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Evaluation of wind energy potential as a power generation source for electricity production in Binalood, Iran

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ABSTRACT

In this paper, the hourly measured wind speed data for years 2007–2010 at 10 m, 30 m and 40 m height for Binalood region in Iran have been statically analyzed to determine the potential of wind power generation. The study showed that the long-term wind speeds were found to be relatively high. The numerical values of the dimensionless Weibull shape parameter (k) and Weibull scale parameters (c) were also determined. Based on these data, it was found that the numerical values of the shape and scale parameters for Binalood varied over a wide range. The yearly values of k at 40 m elevation range from 2.165 to 2.211 with a mean value of 2.186, while those of c are in the range of 7.683–8.016 with a mean value of 7.834. However, the yearly mean wind speed, mean power density and power density of Binalood at 40 m height are found as 5.923 m/s, 305.514 W/m^2 and 2676.30 (kWh/m^2/year) respectively. The results show that Binalood has available great wind energy potential for grid connection system.

1. Introduction

Global climate change and increasing worldwide demand for electricity requires need for harnessing different kinds of renewable energies like wind energy in many countries in the world including Iran. The climate change challenge could become a force for good in humanity. This challenge is about programming, co-operation, planning ahead and thinking of the complex interconnectedness of social, economic, political, cultural and environmental systems [1]. Global warming and climate change are the most critical issues facing the world today [2]. Interest has recently risen toward renewable energy (RE) sources especially wind energy for electricity generation in many countries. Countries have tried to accelerate solutions for wind energy generation design parameters [3]. Electrical power generation by wind turbines grew during the second half of the 20th century and oil price rises in the 1970s promoted intense interest in its value as a fuel-free, renewable energy source in many European and north American countries [4].

The main purpose of this article is to estimate the wind energy potential of the Binalood region in Iran. For this purpose, the collected wind data from the location should be properly analyzed and interpreted. Usually, long-term hourly or three hourly wind data from the meteorological site can be used for the analysis. Collected wind speed data should be carefully extrapolated to represent the wind profile of the site. Feasibility study is the first step for knowing whether a location is suitable or not. Second step is to do a field wind speed measurement for short period of time which is usually one year. Clearly, one year wind speed data is sufficient to represent the long-term variations in the wind profile within an accuracy level of 10 percent [5–7]. For this study, only the primary step was done to estimate the wind potential of Binalood.

Iran joined the group of countries which were using wind energy for electricity production in 1994. As reported by Fadai [8], the construction of first wind power station (the 25 MW and 60 MW power stations at Manjil) began in Iran in 2003. At the present time, Manjil and Binalood wind farms are two major wind sites in Iran. Recently, about 0.17 percent of Iran's required

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electricity has been provided by wind energy. The Binalood site (Fig. 1), which is locally called Dizbad, is located between major cities of Mashhad and Neyshabour.

Iran generated 47 MW of electricity from wind power (ranked 30th in the world) in 2006, an increase of about 47% over 32 MW in 2005. Total wind generation in 2004 was 25 MW out of 33,000 MW total electrical generation capacity for the country. In 2008, Iran's wind power plants in Manjil area (in north of Iran) and Binalood produced 82 MW of electricity. By 2009, Iran had wind power installed capacity of 91 MW [9].

Table 1 illustrated top twenty wind speed stations located in different parts of Iran. Clearly, there are some other locations in Iran with higher wind speeds and potentials, but Iranian Renewable Organization (SUNA) chose some other locations for installation of the 40 m towers to measure wind speeds for preparing of the Iranian wind atlas.

Fig. 1. Edited Iran map with terrains, Binalood is the site studied in the current study [Source: http://www.lib.utexas.edu/maps/middle_east_and_asia/iran_country_profile_2009].

Table 1
Wind speed stations located in different parts of Iran.

Rank	Location	Wind speed (m/s)
1	Khaf	8.9
2	Lootak	7.1
3	Fedesk	6.2
4	Moaleman	6.1
5	Bardkhoon	6.0
6	Bojnoord	5.7
7	Hadadeh	5.7
8	Rafsanjan	5.4
9	Afriz	5.3
10	Mayan	5.3
11	Abadeh	5.3
12	Ghadamgah	5.3
13	Kish	5.2
14	Nosratabad	5.0
15	Namin	4.9
16	Varzaneh	4.9
17	Jangal	4.9
18	Eghlid	4.8
19	Sarakhs	4.8
20	Maraweh Tapeh	4.8

Manjil and Roodbar regions were first locations in Iran which wind turbines were installed. First, two sets of 500 kW turbines with total of more than1.8 million kWh per year production were installed to generate electricity [9,10].

