Wind Energy Potential in Gaza Strip-Palestine state

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Abstract: In this study, wind speed and direction data provided by Meteoblue AG-Switzerland as hourly time-series for 16 years from 2000 to 2015 for selected three cities in Gaza Strip, are used directly to evaluate the wind energy in the three selected sites which are geographically presenting the entire Strip. Jabalia is located in the North of Gaza Strip, Deir-albalah in the Middle and Rafah in the South. The wind rose diagrams have been depicted by using WRPLOT view 7.0.0 (wind rose plots for meteorological data from Lake Environmental, 2011). The statistical analysis of the data shows that; Rafah city is the first candidate to establish a wind farm in the entire Palestinian territory. The reason that, Rafah has the highest wind energy potential than the other sites. The second reason is that Rafah is located on the border crossing to Egypt, which facilitates the transfer of machinery, experts, and reduces transport and communication expanses. In addition to low population density, which increases the economic feasibility of utilizing wind energy at this location for remote area applications. The analysis has been done for a large types of wind turbines types. Gamesa G128-4.5 WT, which is manufactured for classes I and II wind speeds with low cut-in speed, was selected for our project. The estimated annual energy is 15,962 MWh/turbine, with an average utility factor of 40.4%; to cover the shortage of 200 MW we need to 110 WTs. The required area for the wind farm is estimated to be 43 km^2.

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إمكانات طاقة الرياح في قطاع غزة ـ دولة فلسطين

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ملخص: اُستخدمت في هذه الدراسة بيانات عن سرعة واتجاه الرياح والتي قدمتها مؤسسة Meteoblue للأرصاد والتنبؤات الجوية في

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سويسرا محانا كداعمة لدراسة شاملة عن توفر الطاقات المتجددة في قطاع غزة – فلسطين، كسلسلة زمنية لكل ساعة لمدة 16 عامًا (2000 – 2015) لثلاث مدن اختيرت بعناية (جباليا ودير البلح ورفح)، والتي تمثل جغرافيا القطاع بالكامل، وذلك لتقييم طاقة الرياح فيها. تقع مدينة جباليا في شمال قطاع غزة وتقع مدينة دير البلح في الوسط بينما تقع مدينة رفح في الجنوب. تم توضيح مخططات وردة الرياح باستخدام برنامج (WRPLOT view 7.0.0) نسخة 2011 المقدم مجانا من شركة (Lake Environmental).

يشير التحليل الإحصائي للبيانات إلى أن مدينة رفح هي المرشح الأول لإنشاء أول مزرعة رياح في جميع الأراضي الفلسطينية. ويرجع ذلك الى الاسباب التالية: السبب الاول هو أن مدينة رفح لديها أعلى إمكانات طاقة الرياح مقارنة بالمواقع الأخرى. السبب الثاني هو أن رفح تقع على المعبر الحدودي إلى مصر، مما يسهل نقل الآلات والخبراء، ويقلل هذا بطبيعة الحال من تكلفة النقل والاتصالات. بالإضافة إلى انخفاض الكثافة السكانية، مما يسمح بإنشاء مزرعة للرياح في المنطقة. تم إجراء التحليل لأنواع كبيرة من توربينات الرياح. وتم اختيار توربينة رياح امريكية الصنع نوع Gamesa G128-4.5 WT، المصنّعة للفئات الأولى والثانية من سرعات الرياح المنخفضة. أشارت الدراسة إلى أن الطاقة السنوية المنتجة تصل الى 15,962 ميغاواط ساعة لكل توربينة، وكان متوسط معامل الاستفادة 40.4 % ولتغطية العجز من الطاقة في القطاع والذي يقدر بحوالي 200 ميغاواط، نحتاج إلى 110 توربينة رياح، وتقدر المساحة المطلوبة لمزرعة الرياح بحوالي 43 كيلومتر مربع.

Keywords: Gaza Strip, wind data, wind energy, wind farm, utility factor of wind turbine

NOMENCLATURE

A	area swept by the rotor, [m^2]	
c	scale parameter	
cis	cut-in wind speed, [m/s]	
cos	cut-out wind speed [m/s]	
$f_w(v)$	frequency function	
$f_R(v)$	Rayleigh distribution	
$f(v)$	probability density distribution function	
E_{annual}	annual energy production [Wh/year]	
k	shape parameter	
P	Pressure, [kPa]	
P_{gen}	power generation, [kW]	
P_{max}	maximum extractable wind power, [kW]	
$\overline{P}_w$	average power, [kW]	
v	wind speed, [m/s]	
T	Temperature, [ºC]	
U_{wt}	utility factor of the turbine	
Z	height, [m]	
ρ	air density, [kg/m^3]	
σ	variance of the wind speed, [m/s]	
Γ	Gamma function	

1. INTRODUCTION

Global population explosion, environmental pollution and rapidly decreasing reserves of oil resources have been matters of social and economic concern that negatively affects human kind life in all aspects for several years. These reasons have encouraged researchers all over the world to look for alternative resources for energy that have less pollution effects, and can cover the shortage of oil resources with lower costs. Wind energy is one of the major alternatives that has been considered and used in several countries in the world. For example, in Denmark 47% of energy consumption comes from wind power generation stations [1].

Gaza Strip is a small geographical area located along the southeast corner of the Mediterranean. Egypt borders it on the south-west as shown in Figure 1. It is about 41 km long, the narrowest width is 6 km and the widest is 12 km wide, with a total area of 360 km². It lies on Longitude 34°26 east and Latitude 31° 10 north of the equator. According to the last census of the Palestinian Central Bureau of Statistics, at the first of April 2018, the population of Gaza Strip is 2.09 million. The average population density is 4,986 people per square kilometres, while in the camps, the density can rise to as high as 100,000 people per square kilometres. The Gaza Strip is categorized as tropical region with a relatively hot summer and mild winter [2].

During the last decade, Gaza Strip suffered from a continuing crisis of electricity supply due to many political issues which have affected the life of the Palestinians. There are three sources for electricity in Gaza: Israelis (120 MW), Egyptian (17 MW) and the Palestine Electric Company (PEC). PEC supply depends mainly on the fuel amount allowed to cross borders that is totally controlled by Israelis and depends on the political situation. The PEC usually provides around 80 MW or more than 50% of its full capacity of 140 MW.

The total electricity supply in the Gaza from all the mentioned sources is about 217 MW. Also, Gaza's electricity demand varies depending on the time of the year. During the summer and winter, Gaza consumes about 440 MW, and about 380 MW during the Spring and Fall. Usually, there is a noteworthy shortage of approximately 200 MW through the course of the year; this deficit causes recurring interruption of electrical supply to residential, commercial and public facilities [3].

