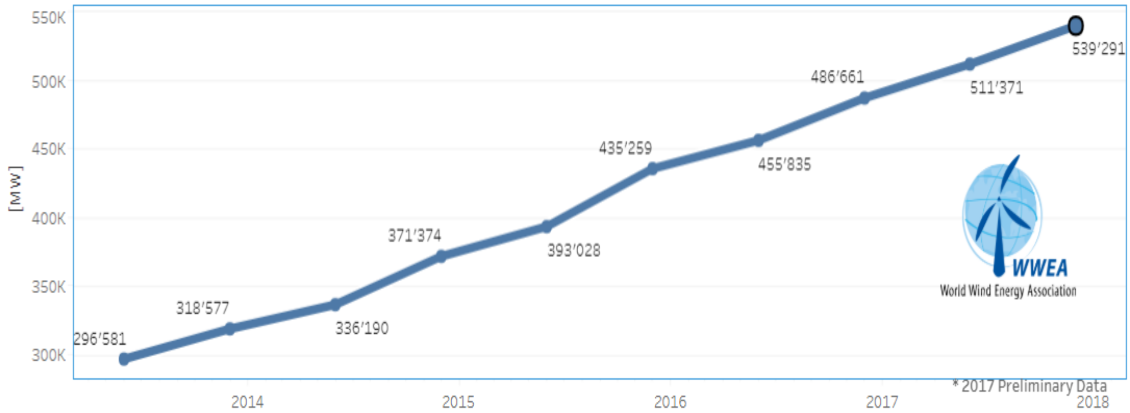

Figure 1. Total installed capacity 2013-2017 [11]

The current scenario in Gaza strip in Palestine is shortage in electricity, one alternative to meet the power demand is using renewable energy. Palestine is spitted into two territories: Gaza Strip (GS) and West Bank (WB) Figure 2 presents the map of Palestine. There is a shortage of physical connection between GS, WB, and East Jerusalem, which is considered a part of West Bank. Furthermore, different areas in the Palestine encounter settlement activities military occupation, and control [3].

Figure 2. Palestine map clarifies Gaza Strip and West Bank [12]

Wind turbine is a good option this is due to less space occupancy and zero-carbon emission during operation. According to the wind speed reports the mean wind speed in Ramallah and Nablus where the speed comes to 5 m/s, which is seen suitable for using a wind turbine [10], [12], [13].

In this study, the daily mean wind speed data was applied to calculate wind energy at three locations in Palestine. Moreover, the wind speed records was fitted well to probability distribution function. Ramallah, where the speed about 5 m/s, which consider suitable for using a wind turbine. The gathered data was well fitted to the function of Weibull distribution [10]. The power created by a wind-generator is listed by (1)

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

Where ρ is the air density, v is the wind speed and A is the area of rotor. The variation of wind speed on a wind turbine is complex one also demands developed technique to reach maximum power from the wind turbine [10], [14]. Weibull distribution is one of the mathematical functions that have been successfully used to suit the wind speed distributions. The two parameters the scale parameter c (m/s) and (the shape parameter k (dimensionless) illustrates the daily average wind speed with a rational accuracy in Weibull distribution [15]. The Weibull functions' results can be used with reasonable accuracy for predicting the output of wind energy needed for final assessment of wind power plants and preliminary design [16].

The Weibull parameters of the wind speed distribution function were computed from the wind speed data for the city of Gaza in Palestine by author in a former study based on wind speed data over a period of 5 years (2012-2015) according to a Graphical Method [17], [18].

