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Wind Resource Estimation and Mapping at Ali Al-Gharby Site (East-South of Iraq) Using WAsP Model

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Abstract

The wind atlas analysis and application program, WAsP, is used to assess wind energy potential، wind climate from geostrophic winds of a given area. In this paper, metrological data from Ali Algharby station was used to predict the wind resource and wind turbine energy production at Ali Algharby site.

Data from metrological station was used to draw up observed wind climates at the anemometer site. Site contour map was digitized using WAsP Map Editortool.

Observed wind climate, digitized contour map, terrain roughness length, obstacle groups and their porosity were used as input to the WAsP model. Vestas V182, 1.65 MW turbine was used. Weibull probability distribution graph of wind speed, power density were drawn. A directional wind rose for January to December 2011 were drawn for site. Results showed that the studied area have Annual Energy Production (AEP) about 5 GWh as mean value. The calculation was obtained at 70 m hub height for the turbine and the roughness length (0.0, 0.03, 0,1,0,4, 1.5) m for the selected area.

Keywords:WAsP Model, Weibull Distribution, Power Density, wind climate, energy production.

تخمين قدرة الرياح لموقع علي الغربي (جنوب شرق العراق) باستخدام نموذج WAsP

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الخلاصة:

برنامج تحليل وتطبيق أطلس الرياح WAsP، يستخدم لتقييم مكامن طاقة الرياح، مناخ الرياح، من الرياح الجيوستروفية للمنطقة المحددة. في هذا البحث فان البيانات الأنوائية من محطة علي الغربي استخدمت لتخمين مصادر الرياح والطاقة المنتجة في موقع علي الغربي. بيانات المحطة الانوائية استخدمت لرسم مناخ الرياح المرصود عند موقع الانيمومتر. الخرائط الكنتورية للموقع رقمت باستخدام الاداة WAsP Map Editor. مناخ الرياح المرصود ، الخرائط الكنتورية المرقمه، طول خشونة التضاريس، مجموعة العوائق ونفاذيتها استخدمت كمدخلات لنموذج WAsP. توربين الرياح (1.65 MW) Vestas V82 استخدم كتوربين مناسب. منحني احتمالية توزيع ويبل لسرعة الرياح وكثافة الطاقة رسمت. وردة الرياح لشهر كانون الثاني لغاية شهر كانون الاول ٢٠١١ رسمت للموقع.بينت النتائج ان منطقة الدراسة تمتلك انتاج طاقة سنوي تقريباً (٥ ميكا واط. ساعة) كقيمة متوسطه. الحسابات استحصلت على ارتفاع (٧٠) متر لمحور التوربين، وطول الخشونة (٠،٠.٠٣،٠.١،٠.٤،١.٥) متر للمنطقة المحددة.

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Introduction

Since early recorded history, people have been harnessing the energy of the wind. Windmills used for centuries in various parts of the world, converting the energy of the wind into mechanical energy for grinding grain, pumping water.[1]

One of the most important actions necessary to study a specific area to erect a wind turbine is the resources availabilities gained from the wind. Over years, wind atlas analysis and application program, WAsP, has become the de facto industry standard for wind resource assessment and sitting of wind turbines[2]. The WAsP program has shown certain accurate climatological predictions over low heights, smooth hills of small to moderate dimensions with sufficiently gentle slopes to ensure attached flows.[3]

This paper evaluates and validate the predictions using wind speed and directions data from metrological stations. The studied area (Ali-Al-Gharbi district in Mysan province, east-south of Iraq) has been selected upon previous studies that locate the promising area in Iraq for establishing wind farms due to the wins speed amount by using GIS techniques [4,5]. theWeibull probability density function was used to estimate a site's probability distribution of wind speeds. The Weibull distribution technique is widely accepted and preferred method for describing wind speed variations at a given site, also it is a best fit for describing wind speed variations at a given site [6].

The Weibull probability density function *Pr(u)* is given by;

$$P_r(u) = \frac{k}{A}\left(\frac{u}{A}\right)^{(k-1)} e^{\left(-\left(\frac{u}{A}\right)^k\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where *Pr(u)* is the probability of observing wind speed (u), k is a dimensionless Weibull shape parameter and A is the Weibull scale parameter (m/s).