A recent study showed the wind energy resource mapping of Palestine [4], where the main conclusion was confirmed what Hasan provided early [5], that wind potential all over Gaza is not worth to be utilized. Other studies showed the utilization of wind energy could be feasible in many locations in Palestine for cutting-off electricity production [6-8]. Electricity generation by using wind energy requires studying wind speed based on the available data and topographical features of the land in different locations. The coastal strip region (Gaza Strip) is characterised by a very low wind speed throughout the year, with an annual average of about 2.5–3.5 m/s.

In fact, the electricity crisis in the Gaza Strip can be solved by exploitation of the local renewable energy resources. The wind energy can have the opportunity to leadership all other energies, so that it does not really need a space dedicated to the farm, as in the solar energy of PV panels, concentrators or heliostats fields, we can use the wind farm land in any other activities. The wind turbines can be deployed along the border with Egypt and the coastal strip along a distance of 22 km. The present study is considered the first comprehensive study of the Gaza Strip, thanks for Meteoblue to provide us with 16 years collected hourly climatic data

2. ANALYSIS OF THE ENERGY SECTOR IN GAZA STRIP

The Palestinian Authority imports most of the regions' energy from neighbours mainly from Israel (55%), and Egypt (8%); the rest (37%) is generated in the unique Gaza power plant. Palestinian government is trying to make a reconstruction and development scheme of the infrastructure, including the energy sector. They are expected to make advantage of this opportunity and develop a reliable and secure energy strategy based

on renewable energy. Independent renewable energy projects provide decentralized and reliable electricity generation, which is urgently needed in Palestine.

Figure (1). Location and the cities of Gaza Strip

Although governmental levels are not doing very well in the renewable energy sector, there are several encouraging moves in other sectors. The Energy Research Centre (ERC), which was established in 1996 at An-Najah National University (ANNU) has been conducting important research in this field, including: development, system design, feasibility studies and training. The centre has expanded its strategy to include the impacts of energy on global environment, health and social development
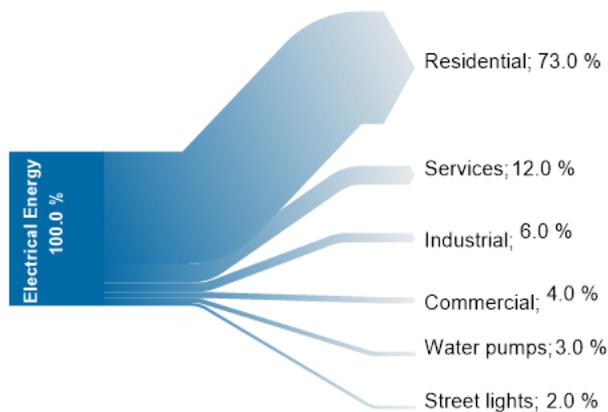

Figure (2). Sankey diagram of electricity consumption by sectors in Gaza Strip [2]

Table (1). Imported energy in Palestine by type of energy in year 2016 [2]

Electricity (MWh)	Gasoline (m³)	Diesel (m³)	Fuel Oil (m³)	Kerosene (m³)	LPG (ton)	Bitumen (ton)	Oils & Lubricants (ton)	Wood& Charcoal (ton)
1,024,120	53,999	239,707	-	150	59,915	748	25	427

3. WIND DATA COLLECTION

In this study, wind speed and direction data at 10m above the ground is provided by Meteoblue AG - Switzerland as hourly time-series for 16 years from 2000 to 2015 for three cities in Gaza Strip. These cities are selected so that covered all the Strip, Jabalia **is** located in the north, Deir-albalah **is** located in the centre and Rafah **is** located in the south. Figure 3 represents the wind-rose and the probability density distribution functions plots of the hourly wind speed for the 16 years for the three selected cities; 80 m above the ground, by using WRPLOT view 7.0.0 (wind rose plots for meteorological data from Lake Environmental, 2011).

3.1. Climatic parameters variation with altitude

Wind speed near to the ground changes with altitude, which requires an equation that predicts the wind speed at one height in terms of the measured speed at another height. For a wind turbine, it is also necessary to know the wind speed at its hub height. The most common expression is the power law, expressed as [9]:

$$v = v_0 \left(\frac{Z}{Z_0} \right)^{\alpha} \quad \text{..} \quad (1)$$

where v is wind speed estimated at desired height, Z; v_0 is wind speed measured at the reference height, Z_0. The exponent α is Hellmann exponent or wind shear coefficient, It depends on site, time, season and height of wind speed measurements. Numerically, α lies in the range of 0.05–0.5, with the most used value of 1/7 (applicable normally to low surface irregularity and well exposed sites). Using this value for α, the measured values of wind speed were induced to 80 m, the hub height of the selected wind turbine [10].

The air temperature T(Z) and air pressure P(Z) are also varying with the altitude. For this reason, correction must be made through equations (2) and (3) (at low altitudes) for temperature in (*K*) and pressure in (*kPa*) respectively [11]:

$$T(Z) = T(Z_0) - 0.0065 \times (Z - Z_0) \quad \text{................................} \quad (2)$$

$$P(Z) = P(Z_0) - 0.0113 \times (Z - Z_0) \quad \text{................................} \quad (3)$$

Accordingly, and from the gas law, $\rho(Z)$ the density of the air is also varied squirearchy with the varied

of the temperature and the pressure according with the relation:

$$\rho(Z) = \frac{3.48432 \times P(Z)}{T(Z)} \quad \text{................................} \quad (4)$$

4. SIMULATION OF WIND POWER AND WIND TURBINE CHARACTERISTICS

For assessment of wind energy potential for a place, and consequently the possible electricity generation, we need to process meteorological data in several mathematical equations. Wind power density has been chosen over wind speed because the power density integrates in a single number the combined effect of

wind speeds distribution and the dependence of power on air density, as well as the cube of wind speed. The maximum extractable wind power from a wind mill working at its optimum efficiency is P_{max} which is expressed as [6]:

$$P_{max}(Z) = 0.2963 \, \rho A \upsilon^3 \quad \text{..} \quad (5)$$

Where A is the area swept by the rotor in $[m^2]$, ρ is the air density in (kg/m^3), and υ is the wind speed in (m/s). The power duration curves are drawn from velocity duration curves using equation (1). The area under the power duration curve represents the energy potential, that is the maximum annual wind energy.