2. WIND ENERGY POTENTIAL IN PALESTINE

Wind speed for a given three locations can be characterized by probability distribution functions (Weibull curve). The Weibull probability distribution function is given by [19]-[25]

$$F(V) = K\frac{V^{(K-1)}}{C^K}e^{-\left(\frac{V}{C}\right)^K} \quad k>0, \quad v>0 \ , c>1 \tag{2}$$

Where $f(v)$ the probability of occurrence of speed is, v is the annual MWS, k is a shape factor weibull parameter (dimensionless), c is a scale factor with m/s units. The parameters of Weibull can be calculated using the annual MWS.

$$k = \left(\frac{\sigma}{\overline{\upsilon}}\right)^{-1.086} \quad , \quad 1 \le k \le 10 \tag{3}$$

$$c = \frac{\overline{\upsilon}}{\Gamma\left(1-\frac{1}{k}\right)} \tag{4}$$

Where Γ is the complete gamma function. The maximum power that can extracted from the wind given by (5).

$$P_m = 0.2965\rho A v^3 \tag{5}$$

Where A is the area swept by the rotor in m^2, ρ is the air density in kg/m^3, and v is the wind speed in m/s.

$$E_{using\ weibull} = P * Values\ of\ Weibull * 8760 = Whr\ /\ m^2 \tag{6}$$

$$E_{using\ data} = P\ * D\ =\ Whr\ /\ m^2 \tag{7}$$

Where: yearly mean wind speed v is depend on the site in m/s, swept area $A = 1m^2$, Weibull shape factor $k = 1.785$ (dimensionless), Weibull scale factor $c = 4.3642\ m/s$ Density of air $\rho = 1.21\ kg/m^3$
P: Power available in wind calculated by 1.

3. RESULTS AND ANALYSIS

Different wind speed measurement had been measured for every single month during the year 2006. Wind speed records obtained including the hourly mean wind speed for every single hour from the total (8760 a year).

The data categorized based on the range for wind speed records. This study calculated the maximum power and power density per unit area from the wind based on the mid range of monthly wind speed.

The energy has been estimated using Weibull value and wind speed data. The power calculated using 1, power density by multiplying the power available with percentage of occurrence, Weibull value using 2, energy using Weibull 6 and finally energy using data by 7.

Table 1. Yearly Wind Speed, Power and Energy Calculations for WB for Nablus Site 2006 [26]

Wind Speed (m/s)	Mid range	Duration (hours)	Occurrence percentage (%)	Power (W/m^2)	Power density (W/m^2)	Weibull values	Energy (Wh/m^2) Weibull	Energy (Wh/m^2) data
0	0	0	0	0	0	0	0	0
0—1	0.5	733.68	8.38	0.08	0.01	0.073116798	51.24	58.69
1—2	1.5	376.64	4.3	2.04	0.09	0.152437868	2724.13	768.35
2—3	2.5	1105.78	12.62	9.45	1.19	0.182449448	15103.53	10449.62
3—4	3.5	1786.15	20.39	25.94	5.29	0.175228253	39817.89	46332.73
4—5	4.5	1802.06	20.57	55.13	11.34	0.14570336	70365.81	99347.57
5—6	5.5	1285.92	14.68	100.66	14.78	0.108216597	95423.4	129440.71
6—7	6.5	788.24	9	166.15	14.95	0.072985191	106228.05	130966.08
7—8	7.5	440.14	5.02	255.23	12.81	0.04515086	100948.96	112336.93
8—9	8.5	205.65	2.35	371.55	8.73	0.025794746	83956.17	76409.26
9—10	9.5	101.65	1.16	518.71	6.02	0.013675776	62141.35	52726.87
10—11	10.5	55.81	0.64	700.36	4.48	0.006753629	41434.55	39087.09
11—12	11.5	25.93	0.3	920.13	2.76	0.003115702	25113.61	23858.97
12—13	12.5	9.67	0.11	1181.64	1.3	0.001345985	13932.51	11426.46
13—14	13.5	5.17	0.06	1488.53	0.89	0.00054557	7113.97	7695.7
14—15	14.5	2.83	0.03	1844.42	0.55	0.000207835	3358.01	5219.71
15—16	15.5	8.17	0.09	2252.94	2.03	7.45207E-05	1470.72	18406.52
16—17	16.5	3.83	0.04	2717.74	1.09	2.51815E-05	599.51	10408.94
17—18	17.5	0.83	0.01	3242.42	0.32	8.02832E-06	228.03	2691.21
18—19	18.5	0.67	0.01	3830.63	0.38	2.41739E-06	81.12	2566.52
19—20	19.5	0.51	0.01	4486	0.45	6.88097E-07	27.04	2287.86
20—21	20.5	1	0.01	5212.15	0.52	1.85308E-07	8.46	5212.15
21—22	21.5	7.83	0.09	6012.72	5.41	4.72515E-08	2.49	47079.6
22-23	22.5	0.67	0.01	6891.33	0.69	1.14162E-08	0.69	4617.19
23—24	23.5	11.17	0.13	7851.61	10.21	2.61513E-09	0.18	87702.48
Sum		8760	100				670131.42	927097.21