The wind power density WPD in terms of area can be rewritten as;

$$WPD = \frac{1}{2} C_p \rho u^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots...(2)$$

While the wind energy WE that can be extracted by a wind turbine is defined by

$$WE = T\int_0^\infty P(u) P_r\,(u) du \ldots\ldots\ldots\ldots\ldots\ldots\ldots....(3)$$

Where P(u) is the power curve of the turbine, and T is the time period.

Replacing eq.(1) into eq.(3), the wind energy can be determined in terms of Weibull distribution; i.e.

$$WE = T\int_0^\infty P(u) \frac{k}{A}\left(\frac{u}{A}\right)^{(k-1)} e^{\left(-\left(\frac{u}{A}\right)^k\right)} du \ldots\ldots.(4)$$

A Weibull distribution depicts the relationship between wind speed at a specific location and power production

Studied Area

The studied area had a 100 km^2 as a square area with its centre point located at coordinates (658073.41E,٣٥٩١٩ 77.29N) at zone 38N for UTM projection as coordinate system. The studied area called 'Ali Al-Gharbi district shown in figure-1. The observed wind climate data were collected at the meteorological station that's located at the above coordinate with site elevation is 12 m a.s.l.

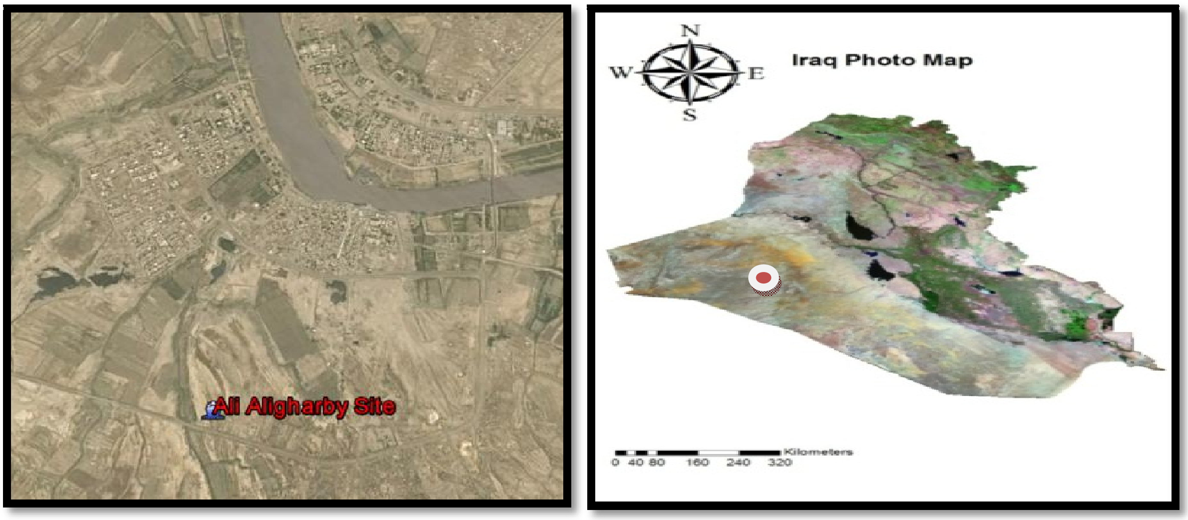


Figure 1- (a) Iraq photo map by LandSat 7 b- Site of the metrological station

Methodology

The parameters that's involve in calculating the wind power in a specified region was calculated and extracted from multiple sources. The first source is the Metrological stations which is a data bank for wind speed measurements through decades, and the readings should be 10 minutes period. The second source is a Google earth satellite image for the region to establish a contour map by surfer program to be a base for calculating the roughness and elevations of the area. A third source is a high resolution photo map to view the interest region and locate the obstacle in it.