Wind energy potential in Iran has been studied and analyzed for some areas such as Shahrbabak in Kerman province [11], Isfahan [12], Manjil in Gilan province [13], Yazd [14], Tehran [15], and Semnan [16] provinces; there are also studies about feasibility of offshore wind turbine installation in Iran and comparison with the world [17], future of renewable energies in Iran [18] and renewable energy issues in Middle East compared with Iran [19].

Purpose of this study is to determine feasibility of wind energy potential in Binalood which is located in northeast province of Khorasan. This paper presents research work involved in determining the feasibility of deploying wind driven devices for Binalood region in northeast of Iran. The next section offers a discussion of yearly Weibull parameters and characteristic speeds is described thoroughly. The wind pattern is presented in Section 3. The monthly Weibull parameters and characteristic speeds are brought forward in Section 4. Also reason for choosing the site is illustrated in Section 5. Finally concluding remarks are presented in Section 6.

2. Yearly Weibull parameters and characteristic speeds

There should be long-term meteorological observations for the Binalood area in order to accurately predict and also to calculate the wind potential and energy. Clearly, wind speed is a random variable, and probability density functions are calculated from variation of wind speed over a period of time.

There are several probability density functions like Rayleigh function, gamma function, beta function, lognormal function, Weibull distribution function, and logistical function, which can be used for frequency of wind speed curve [20,21]. Weibull distribution function is the most popular and best probability distribution for wind speed in studies [11,16,20,22,23]. Weibull function has shown an acceptable distribution function that accurately fit the wind speed frequency in the given duration course. Weibull function is determined by its two parameters i.e. k (dimensionless) and c (m/s) [22]. The shape parameter k shows skewness rate of Weibull curve. The higher values for k (between 2 and 3) means the curve is more skewed toward higher wind velocities, and lower values for k (between 1 and 2) means the curve is more skewed toward lower wind velocities, thus indicating that lower wind velocities are more probable to happen. The scale parameter c shows the peak value of the Weibull curve. In fact, higher values for c mean the distribution is spread over a wider range [11].

3. Wind pattern

3.1. Monthly mean wind speeds

Monthly mean wind speed values and also standard deviation of Binalood are presented in Table 2. Hourly wind data collected over a period of between 2007 and 2010 at three different heights of 10, 30, and 40 m respectively. Most of the monthly mean speed wind values are between 5.00 and 8.00 m/s. The highest whole year average wind speed at elevations of 10, 30, and 40 m occur on July (7.825 m/s), July (8.125), and July (8.615) respectively.

For different years, the trends of monthly mean wind speeds and standard deviations are almost similar. December at different elevations from 2007 to 2010 showed the minimum mean wind speed value of 5.399 m/s, 5.598, and 5.843 at 10, 30, and 40 m elevations respectively. Binalood, therefore, has good potential for developing wind energy sources for electricity production. By analyzing the 48 months of wind speed data at three different elevations, it can be concluded that the wind speed distribution differs remarkably from one month to the next. The monthly and yearly standard deviation values are mostly between 1.3 and 2.3 m/s.

3.2. Yearly Weibull parameters and characteristic speeds

At 10 m elevation, Table 3 shows the average of Weibull scale parameter (c) is 7.352 m/s, Weibull shape parameter value (k) 2.118 and mean wind power density (P/A) 260.144 W/m^2 for period of 2007–2010. Mean wind energy (E/A) is also 2278.86 kWh/m^2/year for same period. Clearly, values for each year are also illustrated in this table.

The mean values of Weibull scale parameter (c) 7.416 m/s, Weibull shape parameter value (k) 2.127 and mean wind power density (P/A) 265.723 W/m^2 at 30 m height are illustrated. Mean wind energy (E/A) is also 2327.73 kWh/m^2/year for period of 2007–2010. It also shows that higher values of k and c yield to higher values of power density and energy which occurred in 2008.