4.1. Probability density function $f(\upsilon)$

Wind speed for a given location can be characterized by probability distribution functions. Weibull and Rayleigh functions can be used to describe wind speed distribution if direct measurements of wind speed and wind frequency are not available. The Weibull distribution is expressed mathematically by a frequency function $f_W(\upsilon)$ as [12]:

$$f_W(\upsilon) = \frac{k}{c}\left(\frac{\upsilon}{c}\right)^{k-1} e^{-\left(\frac{\upsilon}{c}\right)} \quad \text{...............................} \quad (6)$$

where c is the scale parameter, unit of speed; k is the shape parameter; υ is wind speed. Once the mean and variance of the wind speed (σ) are known, the following approximation can be used to calculate the Weibull parameters c and k:

$$k = \left(\frac{\sigma}{\overline{\upsilon}}\right)^{-1.086} \quad \text{...} \quad (7)$$

$$c = \frac{\overline{\upsilon}}{\Gamma(1 + 1/k)} \quad \text{.......................................} \quad (8)$$

Where the symbol Γ denotes to Gamma function.

For simplification, some particular values of the gamma function were presented in [13] are demonstrated graphically for small positive values of x in Figure 4. A trend line is added to the figure attached with the polynomial that presented the values of $\Gamma(x)$ with high precision. The independent variable x is presenting the term $(1 + 1/k)$ in eq. (3):

$$\overline{\upsilon} = \frac{1}{n}\sum_{i=1}^{n}\upsilon_i \quad \text{...} \quad (9)$$

And

$$\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(\upsilon_i - \overline{\upsilon})^2 \quad \text{.................................} \quad (10)$$

The other distribution function is the Rayleigh distribution $f_R(\upsilon)$. This distribution is a special case of Weibull distribution and validate situation where the dimensionless shape parameter k of the Weibull distribution is assumed to be equal to 2. Probability density function of the Rayleigh distribution is given by:

$$f_R(\upsilon) = \frac{\pi\upsilon}{2\overline{\upsilon}^2} e^{\left[-\left(\frac{\pi}{4}\right)\left(\frac{\upsilon}{\overline{\upsilon}}\right)\right]} \quad \text{.................................} \quad (11)$$

| City	Wind rose	Probability density distribution
Jabalia		
Deir-albalah		
Rafah		
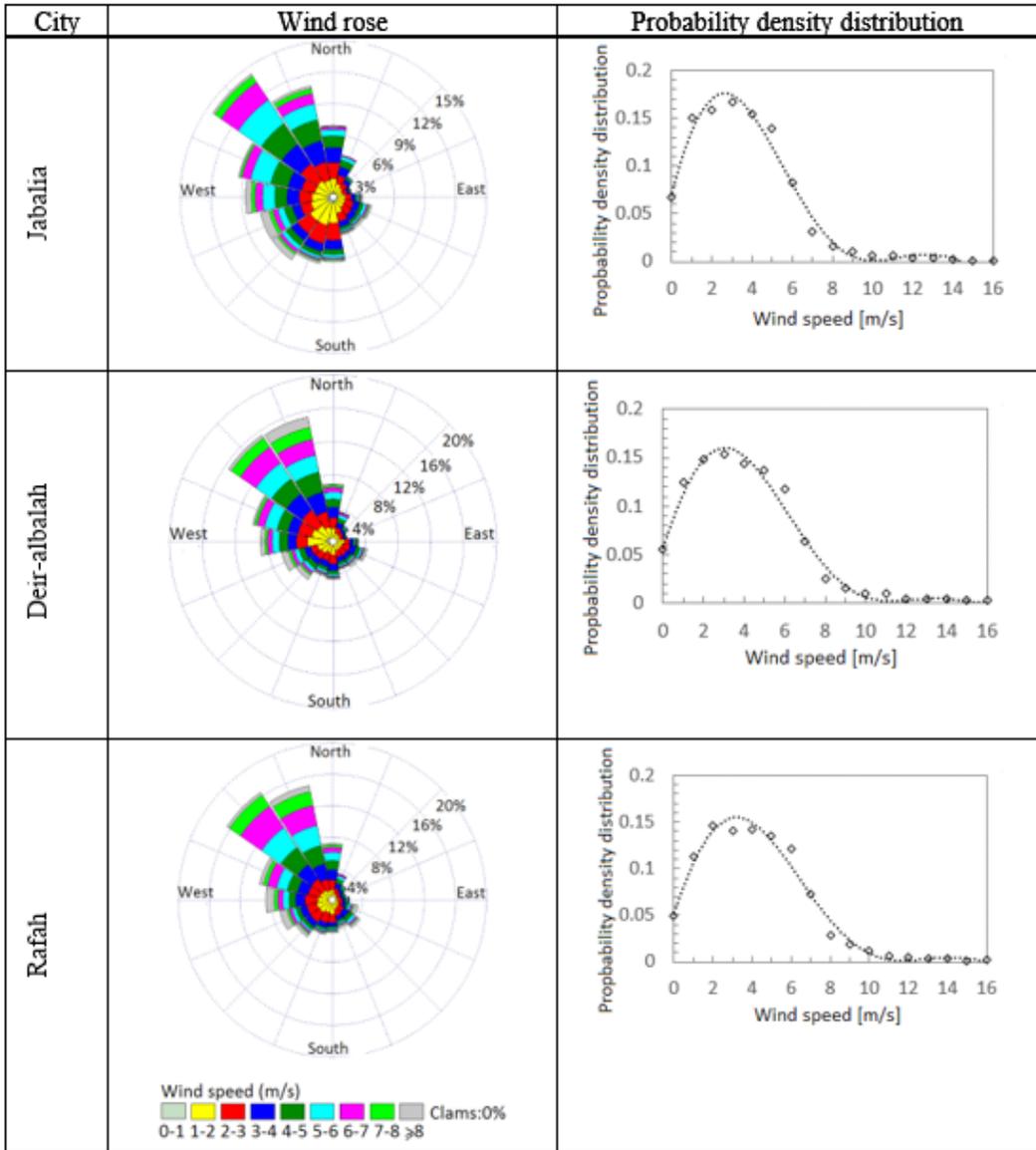
Figure (3). Wind rose and the probability wind density distribution function for the three selected cities.