The air density value used in this research in order to calculate the mean power density. The power curve for any given wind turbine depends on air density, which changes with temperature and air pressure (elevation). The power curve is usually referred to a standard air density of 1.225 kg m^{-3}, corresponding to conditions of standard sea level pressure of 1013.25 hPa and an air temperature of 15ºC.This is also the fixed air density value used in this version of WAsP when calculating the power density. The wind turbine selected for this study was a Vestas V82 with 1.65MW of installed power with blade diameter of 82m, cut-in wind speed of 3.5 m/s, and cut-out wind speed of 20 m/s. Three wind turbines will be installed in the wind farm. Processes followed in this research can be sumrised in the block diagram that been shown in figure-2. The energy capture of the Vestas V82 turbine is exceptionally good across a wide range of wind speeds and comes installed on a 70m freestanding tower for maximum energy capture. The Vestas V82 turbine is intended for a range of harsh conditions, especially exposed locations. The remaining design life of these machines is in excess of 20 years.Site topographical map was made by Surfer program depending on Google Earth application.Site vector map for roughness made by WAsP Map Editor tool.

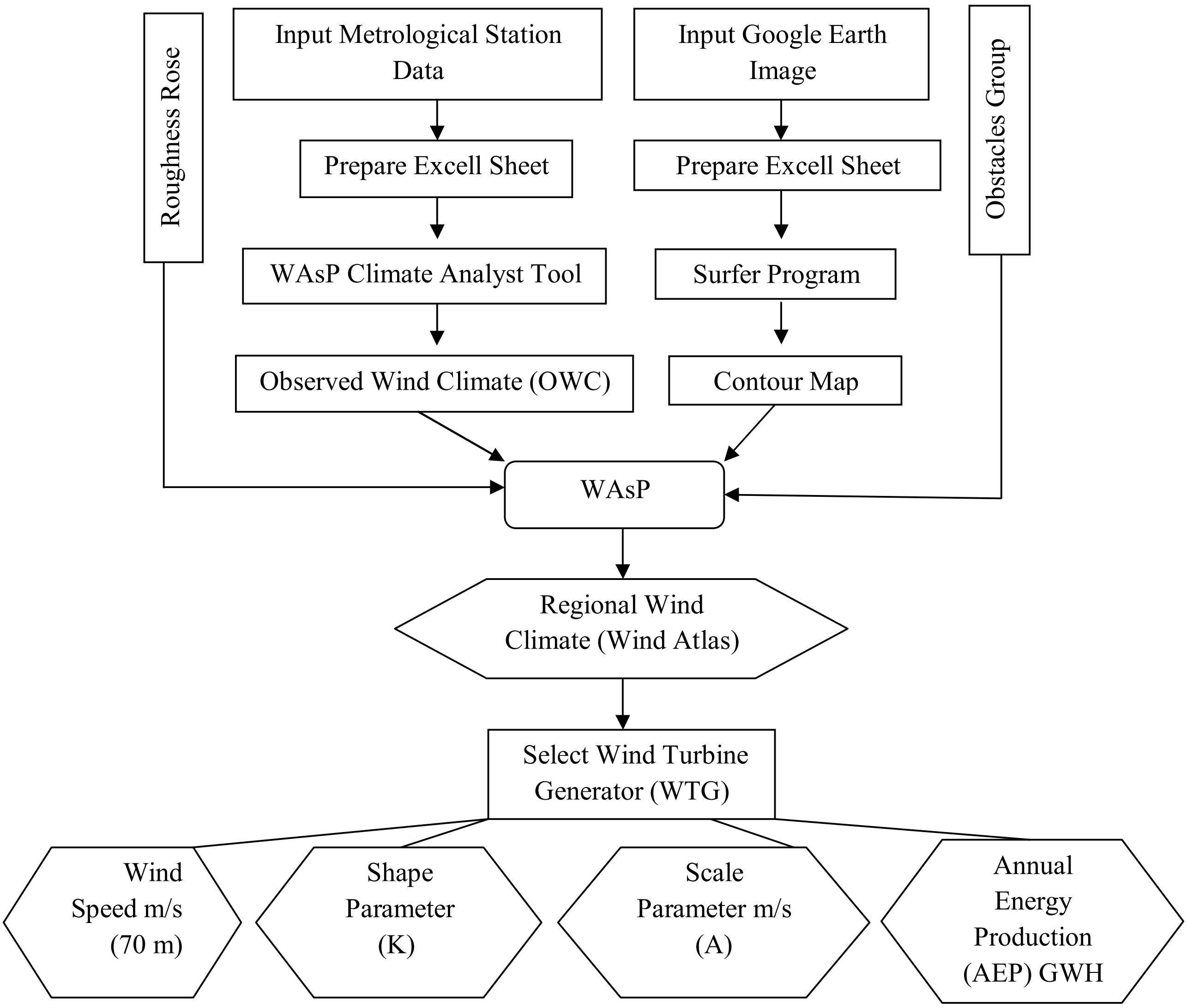


Figure 2- Block diagram of the methodology steps