Also, Table 3 illustrates mean Weibull scale parameter (c) 7.834 m/s, Weibull shape parameter value (k) 2.186 and mean wind power density (P/A) 305.514 W/m^2 of the site at 40 m height. Mean wind energy is 2676.30 kWh/m^2/year for the same period too. Data shows that 2008 is the most favorable year for wind energy harnessing which is similar to the values at 30 m elevation. This means that, under the current wind turbine technique, this area is suitable for year round large-scale electricity generation due to the cost factor. However, utilization of small-scale applications for house appliances and heating is also possible.

A classification [16,24] indicated the wind characteristics and evaluations as following:

$$\frac{\overline{P}}{A} < 100\,\frac{W}{m^2} \text{ is poor}$$
$$\frac{\overline{P}}{A} \approx 400\,\frac{W}{m^2} \text{ is good}$$
$$\frac{\overline{P}}{A} > 700\,\frac{W}{m^2} \text{ is great} \qquad (1)$$

Based upon the above classification, the Binalood region is almost a good location.

Table 2
Yearly mean wind speeds and standard deviations for Binalood region.

Month	Parameter	10(m)					30(m)					40(m)				
		2007	2008	2009	2010	Whole year	2007	2008	2009	2010	Whole year	2007	2008	2009	2010	Whole year
Jan	$\bar{v}$	5.868	5.182	6.462	5.960	5.868	5.769	5.379	5.886	6.042	5.769	6.024	5.587	6.150	6.336	6.024
	σ	1.465	2.454	1.412	2.445	2.059	1.607	2.610	2.529	2.604	2.387	1.673	2.717	2.641	2.700	2.486
Feb	$\bar{v}$	5.724	5.194	6.586	5.392	5.724	5.443	5.246	5.680	5.403	5.443	5.718	5.532	5.952	5.669	5.718
	σ	1.272	2.724	1.044	2.321	2.039	1.560	2.866	2.535	2.389	2.390	1.641	3.046	2.619	2.503	2.508
Mar	$\bar{v}$	6.738	5.843	7.366	6.958	6.726	6.378	5.874	6.347	6.968	6.392	6.723	6.260	6.692	7.276	6.738
	σ	1.367	2.436	1.235	3.248	2.297	1.810	2.619	3.157	3.403	2.840	1.896	2.765	3.303	3.430	2.933
Apr	$\bar{v}$	6.186	5.761	6.360	6.302	6.152	6.174	5.921	5.989	6.293	6.094	6.568	6.343	6.324	6.700	6.484
	σ	1.121	1.809	1.521	2.522	1.831	1.391	1.923	2.728	2.624	2.237	1.471	2.055	2.862	2.788	2.368
May	$\bar{v}$	6.559	7.007	6.529	6.158	6.563	6.675	7.245	6.511	6.374	6.701	7.174	7.751	6.874	7.009	7.202
	σ	1.179	1.869	1.517	2.047	1.712	1.204	1.947	2.445	2.201	2.030	1.302	2.059	2.544	2.224	2.109
Jun	$\bar{v}$	7.661	8.774	7.840	6.392	7.667	7.564	9.006	6.885	6.767	7.556	8.005	9.566	7.253	7.152	7.994
	σ	1.218	1.832	1.289	1.873	1.794	1.278	1.720	2.013	1.982	1.983	1.331	1.786	2.115	2.055	2.084
Jul	$\bar{v}$	7.852	8.263	7.816	7.369	7.825	8.155	8.546	8.115	7.684	8.125	8.644	9.063	8.605	8.148	8.615
	σ	1.466	1.954	1.450	1.973	1.757	1.305	1.777	1.297	1.983	1.646	1.389	1.870	1.373	2.079	1.735
Aug	$\bar{v}$	7.401	7.546	8.070	6.679	7.424	7.783	7.864	8.459	7.201	7.827	8.240	8.337	8.945	7.619	8.285
	σ	1.180	2.105	1.481	1.846	1.761	1.074	2.092	1.420	1.752	1.688	1.149	2.200	1.510	1.856	1.786
Sep	$\bar{v}$	7.174	6.784	7.148	6.480	6.896	7.519	7.054	6.955	6.720	7.062	7.959	7.283	7.293	7.125	7.415
	σ	1.149	1.591	1.114	1.515	1.388	1.233	1.647	1.330	1.654	1.505	1.341	1.789	1.407	1.728	1.610
Oct	$\bar{v}$	6.093	6.786	5.776	6.022	6.169	6.013	6.895	6.066	6.098	6.268	6.392	7.305	6.368	6.468	6.633
	σ	1.580	1.973	1.733	1.845	1.827	2.243	2.024	1.920	2.112	2.109	2.374	2.120	1.986	2.211	2.211
Nov	$\bar{v}$	5.903	5.675	5.394	5.658	5.658	6.287	5.886	5.493	5.888	5.888	6.594	6.197	5.794	6.195	6.195
	σ	2.359	1.738	2.141	1.480	1.967	2.648	1.848	2.274	1.595	2.147	2.719	1.918	2.377	1.642	2.220
Dec	$\bar{v}$	5.443	5.399	5.355	5.399	5.399	5.793	5.598	5.402	5.598	5.598	6.039	5.843	5.647	5.843	5.843
	σ	2.540	1.560	2.212	1.560	2.012	2.639	1.587	2.314	1.587	2.087	2.771	1.658	2.404	1.658	2.180
Yearly	$\bar{v}$	6.555	6.238	6.727	6.555	6.511	6.636	6.719	6.491	6.428	6.568	7.014	7.099	6.834	6.804	6.938
	σ	1.742	2.189	1.796	1.742	2.039	1.950	2.412	2.422	2.308	2.284	2.061	2.556	2.542	2.400	2.401