4.2. Average power in the wind $\overline{P}_w$

The average power $\overline{P}_w$ in the wind can be expressed as:

$$\overline{P}_w = \frac{1}{2}\rho A \int_{0}^{\infty} \upsilon^3 f(\upsilon)d\upsilon \quad \text{...} \quad (12)$$

Where $f(v)$ is the probability density distribution function. If $f(v)$ is the Weibull density function, the average power becomes [14]:

$$\overline{P}_w = \frac{\rho A \overline{v}^3 \Gamma(1 + 3/k)}{2\left[\Gamma(1 + 1/k)\right]^3} \quad \text{..} \quad (13)$$

The chart shows: $\Gamma(x) = 0.1592x^4 - 1.2474x^3 + 3.989x^2 - 5.6221x + 3.7304$, with x-axis labeled X and y-axis labeled $\Gamma(x)$.
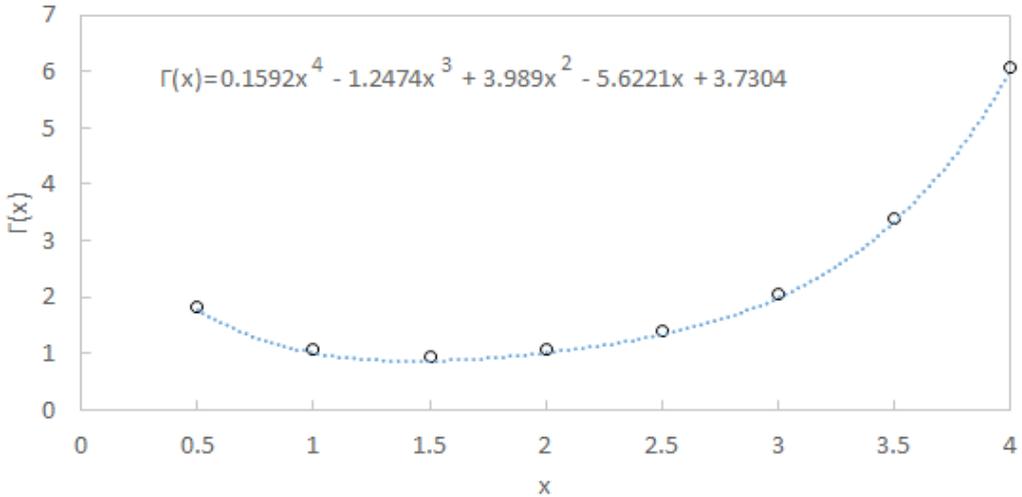
Figure (4). Graphical and polynomial presentation of gamma function [13]

At the last the power generation by a specific wind turbine can be calculated as:

$$\overline{P}_{gen} = \int_{cut-in}^{cut-out} f(v)P(v)dv \quad \text{...} \quad (14)$$

where $P(v)$ is the power curve of the wind turbine, cut-out and cut-in speeds respectively. The annual energy production *Wh/year* is calculated using the following equation:

$$E_{annual} = 8760 \times P_{gen} \quad \text{...} \quad (15)$$

4.3. Probability for different wind speed

For most wind turbines, the range of cut-in wind speed is 3.0–4.0 m/s, so the probability $f(v \geq 3)$ or $f(v \geq 4)$ must be identified. Figure 5 presents a statistic chart for number of hours per year $T(v \geq v_{cut-in})$ in which the wind speed is greater than or equal to a specified speed for example the cut in speed for Rafah city at 80 m above the ground and also the curve fitting.

It is evidence from the figure 5 that in Rafah, the operating hours of turbines can reach 8390 hours per year (96%) if the cut-in speed is 3.0 m/s, and 6715 hours (77%) if the cut-in speed is 4.0 m/s (assuming the cut-off wind speed is infinite). Figure 5 is important for economic feasibility. For more convenience to deals with mathematical correlation, equation (12) and (13) obtained by SegmaPlot software, they present the statistical data depicted in figure 5 with high precision.
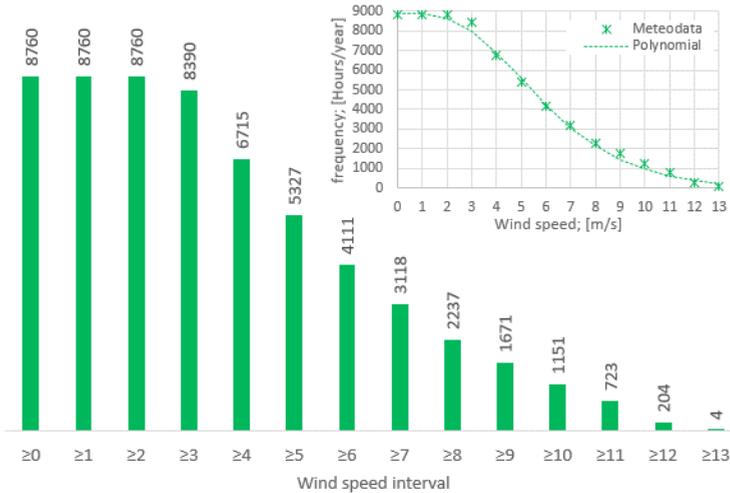
Figure (5). A histogram and curve fitting of number of hours for occurring different wind speed at 80m above the ground for Rafah city

$$\mathrm{T}\left(v \geq v_{\text{cut-in}}\right) = 8925.9 - 9043.84 \; e^{\left[-\left(\frac{1018.91 - v}{1012.24}\right)^{413.873}\right]} \quad .... \quad (16)$$

Consequently, the probability of speeds occurrence greater than or equal to a specific speed will be found as:

$$f\left(v \geq v_{\text{cut-in}}\right) = \frac{1}{8760}\mathrm{T}\left(v \geq v_{\text{cut-in}}\right) \quad .... \quad (17)$$

4.4. Power output of the wind turbine

As different wind generators have different power output performance curves as it illustrated in Figure 6. The wind turbine should be satisfaction three conditions for maximizing energy output:

1. Minimum cut-in speed;
2. The rated wind speed that matches or near - as possible - the maximum-energy wind speed; and
3. Maximum cut-of speed.

Using polynomial regression to define the power output curve of the chosen Gamesa GT128/4500 wind generator. Technical description and characteristics data of the chosen wind generator is documented in the appendix. From figure 6, one can recognize that, the cut in wind speed is 1.0 m/s, the rated power wind speed is 12.0 m/s and the cut out wind speed is 27 m/s. It is explicitly evident that, the Gamesa wind turbines are created for class I wind speed with low cut-in speed which is very suitable the situation of Gaza Strip. Five expressions are used in order to describe the wind turbine power characteristics as a function in the wind speed, these are [15]:

