ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume VII (XVII), 2008

WIND ENERGY PROBABILITY ESTIMATION USING WEIBULL DISTRIBUTION FUNCTION

***Drd.Ing. Luminita BAROTE, **Drd.Ing. Ionela NEGREA,**
* Faculty of Electrical Engineering and Computer Science, Transilvania University of Braşov, Eroilor, 29, 500068 Braşov (Romania), email: barote@leda.unitbv.ro
****** Faculty of Technological Engineering, Transilvania University of Braşov, Eroilor, 29, 500068 Brasov (Romania), email: ionela_n@unitbv.ro

Keywords: Wind turbine, Weibull distribution, Wind energy, Matlab software

Abstract: The principal objectives of the article are to calculate the wind energy probability by using Weibull distribution function. The energy from wind speed for one month is equal with the area under power curve, multiply with the number of days for that month. To estimate the wind energy probability is need the wind speed data. These values are taken from a Meteo Station from TEI University of Crete, Greece.

1. Introduction

The wind generator is situated in the yard of the meteorological station from the Technological Educational Institute of Crete – Heraklion, near the bio-climatic house. The electrical power supply of the house is assured by a hybrid system, which consist of a wind generator with a maximum performance of 1100 Wp and a photovoltaic panel with a maximum performance of 450 Wp. For storage it uses an accumulator blank.

Figure 1. The Bio – climatic house

A meteorological station is mounted near the bioclimatic house. The Bioclimatic house and the meteo station can be seen in Figure 1.
The following parameters are registered:

- Outside temperature
- Interior temperature
- Wind direction
- Wind velocity
- Solar irradiation
- Barometric pressure
- Air humidity
- CO_2 concentration.

My focus is the estimate the wind energy probability using Weibull distribution function from Matlab software. The wind speed was measured with the help of an anemometer AN1 placed at 10 m high. Mean values were recorded and stored from 10 to 10 minutes using a Data logger (DL2).

2. Determination of the available wind power resource

2.1 Weibull Distribution

It is very important for the wind industry to be able to describe the variation of wind speeds. Turbine designers need the information to optimize the design of their turbines, so as to minimize generating costs. Turbine investors need the information to estimate their income from electricity generation. If wind speeds are measured throughout a year, it is noticeable that in most areas strong gale force winds are rare, while moderate and fresh winds are quite common. The wind variation for a typical site is usually described using the so-called Weibull distribution.

The wind speed variation is best described by the Weibull probability distribution function. There are two important parameters, the shape parameter "k", and the scale parameter "c". The probability of wind speed being "h" during any time interval is given by the following equation:

$$h_{(v)} = \left(\frac{k}{c}\right) \cdot \left(\frac{v}{c}\right)^{(k-1)} \cdot e^{-\left(\frac{v}{c}\right)^k} \quad \text{for } 0 < v < \infty \tag{1}$$

The average wind speed and the most probable wind speed are then given by:

$$vmp = c \cdot (1 - \frac{1}{k})^{\frac{1}{k}} \tag{2}$$

$$v_{prob} = \left(\frac{k}{c}\right) \cdot \left(\frac{vmp}{c}\right)^{(k-1)} \cdot e^{-\left(\frac{vmp}{c}\right)^k} \tag{3}$$

2.2 Wind power

The wind power can be determinate using the equation:

$$P_{wind} = \frac{1}{2} \cdot \rho_{air} v_{wind}{}^3 \tag{4}$$

where:

P_{wind} - the specific wind power, [W/m^2]

v_{wind} - the average wind speed, [m/s]

$\rho_{air} = 01{,}225$ - the density of dry air, [kg/m^3] (average atmospheric pressure at sea level at 15° C).

3. Calculate the wind energy probability using Matlab software

The characteristics curves of the model were made in Matlab using Weibull distribution and the appropriate fitting option from the program. Below one can see all the steps for wind speed distribution the wind power calculation.