Another classification done by European Wind Energy Association (EWEA), the wind characteristics and categories are indicated as below [24]:

Fairly good (6.5 m/s, ≈300–400 W/m^2);
Good (7.5 m/s, ≈500–600 W/m^2);
Very good (8.5 m/s, ≈700–800 W/m^2).

According to the above classification, Binalood is a fairly good location for wind turbine installation. Also, the following classification shows that the city is categorized as fairly good. The Binalood wind site has a noticeable potential for development and providing more electricity from wind energy, and also exporting electricity to the neighboring countries.

Having suitable basic factors of a wind site, such as: acceptable speed and density and low turbulence intensity of the wind, near access roads to the site and close location of transfer lines and electric network of the region, caused the site to be taken under serious consideration for producing electricity in future.

3.3. Monthly mean wind speed

It is observed from Fig. 2 and Table 2 that Binalood has high mean wind speed. The monthly mean wind speed at 10 m height is 6.555, 6.238, 6.727, and 6.555 m/s respectively from 2007 to 2010. The maximum mean 4 years wind speeds occur in June and July, whilst minimum mean 4 years wind speeds start from November to January.

Fig. 3 illustrates the actual monthly mean wind speed of the region at 30 m height. The values from 2007 to 2010 are 6.636, 6.719, 6.491, and 6.428 m/s respectively. The maximum and minimum actual mean wind speeds of 4 years period occur in July and February, respectively at 30 m elevation. Clearly, when the height increases, the speed also increases. The wind speed is given as 6.727 at 10 m above the ground level, but, the wind speed is given as 6.491 m/s at 30 m above the ground level. The higher value of wind speed is supposed to occur at a higher level above the

Table 3
Yearly Weibull parameters and characteristic speeds (at 10 m height, in m/s), wind power and energy density.

Year	Height (m)	k	c (m/s)	V_{mp}	v_{op}	$\bar{v}$ (measured)	P/A (W/m^2)	E/A (kWh/m^2/year)
2007	10	2.125	7.401	5.487	10.113	6.555	264.347	2315.68
2008	10	2.120	7.369	5.454	10.080	6.526	261.383	2289.72
2009	10	2.153	7.596	5.683	10.307	6.727	282.268	2472.67
2010	10	2.073	7.042	5.126	9.754	6.238	232.578	2037.38
Whole year	10	2.118	7.352	5.437	10.064	6.511	260.144	2278.86
2007	30	2.138	7.493	5.580	10.205	6.636	272.766	2389.43
2008	30	2.151	7.586	5.673	10.298	6.719	281.440	2465.41
2009	30	2.115	7.329	5.414	10.040	6.491	257.746	2257.85
2010	30	2.104	7.258	5.342	9.969	6.428	250.940	2198.23
Whole year	30	2.127	7.416	5.502	10.128	6.568	265.723	2327.73
2007	40	2.198	7.920	6.010	10.631	7.014	314.206	2752.45
2008	40	2.211	8.016	6.106	10.726	7.099	323.994	2838.19
2009	40	2.170	7.716	5.804	10.427	6.834	293.843	2574.06
2010	40	2.165	7.683	5.771	10.394	6.804	290.012	2540.51
Whole year	40	2.186	7.834	5.923	10.544	6.937	305.514	2676.30