Result and Discussions

The first step is the estimation of the Vector Map that present in figure- 3, which is shows the low roughness of the terrain. The vector map was established by using ArcGIS software. The mean wind speed estimation for the studied area can be shown in figure- 4, for the 12 sector which is vary between 4.59 to 4.63 m/s and its mean is 4.62 m/s.

Figure- 5 presents the power density (W/m^2) of the wind for all 12 sector and it is vary between 108 to 110 W/m^2 and the mean value is 110 W/m^2. The Annual Energy Production (AEP) was calculate for the studied area and present in figure- 6. AEP varies between 214 to 220 MWh with the mean value 219 MWh.

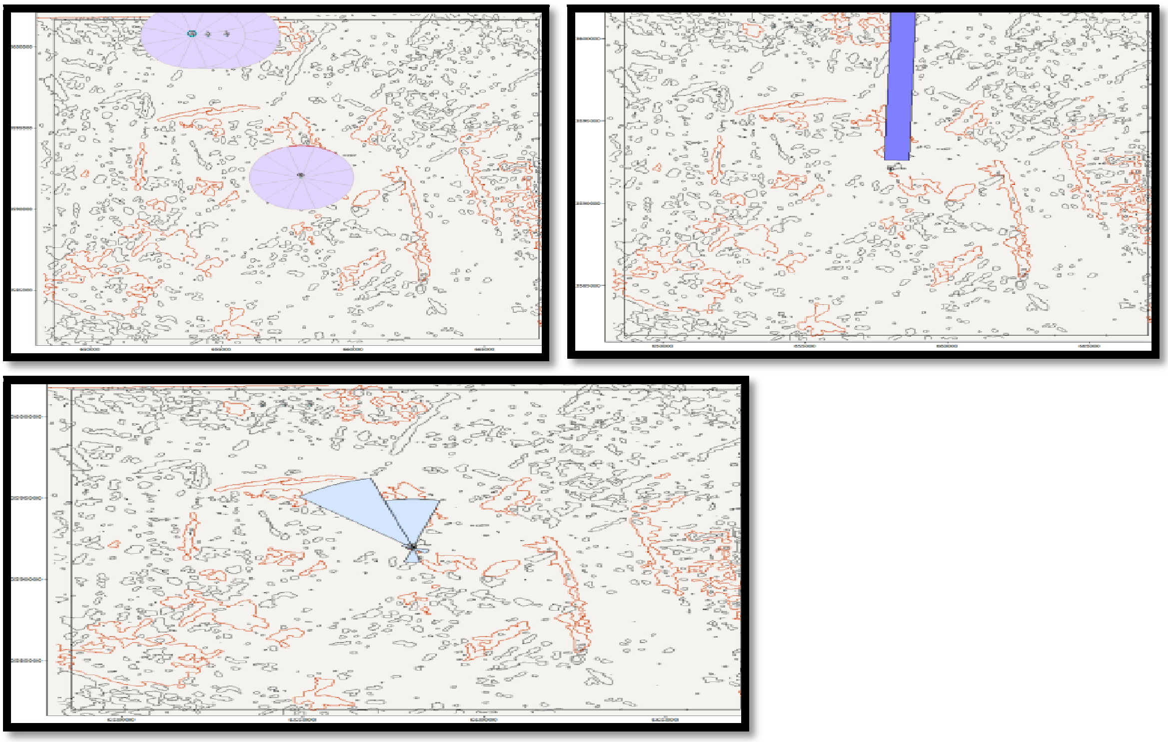


Figure 3- Typical demonstration for obstacle effects for the turbine located at current wind metrological site(left),Vector map consisting of topographic terrain, roughness and obstacle groups (Middle), Observed wind frequency and Power density (right),

The assessment of a wind farm should be locate a good place for establishing wind turbine and for that, three sites was selected in addition to the metrological station site. Also wind turbine type Vestas 82 with 1650 kW output power was selected for this site certifiedon the basis of calculated data. For each location the elevation was located and the AEP was calculated at 70 m hub height. These data was presents in table 1-.