Table 1 lists in details the mean wind speed, duration hours for mid range wind speed, power available in wind for every single range of wind speed per unit area and energy using two different methods.

The total energy estimated for Nablus site is 670.13 $kwhr/m^2$ whereas, the total energy calculated based on data is 927.1 $kwhr/m^2$.The calculation of Weibull value based on shape factors 1.785 and scale factor 4.364 m/s using graphical method. The yearly MWS $v = 4.346\ m/s$, the density of air $\rho = 1.21\ kg/m^3$.

Figure 3 shows the energy distribution for mid range wind speed per unit area. It's clear that almost of gathered energy between 3 m/s to 9 m/s due to the increase the duration time of wind speed data. Figure 4. Presents the probability distribution function for mean wind speed for 2006 in Nablus site. The curve is represent Weibull probability distribution because of shape factors value $k = 1.785$. Figure 5 illustrates a graphical demonstration of the distribution per hour duration for each range of wind speed. The graph is very similar to Weibull distribution function.

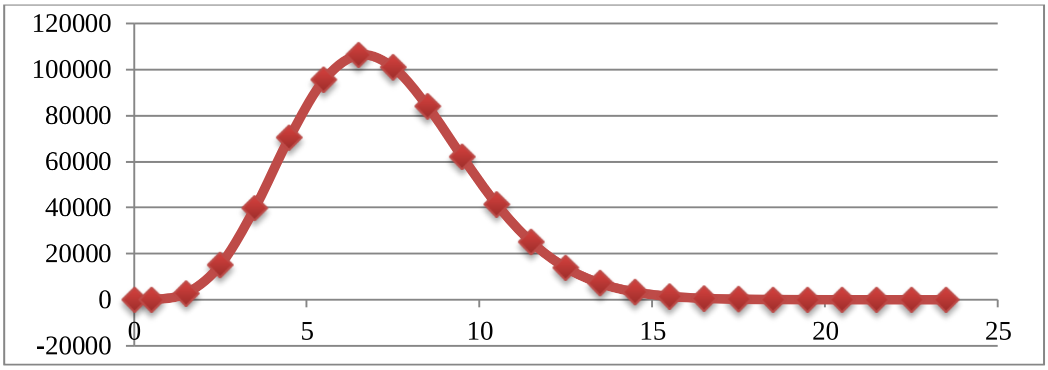

Figure 3. Yearly energy distributions for nablus site 2006

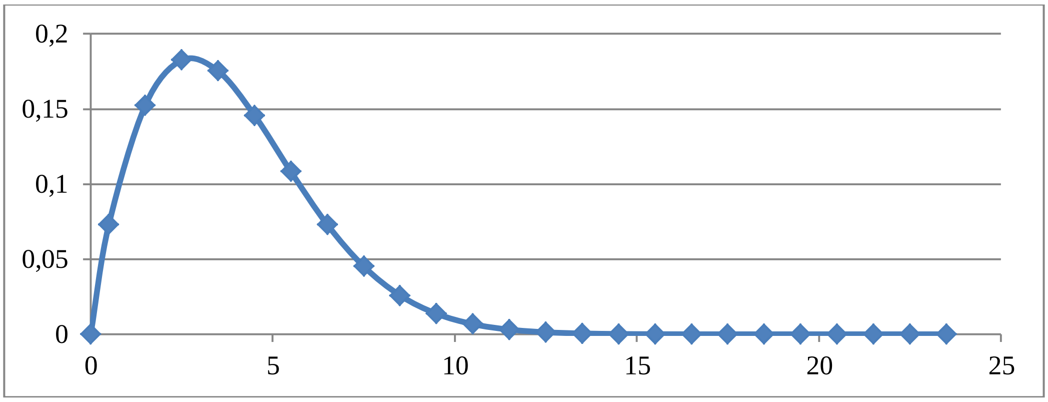

Figure 4. Yearly probability distribution function for Nablus site 2006

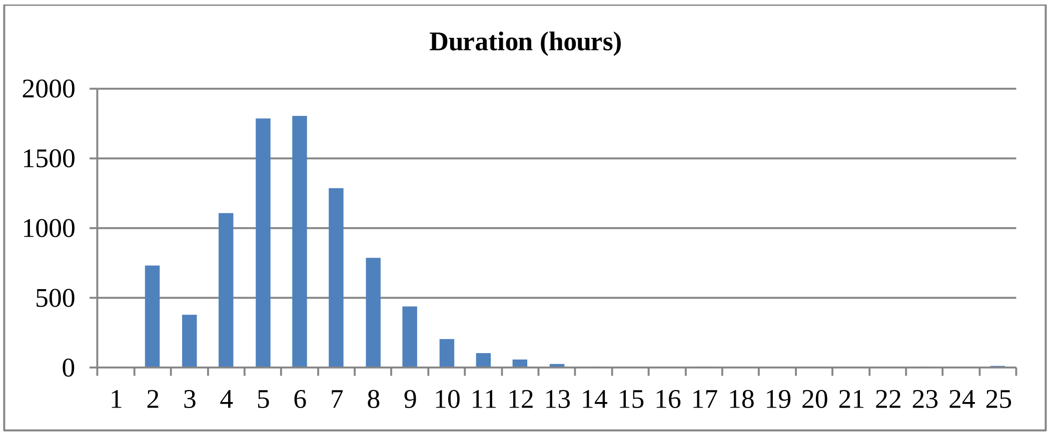

Figure 5. Number of hours for 2006 for Nablus site for each wind speed range

Table 2 shows total energy estimated value based on Weibull distribution is $628.11\,kwhr/m2$ compared to $2008.01\,kwhr/m2$ based on data wind speed, there is the a clear gap between estimated and calculated energy for Ramallah site at WB. The yearly average wind speed $v = 5.521\,m/s$, with Weibull parameters $\mathrm{k} = 1.9389, \mathrm{c} = 4.4173$.

Table 2. Yearly Wind Speed, Power and Energy Calculations for WB for Ramallah Site 2006 [26]

