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/m2, whereas 2008.0141 kwhr/m2 from Ramallah site.This significant study to assess the wind energy production in Palestine to encourage investment in renewable energy sectors.*

***Keywords****: Power energy, Power density, probability distribution function, wind energy*

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**1. Introduction**

The motivation and interest for using wind energy have increased dramatically throughout the Nineteen Eighties in several developed and wealthy countries as a result of continual energy crises on the one hand and continuous problems of environmental pollution on the opposite. Because of the increase consecutive consumption of non-renewable sources in various fields of life, a very challenging needs for sustainable and new energy resources. Beside, fossil fuel and petroleum consumption is considered one of the main sources of air pollution together with sulfur, carbon, and nitrogen oxides. All these pollutants are menacing the health of climate change and global ecosystem. Ocean water, solar cells wind power, are representative examples of potential sources of energy[1-6].

On the last decade, crisis problem of electrical energy has been considered as one of the big problems around the world[1].

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. The environment of political risk and uncertainty has inhibited investors from making large scale energy or industrial investments. Regardless of all these challenges, Palestine has gone forward to use its natural resources for rehabilitation and construction[7, 8]

The renewable wind power shows a cheap and feasible solution to spread power generators through large areas worldwide. 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[2, 9].

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 and2015. 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[9].



Figure 1. Total Installed Capacity 2013-2017[9]

Many Palestinian communities experienced nonexistent or dwindling energy resources, for many years. Accordingly, the economic development in such areas is negatively affected; however the cost of energy skyrocketed close to their adjacent neighbors. In addition, satisfactory level was not reached despite the increase attention to both renewable energy and their utilization, also, the environmental pollution from traditional resources actually menace various aspects of life. Applications in the renewable energy field are very limited because of small investments in this sector with the remarkable exception of solar water heaters. In the sector of electrical energy, the bulk of the electrical resource to the Palestinian territories drives from Israeli electrical company. This monopoly also affects the cost of electricity, and leads to electricity shortages, with the a great threat of a future energy dilemma in the future [2].

 Palestine is spitted into two territories: Gaza Strip (GS) and West Bank (WB) Fig. 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].

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[2, 10].



Figure 2. Palestine map clarifies Gaza Strip and West Bank[10]

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[2].

The power created by a wind-generator is listed by equation (1)

(1)

Where is the air density, is the wind speed and 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[2, 6]. 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 and (the shape parameter (dimensionless) illustrates the daily average wind speed with a rational accuracy in Weibull distribution[11]. 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[12].

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[13].

**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 [14]

 (2)

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

 (3)

. (4)

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

 (5)

Where is the area swept by the rotor in is the air density in , and is the wind speed in

(6)

 (7)

Where: yearly mean wind speed is depend on the site in, swept area , Weibull shape factor (dimensionless), Weibull scale factor Density of air

: Power available in wind calculated by equation 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 equation 1, power density by multiplying the power available with percentage of occurrence, Weibull value using equation 2, energy using Weibull equation 6 and finally energy using data by equation 7.

Table 1. Yearly wind speed, power and energy calculations for WB for Nablus site 2006[1]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Wind Speed  | Mid range | Duration (hours) | Occurrence percentage (%) | Power | Power density | Weibull values | Energy Weibull | Energy 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 whereas, the total energy calculated based on data is .The calculation of Weibull value based on shape factors and scale factor using graphical method. The yearly MWS the density of air

Figure 3. Yearly Energy distributions for Nablus site 2006

Figure 3. shows the energy distribution for mid range wind speed per unit area. It’s clear that almost of gathered energy between to due to the increase the duration time of wind speed data.

Figure 4. Yearly probability distribution function for Nablus site 2006

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 .

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

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.

Table 2. Yearly wind speed, power and energy calculations for WB for Ramallah site 2006[1]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Speed range (m/s) | Mid range | Duration (hours) | Occurrence percentage (%) | Power  | Power density | Weibull values | Energy using Weibull | Energy 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 2 shows total energy estimated value based on Weibull distribution is compared 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 , with Weibull parameters .

Table 3.Yearly wind speed for 2004 and 1998, power and energy calculations for Gaza site[1]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Month | 2004 | 1998 | Average | Available Power  | Weibull | Energy  |
|  |  |  |  |  |  |  |
| 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 |

|  |
| --- |
|  |

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 per unit area. The average monthly energy is . MWS .

Figure 6. Average monthly Energy in Gaza site for 1998 and 2004

Figure 6 presents the average monthly energy curve in GS, Gaza site for two years. It can be clearly seen that the gathered energy in winter is larger than in summer due to variety of mean wind speed.

**3. 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 because of altitude and above than sea level. Therefore, the largest amount of gathered energy was in Ramallah site followed by Nablus , ,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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