Table 1- presents the calculated Weibull parameters (shape and scale A & k) at 70 m hub heights (H) also the mean wind speed (U) and the power density (E) annual energy production (AEP) was calculated for each selected sites.

Site	**Location [m]**	**H [m]**	**A [m/s]**	**k**	**U [m/s]**	**E [W/m²]**	**AEP [GWh]**
Turbine site 1	(653898.2,3600673.0)	70	8.1	2.60	7.17	347	5.617
Turbine site 2	(654511.4,3600637.0)	70	8.1	2.60	7.15	344	5.591
Turbine site 3	(655232.9,3600673.0)	70	8.1	2.60	7.16	345	5.602

Table 2-, presents the calculated Weibull parameters (shape and scale A & k) at 70 m hub heights (H) also the mean wind speed (U) and the power density (E) was calculated for each selected sites.

Table 2- Project Site wind climate summary (regional wind climate)

Height	**Parameter**	**Roughness Length**				
		0.00 m	**0.03 m**	**0.10 m**	**0.40 m**	**1.50 m**
10.0 m	Weibull A [m/s]	7.39	5.33	4.71	3.77	2.53
	Weibull k	2.44	2.08	2.19	2.17	2.25
	Mean speed U [m/s]	6.55	4.72	4.18	3.34	2.24
	Power density E [W/m²]	277	119	78	40	12
25.0 m	Weibull A [m/s]	8.09	6.38	5.82	4.97	3.84
	Weibull k	2.51	2.24	2.34	2.31	2.37
	Mean speed U [m/s]	7.17	5.65	5.15	4.40	3.40
	Power density E [W/m²]	356	190	139	88	40
50.0 m	Weibull A [m/s]	8.68	7.36	6.80	6.00	4.91
	Weibull k	2.58	2.51	2.58	2.51	2.54
	Mean speed U [m/s]	7.71	6.53	6.04	5.32	4.36
	Power density E [W/m²]	433	268	208	145	79
100 m	Weibull A [m/s]	9.42	8.69	8.07	7.23	6.14
	Weibull k	2.51	2.68	2.84	2.83	2.87
	Mean speed U [m/s]	8.36	7.72	7.19	6.44	5.47
	Power density E [W/m²]	563	424	330	237	145
200m	Weibull A [m/s]	10.38	10.62	9.85	8.87	7.67
	Weibull k	2.40	2.58	2.73	2.73	2.83
	Mean speed U [m/s]	9.20	9.43	8.76	7.89	6.83
	Power density E [W/m²]	774	793	612	447	284

The observed wind frequency for the metrological station site was shown in figure- 7. The predicted wind frequency for the other sites was established in figure- 8 and the mainstream or the trend of the wind was obviously almost stable direction. Figure- 9 shows the self prediction for metrological station site and figure- 10 presents the assessment of wind farm in the studied area.