$$\mathrm{P}(v) = \begin{cases} 0, & v < 1.0 \; or \; v > 27.0 \\ -0.874v^4 + 19.661v^3 - 90.865v^2 + 207.39v - 98.1, & 1.0 \leq v < 9.0 \\ -2.424v^3 - 65.065v^2 + 2668v - 13956, & 9.0 \leq v < 12.5 \\ 4500, & 12.5 \leq v < 18.0 \\ -193.58v + 7984.5, & 18.0 \leq v < 27 \end{cases} \quad ..... \quad (18)$$
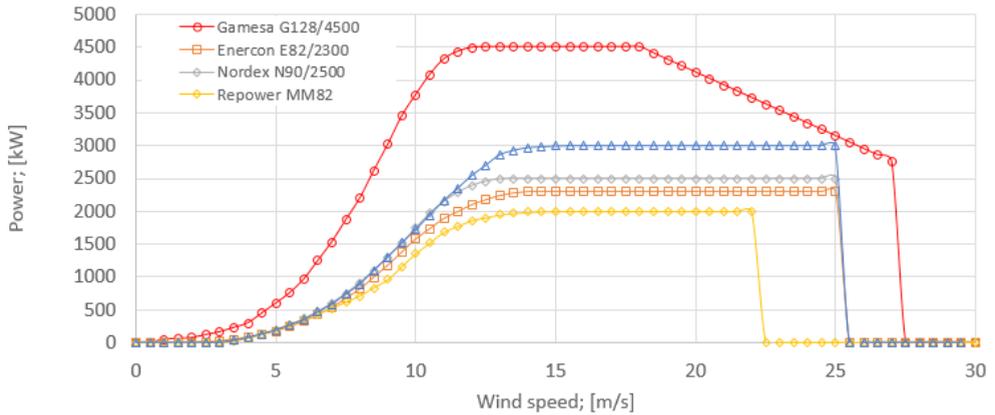
Figure (6). The power curves for selected wind power turbines

Figure 7 illustrates the maximum energy production for Rafah city. The maximum energy production is obtained by introducing the wind speed interval into equation (5) then multiplying by the probability density distribution function $f(v)$. The maximum energy corresponding to the rated wind speed will be expressed as:

$$E_{max}(v_{rated}) = 8.760 P_{max} f(v) \quad \text{... (19)}$$

As it is evidence from Figure 7, the rated wind speed is about 7 m/s, so we have to choose a wind turbine with rated wind speed of 7 m/s for maximum energy output. Indeed, the area under the curve is presented the maximum power extracted from the wind characteristic of the given site.

The utility factor (U_{wt}) indicates to how much of the wind turbine power capacity is employed, and it is calculated as [15]:

$$U_{wt} = \frac{real\ power\ generated\ from\ the\ turbine}{power\ capacity\ of\ the\ turbine} \quad \text{... (20)}$$
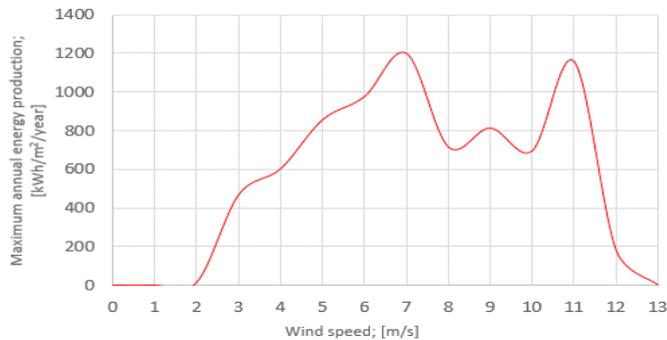
Figure (7). The maximum annual energy production vs the wind speed for Rafah city at 80m above ground

5. RESULTS AND DISCUSSION

The total annual wind energy production for Rafah, Deir-albalah and Jabalia were evaluated. In the first step the meteorological data is reformatted and tabulated in separate sheets for each city by using MATLAB software. Then the output files are uploaded to WRPLOT view 7.0.0 (wind rose plots for meteorological data

from Lake Environmental software 2011) in order to plot the wind rose and the frequency distribution of the three cities. While for the statistical and mathematical analysis, the Ms Excel software is used, three separate sheets are created for the considered cities
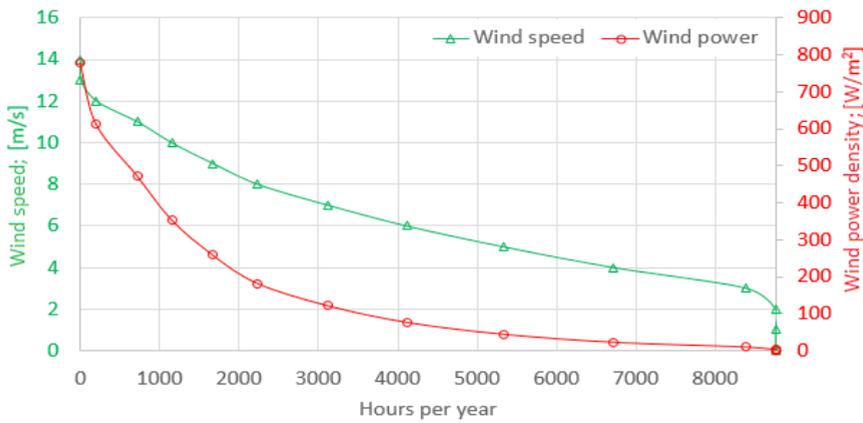
Figure (8). Velocity and power duration curves for Rafah city

The potential of wind energy is calculated using equation (9), and the results tabulated in Table 2. Table 2 also, presents annually and monthly mean velocity over 16 years, the shape parameter (*k*), the scale parameter (*c*), and the average wind energy potential for the selected sites in Gaza Strip. While Figure 8 depicts velocity and power duration curves for Rafah city.

Table (2). Average monthly and annually mean wind speed (*m/s*), the Weibull parameters and power density (*W/m²*) for the selected sites at 80 m above the ground.

Month	Rafah				Deir-albalah				Jabalia			
	$\overline{v}$ (m/s)	k	c (m/s)	$\overline{P}_w$ (W/m²)	$\overline{v}$ (m/s)	k	c (m/s)	$\overline{P}_w$ (W/m²)	$\overline{v}$ (m/s)	k	c (m/s)	$\overline{P}_w$ (W/m²)
Jan.	6.79	1.70	6.33	446.0	5.27	1.63	5.96	217.7	4.93	1.54	5.53	191.8
Feb.	7.11	1.60	6.98	547.4	5.93	1.53	6.65	336.8	5.50	1.42	6.08	297.3
Mar.	6.76	2.07	5.23	365.2	4.43	2.01	5.11	105.7	4.05	1.94	4.65	83.1
Apr.	6.48	1.93	6.08	341.1	4.99	1.95	5.74	154.2	4.70	1.85	5.38	135.3
May	5.43	1.87	4.89	207.0	4.17	1.90	4.79	92.5	3.72	1.92	4.27	64.8
Jun.	6.43	2.02	4.92	321.2	4.12	2.06	4.75	83.4	3.73	2.07	4.30	61.2
Jul.	6.33	1.67	4.26	368.4	3.69	1.72	4.21	70.7	3.20	1.68	3.63	47.2
Aug.	6.10	1.84	4.54	298.1	3.83	1.83	4.39	74.4	3.30	1.77	3.77	49.3
Sep.	6.19	1.96	4.91	293.3	4.24	2.01	4.88	92.3	3.60	1.97	4.14	57.4
Oct.	5.77	2.22	4.87	215.2	4.09	2.13	4.71	78.8	3.53	2.15	4.07	50.4
Nov.	5.63	2.47	5.26	183.9	4.23	2.28	4.89	83.0	3.81	2.18	4.39	62.5
Dec.	6.20	1.94	4.90	298.3	4.01	1.92	4.61	81.7	3.79	2.00	4.36	66.4
Annual	6.34	1.86	5.25	331.1	4.41	1.83	5.05	113.1	3.98	1.75	4.54	86.7