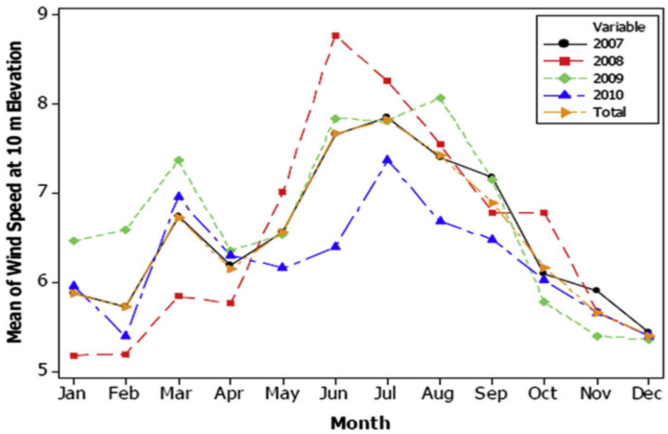

Fig. 2. Monthly mean wind speed at 10 m elevation (2007–2010).

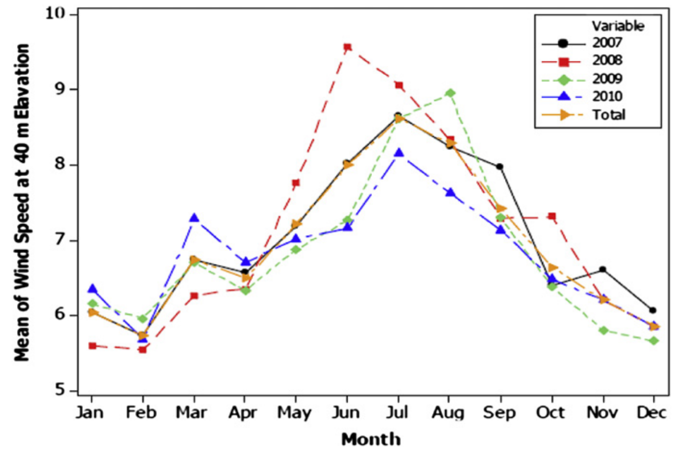

Fig. 4. Monthly mean wind speed at 40 m elevation (2007–2010).

ground. It is an exception, because of some natural parameters like ground specification or turbulence.

At 40 m height, the actual monthly mean wind speed 40 m height is 6.014, 6.099, 7.834, and 6.804 m/s respectively from 2007 to 2010 which is illustrated in Fig. 4. The maximum and minimum mean 4 years wind speeds occur in July and February, respectively at 40 m elevation.

The monthly mean wind speeds at different elevations (Figs. 2–4) indicates that the whole year wind speed has the lowest value in the month of December and the highest in the month of June, In Binalood, the higher heating demand also occurs from October to April, which can be grouped as the cold season. The wind energy may be applied as a supplement to the current gas or electricity heating. But it is applicable all the year for supplying required energy for different sectors.

3.4. Mean wind speed at different hours

The annual hourly mean wind speed is demonstrated in Fig. 5. This figure shows hours of day that have a suitable wind speed in all over the year at three different heights from 2007 to 2010. Best wind speeds occur at 15 PM in the year.

The cumulative distribution function is helpful for estimation of the time for which wind is within a certain velocity interval. Fig. 6 presents the cumulative distribution curves of the studied wind speeds for Binalood at three different heights. It can be noted that, for example, the wind speed at 10 m, 30 m and 40 m heights is greater than 4 m/s for most of the time in the year. The 4 m/s wind speed limit is important, because it is the cut-in speed of many commercial turbines. The cut-out speed is usually between 20 and 25 m/s However, the cut-out wind speed does not exceed 25 m/s at this site.

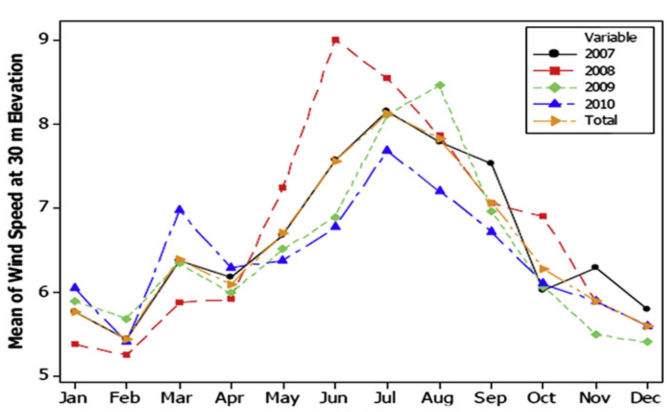

Fig. 3. Monthly mean wind speed at 30 m elevation (2007–2010).