Speed range (m/s)	Mid range	Duration (hours)	Occurrence percentage (%)	Power w/m^2	Power density(w/m^2)	Weibull values	Energy(wh/m^2) using Weibull	Energy (wh/m^2) using data
0	0	0	0	0	0	0	0	0
0—1	0.5	82	0.94	0.08	0	0.055932867	39.2	6.56
1—2	1.5	589	6.72	2.04	0.14	0.140766016	2515.55	1201.56
2—3	2.5	1058	12.08	9.45	1.14	0.184610221	15282.4	9998.1
3—4	3.5	1209	13.8	25.94	3.58	0.186607958	42403.75	31361.46
4—5	4.5	1242	14.18	55.13	7.82	0.158403274	76499.09	68471.46
5—6	5.5	1240	14.16	100.66	14.25	0.116805944	102997.33	124818.4
6—7	6.5	961	10.97	166.15	18.23	0.076115378	110783.95	159670.15
7—8	7.5	728	8.31	255.23	21.21	0.044272593	98985.32	185807.44
8—9	8.5	563	6.43	371.55	23.89	0.02313403	75296.13	209182.65
9—10	9.5	390	4.45	518.71	23.08	0.010908179	49565.67	202296.9
10—11	10.5	218	2.49	700.36	17.44	0.00465631	28567.18	152678.48
11—12	11.5	159	1.82	920.13	16.75	0.001803783	14539.1	146300.67
12—13	12.5	103	1.18	1181.64	13.94	0.00063535	6576.62	121708.92
13—14	13.5	60	0.68	1488.53	10.12	0.000203798	2657.43	89311.8
14—15	14.5	56	0.64	1844.42	11.8	5.96071E-05	963.08	103287.52
15—16	15.5	28	0.32	2252.94	7.21	1.59137E-05	314.07	63082.32
16—17	16.5	15	0.17	2717.74	4.62	3.88166E-06	92.41	40766.1
17—18	17.5	14	0.16	3242.42	5.19	8.65722E-07	24.59	45393.88
18—19	18.5	10	0.11	3830.63	4.21	1.76667E-07	5.93	38306.3
19—20	19.5	9	0.1	4486	4.49	3.30079E-08	1.3	40374
20—21	20.5	4	0.05	5212.15	2.61	5.64939E-09	0.26	20848.6
21—22	21.5	7	0.08	6012.72	4.81	8.86181E-10	0.05	42089.04
22-23	22.5	7	0.08	6891.33	5.51	1.27461E-10	0.01	48239.31
23—24	23.5	8	0.09	7851.61	7.07	1.68168E-11	0	62812.88
Sum		8760	100			1.004936186	628110.42	2008014.5

Table 3 lists the mean wind speed for two different years because of lack of data wind speed records. The average monthly available power in GS, Gaza site is $18.28\,w/m^2$ per unit area. The average monthly energy is $160.147\,kwh/m^2$. MWS $v = 2.85\,m/s$. It can be clearly seen that the gathered energy in winter is larger than in summer due to variety of mean wind speed.

Table 3.Yearly Wind Speed for 2004 and 1998, Power and Energy Calculations for Gaza Site [26]

Month	2004(m/s)	1998(m/s)	Average	Available Power w/m^2	Weibull	Energy (wh/m^2)
Jan	3.61	3.36	3.485	25.4	0.17554	18542
Feb	3.33	3.36	3.345	22.46	0.178202	16395.8
Mar	2.78	3.36	3.07	17.36	0.181979	12672.8
Apr	3.33	3.36	3.345	22.46	0.178202	16395.8
May	2.67	3.36	3.015	16.44	0.182481	12001.2
Jun	2.19	3.36	2.775	12.82	0.18358	9358.6
Jul	2.67	3.36	3.015	16.44	0.182481	12001.2
Aug	2.69	3.36	3.025	16.61	0.182397	12125.3
Sep	2.86	3.36	3.11	18.05	0.181558	13176.5
Oct	2.67	3.36	3.015	16.44	0.182481	12001.2
Nov	3.03	3.36	3.195	19.57	0.180515	14286.1
Dec	2.53	3.36	2.945	15.33	0.182989	11190.9
average				18.281		160147.4

4. CONCLUSION

This study analyzed data for three different locations in Palestine to estimate the wind power potential in Palestine per unit area. WB monthly wind speed has strong energy potential while The coastal plain area of the GS has low wind energy potential The monthly mean wind power potential found to be higher during winter and lowers during summer in the three locations especially in Gaza site. The highest wind speed was in Ramallah around $5.521 m/s$ because of altitude $850\ m$ and above than sea level. Therefore, the largest amount of gathered energy was in Ramallah site followed by Nablus $2008.01\ kwhr/m^2$, $927.1\ kwhr/m^2$,respectively. The power in the wind grows with the cube of the wind speed that is why wind speed is play significant role in the total amount of gathered energy. This study is considered the initial step towards the feasible installation of wind turbines in Palestine.

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