5.1. Average yearly probability density function

The Weibull and Rayleigh distribution are calculated for Rafah city as an average for the 16 years. The recorded wind data shows that, *k* (the shape parameter) is found to be 1.69, and c (the scale parameter) *is* 4.91 m/s using Equations (3-6). The distributions are shown in Figure 9.
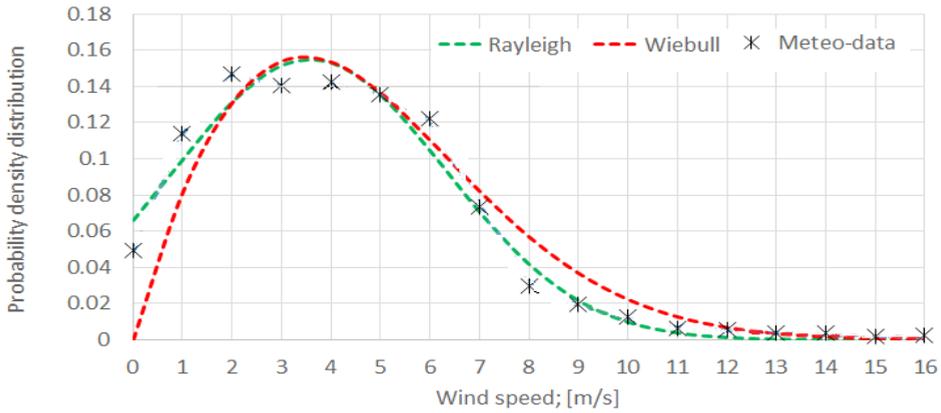
Figure (9). A comparison of the probability wind density distribution function obtained by Weibull and Rayleigh models and the meteo-data for Rafah city at 80 m above grd for the 16 years.

It is clear from figure 9 that, the Weibull function does not implicitly fit the distribution of wind speed data (because we have zero wind speeds). However, the Rayleigh function is better representing the data.
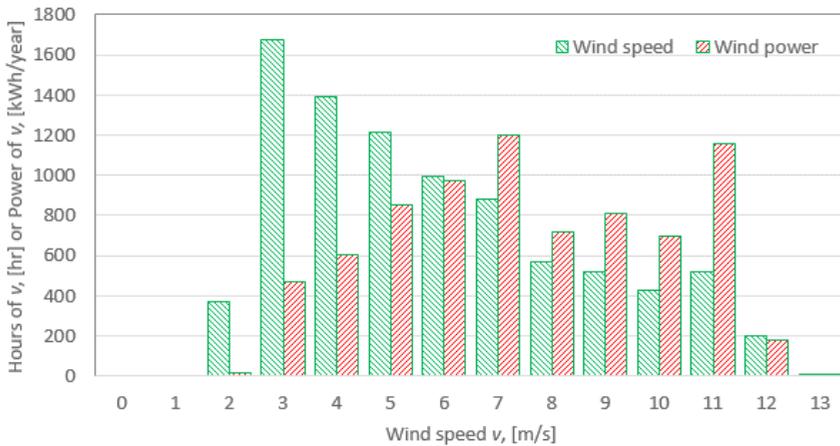

Figure (10). The power at any wind speed with the hours the wind blows at that speed for Rafah city at 80 m above the ground and for Gamesa G128-4.5 MW turbine
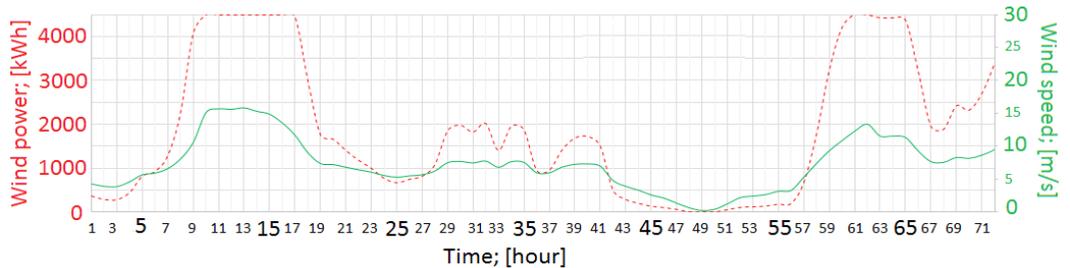