4. Monthly Weibull parameters and characteristic speeds

The monthly Weibull parameters of k and c were calculated (Tables 4–6). Clearly, the monthly wind speed distribution (2007–2010) differs over a whole year. At 10 m height (Table 4), values of c are between 6.451 and 9.715. The minimum value of c is found in July, but the maximum belongs to December. K value ranges from 1.985 to 2.436. Maximum wind power density of 556.080 W/m^2 occurs on December whilst lowest is for month of July with value of 179.857 W/m^2. Whole year average wind energy density of region is also 347.858 kWh/m^2/month. Clearly, December gains maximum wind energy density with value of 400.378 kWh/m^2/month.

The monthly Weibull parameter characteristic speeds (at 30 m height), wind power and energy density are given in Table 5. The biggest value of the monthly mean power density occurs as 477.137 W/m in January and the lowest value of it occurs as 159.138 W/m in July. By examining the data, it is seen that the

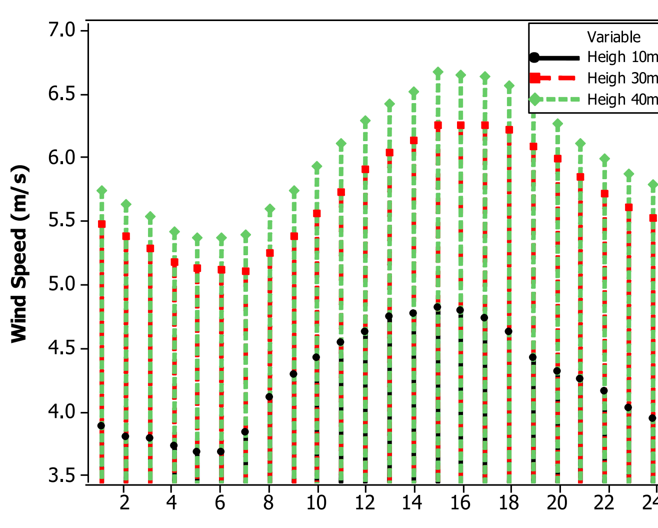

Fig. 5. Mean wind speed at different hours of the year-Binalood.

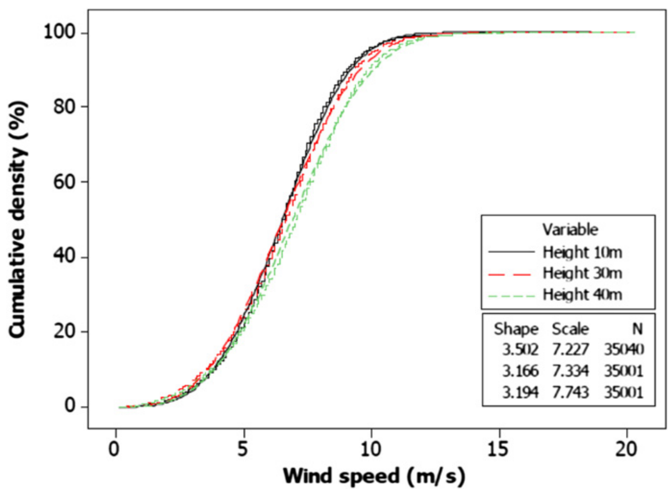

Fig. 6. Cumulative density at three heights for Binalood.

changes of monthly mean wind speed and power density are proportional and the values are especially bigger in October, November and December months. Whole year average wind energy density of region is also 299.925 kWh/m^2/month. Clearly, December gains maximum wind energy density with value of 343.539 kWh/m^2/month.

The monthly mean power density, energy density, *k* and *c* values at 40 m elevation are given in Table 6. The biggest actual value of the monthly mean power density occurs as 432.664 W/m^2 in December and the lowest value of it occurs as 180.350 W/m^2 in July. Whole year average wind energy density of region is also 261.600 kWh/m^2/month. Clearly, December gains maximum wind energy density with value of 311.518 kWh/m^2/month. Values of *c* are between 6.451 and 8.832. The minimum value of *c* is found in February, but the maximum belongs to December. *K* value ranges from 1.985 to 2.322 at this elevation. By examining data of Table 6, it is seen that the changes of monthly mean wind speed, power density, and energy density are proportional and the values are especially bigger in December, November and May. Clearly, when the height increases, the speed and power density also increase.