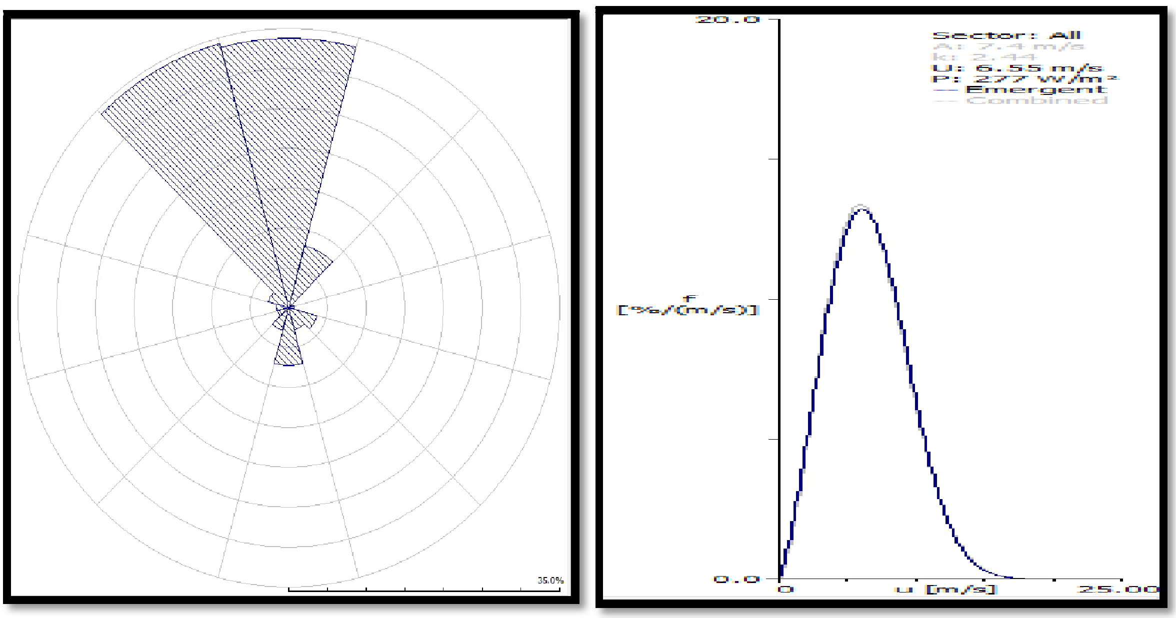
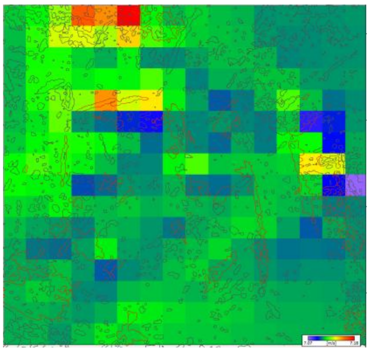


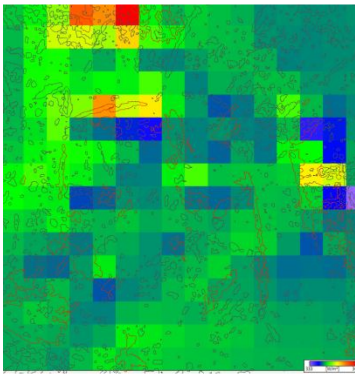
Figure 5- Wind rose showing the percentage variation in wind direction(left), percentage frequency of wind speed distribution with a weibull(right).

Therefore, the site summarized wind resource as predicted by WAsP presented as below:



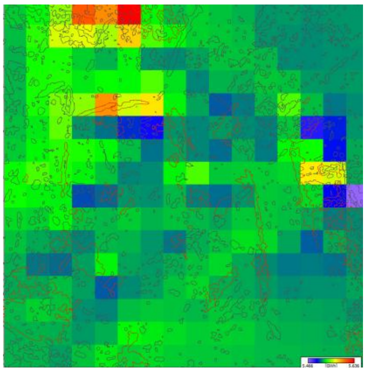
Maximum Value:	7.18 m/s at (655387, 3601052)
Minimum Value:	7.07 m/s at (667687, 3591212)
Mean Value:	7.11 m/s

Figure 6- Wind speed Resource Map at 70m wind turbine heights



Maximum Value:	349 W/m² at (655387, 3601052)
Minimum Value:	333 W/m² at (667687, 3591212)
Mean Value:	339 W/m²

Figure 7- Power density Map at 70m wind turbine hub heights



Maximum Value:	5.636 GWh at (655387, 3601052)
Minimum Value:	5.466 GWh at (667687, 3591212)
Mean Value:	5.527 GWh

Figure 8- Annual energy production at 70m wind turbine hub heights

Conclusions:

WAsPmodelling can be used successfully for wind energy resource assessment of any candidate site provided adequate data is given for analysis and application by the model.

As a result of the analysis, for the selected site, Ali Algharby the most suitable one in terms of electricity production with wind turbine. The best choice for erecting wind turbine is Vestas 82 with hub height 70 m and 1650 kW power due to the output data that calculated in this paper. The studied area has a good wind power to establish a wind farm. The low roughness of the terrain led to stability in wind direction and easy to establish the wind farm. The output power could be about 5GWh for each turbine in the established farm. This study was made for suitability of investments in order to determine of existing wind energy potential in Ali Aligharby. Even if the wind energy systems have high investment costs today, they will provide significant contributions in terms of meeting future energy needs by the help of studies and supports.

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