Figure (11). The hourly power production and wind speed variation for the first 72 hours of January average of (2000-2015) for Rafah city at 80 m above grd with Gamesa G128-4.5 turbine
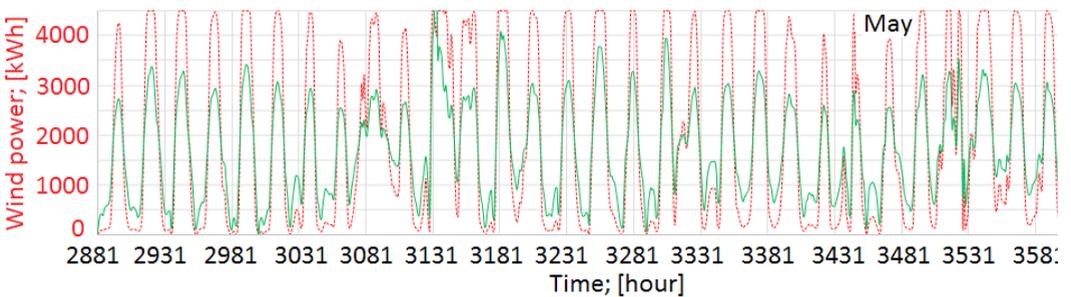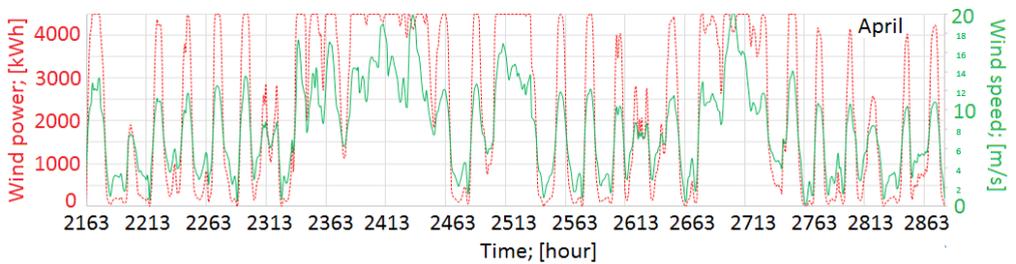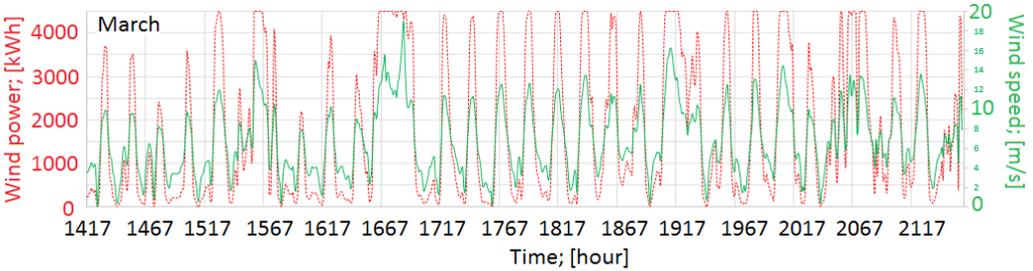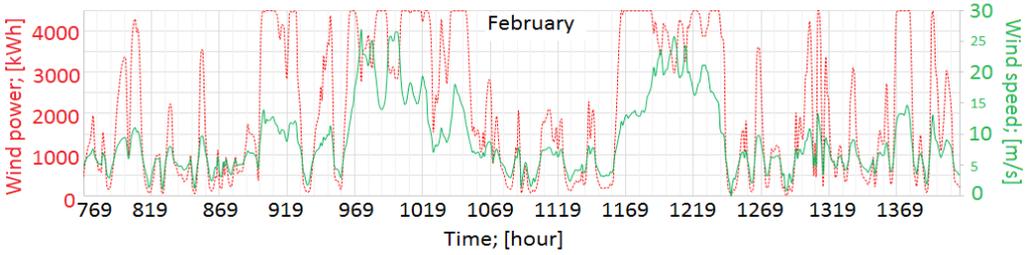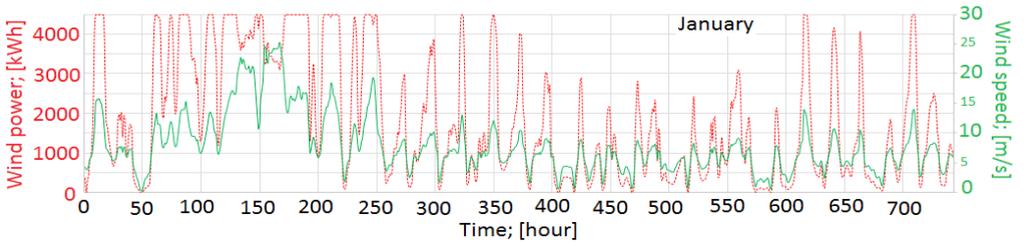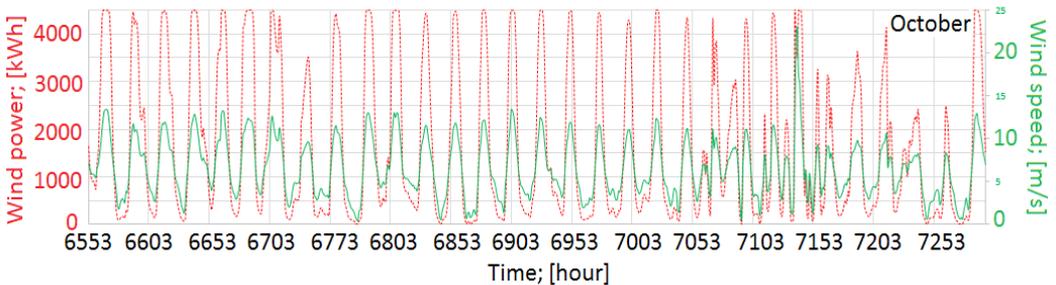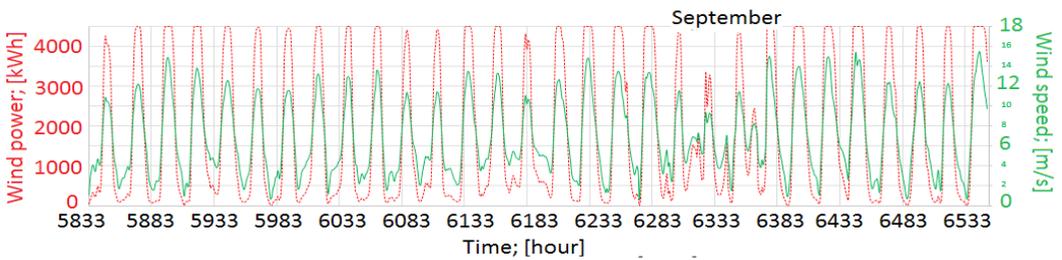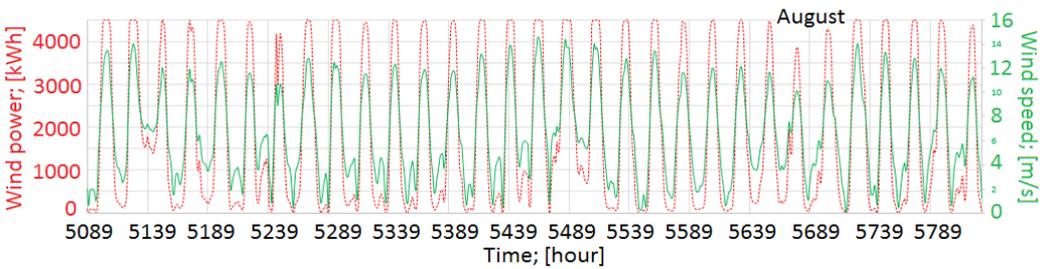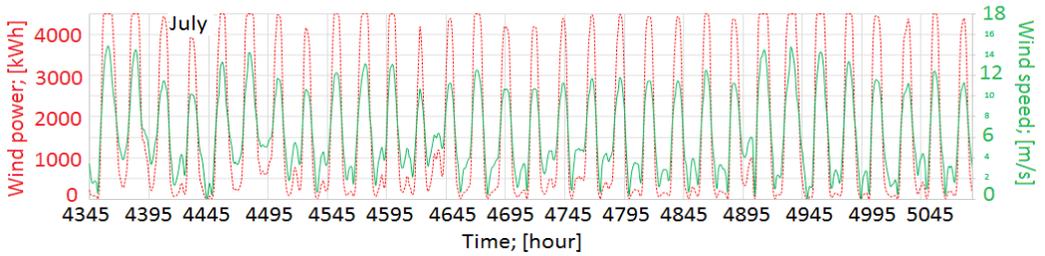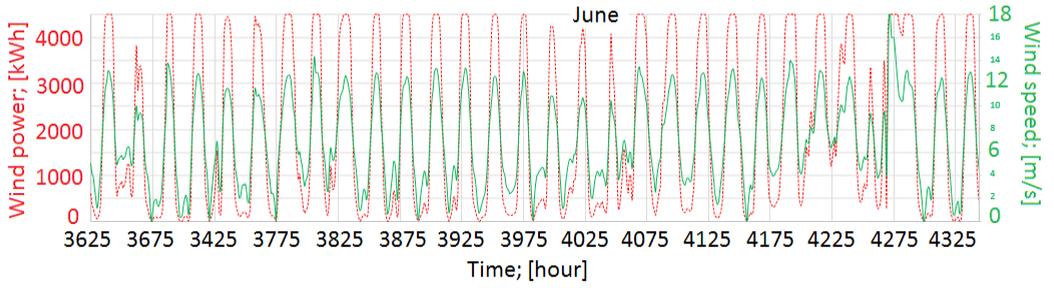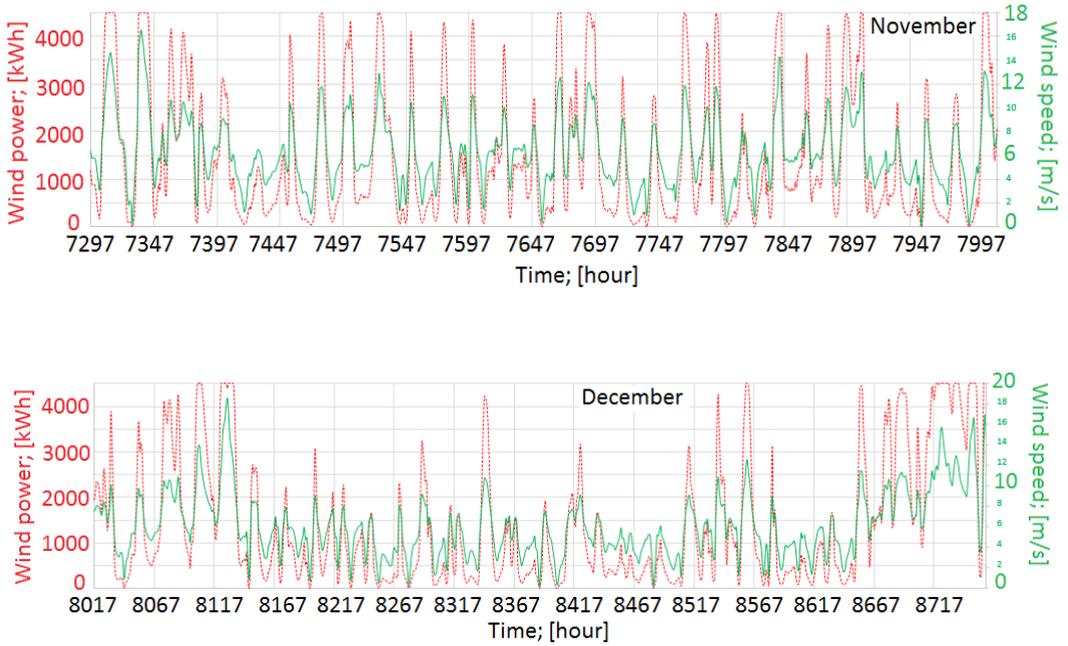
Figure (12). The average hourly power production and average wind speed for each month (2000-2015) for Rafah city at 80 m above the ground with Gamesa G128-4.5 turbine