The maximum occurrence probability of the site at 10 m height is obtained as 15.5% at the wind speed of around 6.6 m/s. Maximum occurrence probability of the site at 30 m and 40 m heights are obtained respectively as 11.9% and 11% at the wind speeds of around 6.9 m/s and 7.1 m/s. The wind speed at 10 m, 30 m and 40 m heights is greater than 4 m/s for most of the time in the year. The 4 m/s wind speed limit is important, because it is the cut-in speed of many commercial turbines. The cut-out speed is usually between 20 and 25 m/s However, the cut-out wind speed does not exceed 25 m/s at this site.

5. Advantages of Binalood for installation of turbines

5.1. Economic advantage

An important and major factor for construction of a wind farm in any location is profitability of the project. Economic evaluation for installing wind turbines in Binalood region illustrated that the site is suitable for this purpose.

5.2. Environmental issues

An important environmental advantage of wind energy is that it does not pollute the atmosphere with toxic chemicals. The impact of wind turbines on avian population is an important issue. Studies conducted at the Binalood area indicated low levels of bird mortality due to collision with wind turbines.

Wind turbines create some noise during the operation. Clearly, noise is an unwanted sound.

In the 80's, most of the turbines were noisy which annoyed many residents even at the far distance to the wind farms. Now, modern turbines with new design modifications are much quieter [5].

The noise emitted from the turbines is not a matter of great concern, because the residential areas are not very close to the Binalood wind farm. The impact of the wind turbines on scenic beauty of the landscapes is a barrier for wind farm establishment in any area.

Aesthetically, there are different opinions among people [5]. Fortunately, this issue has not been important in Iran, because people are in favor of any renewable energy projects. As a matter of fact, Manjil wind farm in north of Iran is located in heart of the city. Binalood wind farm is not surrounded by private farms or residential areas. Local people are quite calm which have accepted new renewable technology.

5.3. Durable flow of wind

The average wind speed of Binalood is great, because it is located in the natural wind tunnel with almost permanent wind flow. The average wind speed of Hossein Abad meteorology station with 10 km distance from Binalood is 7.7 m/s (data were collected from 1996 to 1997 at height of 20 m and from 1998 to 2000 at height of 10 m).

Table 4
Monthly Weibull parameter characteristic speeds (at 10 m height, in m/s), wind power and energy density.

Month	*k*	*c* (m/s)	V_{mp}	v_{op}	$\bar{v}$ (measured)	Wind power density (W/m^2)	Wind energy density (kWh/m^2/month)
Jan	2.059	6.945	5.028	9.658	6.152	236.319	170.149
Feb	2.126	7.411	5.497	10.122	6.563	275.272	198.196
Mar	2.298	8.654	6.750	11.364	7.667	398.866	287.184
Apr	2.322	8.832	6.929	11.542	7.825	416.605	299.956
May	2.261	8.381	6.475	11.091	7.424	356.133	256.416
Jun	2.037	6.800	4.882	9.513	6.024	206.203	148.466
Jul	1.985	6.451	4.531	9.165	5.718	179.857	129.497
Aug	2.154	7.608	5.695	10.319	6.738	273.606	196.996
Sep	2.113	7.321	5.406	10.032	6.484	253.013	182.169
Oct	2.227	8.132	6.223	10.842	7.202	335.586	241.622
Nov	2.347	9.021	7.120	11.731	7.994	447.918	322.501
Dec	2.436	9.715	7.821	12.425	8.615	556.080	400.378
Whole year	2.197	7.939	6.030	10.650	7.035	327.955	236.127

Table 5
Monthly Weibull parameter characteristic speeds (at 30 m height, in m/s), wind power and energy density.