5.2. Estimating the annual energy production

The total kWh of energy produced for a specific wind turbine is estimated from the combination of the power at any wind speed with the hours the wind blows at that speed as given in equation (14). Weibull or Rayleigh statistical distribution can be alternatively used in the case that only the average wind speed is known. Figure 10 corresponds to Gamesa G128-4.5 MW turbine and hourly wind speed. Figure 11 illustrates the hourly power production and wind speed variation for the first 72 hours of January (2000-2015). While Figure 12 illustrates the hourly power production and the average wind speed through the 16 years for Rafah city at 80 m above the ground every month.

Accordingly, the total power generated from one Gamesa G128-4.5 wind turbine can be obtained as the area under the curve of power of Figure 12. Table 3 tabulated the monthly power generated and also the total annual power is presented.

As it indicates in Table 3 the utility factor of Gamesa G128-4.5 wind turbine is greater than PV solar systems which equal to in best conditions 30% (at STC).

Table (3). Annual and monthly power generated and the utility factor for Rafah

Item	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.
MWh	1385	1383	1334	1649	1419	1434	1281	1353	1339	1246	1070	1047	15962
U_{wt}	0.414	0.457	0.398	0.509	0.424	0.443	0.383	0.404	0.413	0.372	0.330	0.313	0.404

6. CONCLUSIONS

This paper deals with 16 years hourly climatic data for three sites in Gaza Strip in order to determine the best location to build up the first wind power farm in the Palestinian territory. The data used in the research were provided from Meteoblue for the purpose of assessment the wind energy potential in three sites, which present the all Gaza-Strip (Jabalia in the north, Deir-albalah in the centre and Rafah in the south of the Strip). This data is published for the first time. Wind speed and the frequency measurements were taken from Gaza Strip showed that Rafah City has the highest wind energy potential, with an annual average wind speed of 6.38 m/s and a speed higher than 7 m/s for 3118 hours per year (36%) and about 200 hours of rated wind speed. Since Rafah sites are less populated and have isolated and scattered areas, this increases the economic feasibility of utilizing wind energy.

More energy can be produced by using higher towers and larger rotor diameters. A tower of 140 m height is technically available from Gamesa G128-4.5 MW turbine for example at 140 m above the ground the energy produced by one turbine increases by 10.315% of that produced at 80 m altitude.

ACKNOWLEDGMENTS

APPENDIX

Wind turbine model Gamesa G128-4.5 MW characteristics [16]

Parameter	Value
Cut-in wind speed	1.0 m/s
Rated wind speed	12.0 m/s
Cut-out wind speed	27.0 m/s
Rotor diameter	128.0 m
Swept area	12,868.0 m^2
Number of blades	3
Power density 1	349.7 W/m^2
Power density 2	2.9 kW/m^2
Hub height	81/120/140 m
Type	Steel tube/concrete
Shape	Conical

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