Month	k	c (m/s)	V_{mp}	v_{op}	$\bar{v}$ (measured)	Wind power density (W/m^2)	Wind energy density (kWh/m^2/month)
Jan	1.994	6.509	4.590	9.223	5.769	201.098	144.790
Feb	1.936	6.137	4.217	8.853	5.443	172.089	123.904
Mar	2.098	7.217	5.301	9.928	6.392	250.312	180.225
Apr	2.049	6.879	4.962	9.592	6.094	219.836	158.282
May	2.149	7.567	5.654	10.278	6.701	273.883	197.196
Jun	1.994	6.509	4.590	9.223	5.769	185.003	133.202
Jul	1.936	6.137	4.217	8.853	5.443	159.138	114.579
Aug	2.098	7.217	5.301	9.928	6.392	239.321	172.311
Sep	2.049	6.879	4.962	9.592	6.094	216.366	155.783
Oct	2.149	7.567	5.654	10.278	6.701	279.058	200.922
Nov	2.281	8.529	6.624	11.239	7.556	386.944	278.600
Dec	2.366	9.168	7.268	11.878	8.125	477.137	343.539
Whole year	2.322	8.834	6.931	11.543	7.827	416.562	299.925

Table 6
Monthly Weibull parameter characteristic speeds (at 40 m height, in m/s), wind power and energy density.

Month	k	c (m/s)	V_{mp}	v_{op}	$\bar{v}$ (measured)	Wind power density (W/m^2)	Wind energy density (kWh/m^2/month)
Jan	2.037	6.800	4.882	9.513	6.024	224.142	161.382
Feb	1.985	6.451	4.531	9.165	5.718	194.494	140.035
Mar	2.154	7.608	5.695	10.319	6.738	286.171	206.043
Apr	2.113	7.321	5.406	10.032	6.484	257.071	185.091
May	2.227	8.132	6.223	10.842	7.202	329.363	237.142
Jun	2.011	6.622	4.703	9.336	5.868	193.059	139.003
Jul	1.986	6.458	4.539	9.172	5.724	180.350	129.852
Aug	2.153	7.595	5.682	10.306	6.726	272.463	196.173
Sep	2.059	6.945	5.028	9.658	6.152	221.595	159.548
Oct	2.126	7.411	5.497	10.122	6.563	264.676	190.567
Nov	2.298	8.654	6.750	11.364	7.667	401.856	289.337
Dec	2.322	8.832	6.929	11.542	7.825	432.664	311.518
Whole year	2.261	8.381	6.475	11.091	7.424	363.334	261.600

5.4. Soil conditions and transportation facilities

It is very important to consider soil condition for turbine foundation and also road construction [25]. The area is semi-arid which the land is not suitable for agriculture. Therefore, it is an advantage for wind farm development.

The Binalood region is located in an area which has easy access to other major cities by railway and main road. Hence, transportation cost and time would be very low. Also, there is not any major limitation for existing bridges and tunnels in order to transport the turbine and other equipments to the location [13].

5.5. Distance to the residential areas

As a matter of fact, new wind farms do not create noise because of advanced technological developments [25]. There is an acceptable distance between the Binalood region and the surrounding residential areas. It would yield to lower cost of power line, also easier operation and maintenance too. Noise is also another barrier for wind farm locations, but Binalood is far from residential zones.

6. Conclusions

Since the geography of Binalood provides suitable conditions for harnessing the wind energy, it is inevitable to construct more wind farms in the region. The region has strong wind potential at 40 m height and ideally suited for large wind turbines installation. This region is highly suitable for the wind energy generation, since the wind speeds exceed 6 m/s most of the time. In this study, the mean wind speed and energy density measured at Binalood for 4 years reveals that the current technology provides the economical electricity production from the wind energy. Region has an important and significant wind resources with wind speed mean of 6.511, 6.568, and 6.938 m/s for 10, 30, and 40 m respectively from 2007 to 2010. Average four year (2007–2010) wind power density at 40 m height was estimated 305.514 W/m^2 with wind energy density of 2676.30 kWh/m^2/year. For this area with Weibull parameters k and c, see Table 5, we can derive that the wind is sufficient during the whole year for generating the electricity. The yearly values of k (dimensionless Weibull shape parameter) at 40 m elevation, ranged from 2.165 to 2.211 with a mean value of 2.186, while those of c (Weibull scale parameter), were in the range of 7.683–8.016 with a mean value of 7.834. Net Present Worth of project for 20 years period was estimated as positive $ 615,952. This high indicates that the region is economically feasible for wind turbine installation. Clearly, equivalent worth of cost is much less than the calculated benefit. The region must be considered as a potential area for future prospection. It is recommended that at Binalood station, there should be more wind turbines with rated power greater or equal to 600 kW like S47-660 kW which is popular in Iran.

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