- **Step 1.** The first step was to import the wind speed data from the Excel file in the Matlab Workspace with the following command:

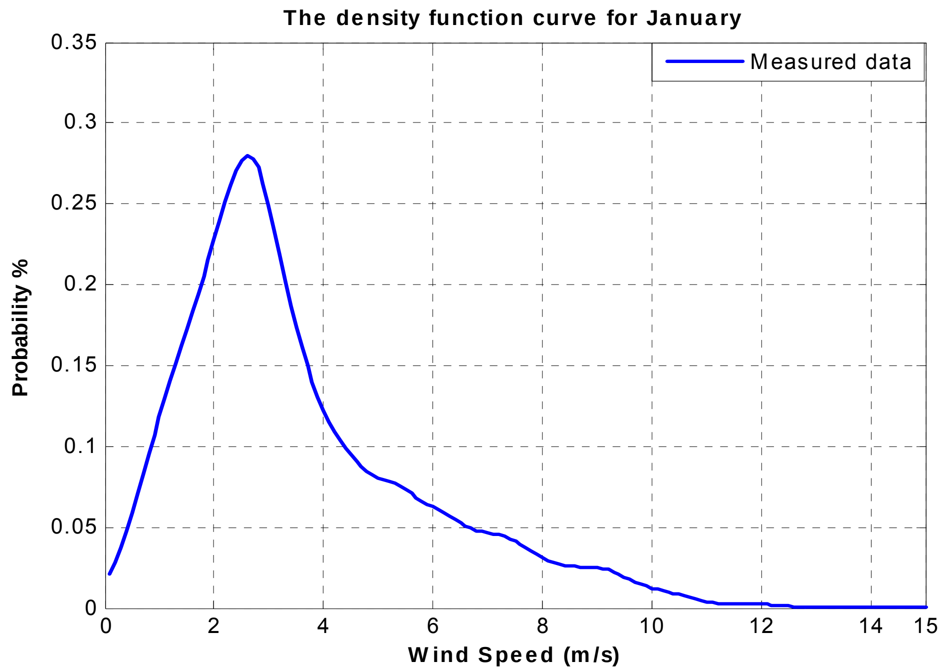
Edit → Paste to Workspace → Import Wizard →Finish

The data will be stored in a vector called *A_pastespecial.* The name will be changed into *data*. The vector size is depending on the month (e.g. for a 31 days month is 4320 values).

- **Step 2.** The second step was to estimate the probability of the wind speed by the help of the following function: ***[f, x] = ksdensity (Wind Speed, X)*.**

The vector "x" is defined as*:* ***X = [X1:X2:X3],*** where X1 represents the beginning of the x value, X2 represents the increment value of x and X3 is the end point for the density estimation.

- **Step 3.** In the third step we have plotted the results on graphic using "***plot***" instruction from Matlab, e.g. plot (x, f); → grid on; → it makes the curve of the density function for January.



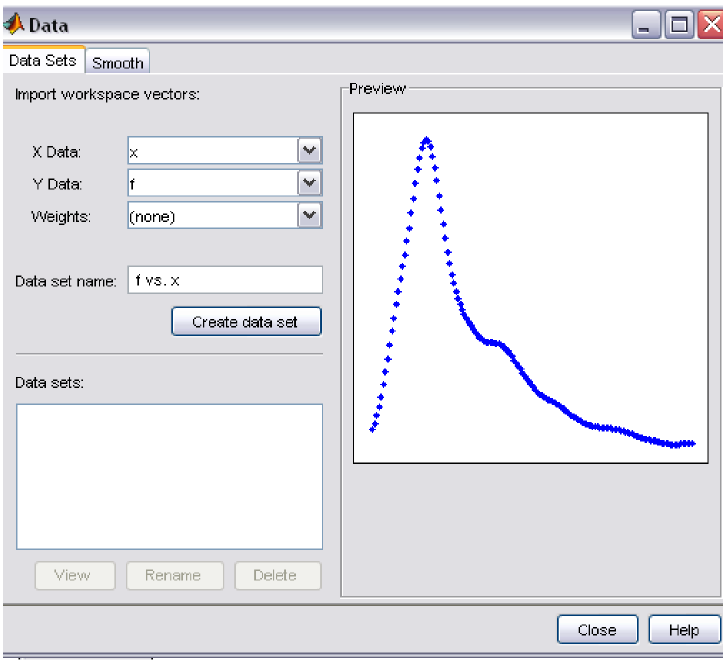
- **Step 4.** The data are fitted with the Weibull distribution. One can do this by using use the "***cftool***" instruction which will open the window → ***Curve Fitting Tool*** where data are loaded from the "Data" button:

X Data: x vector
Y Data: f vector

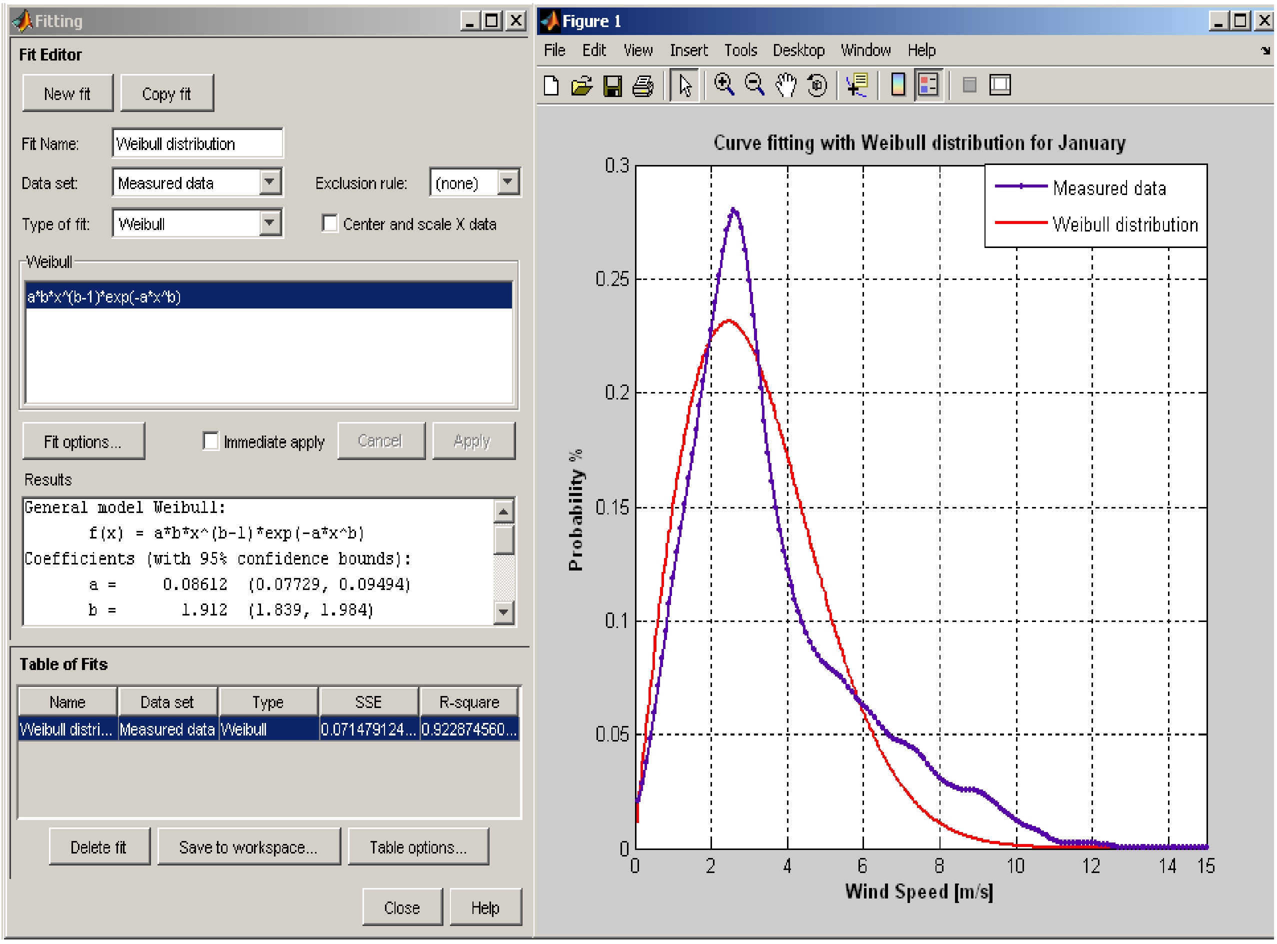
Date set name: fvs.x

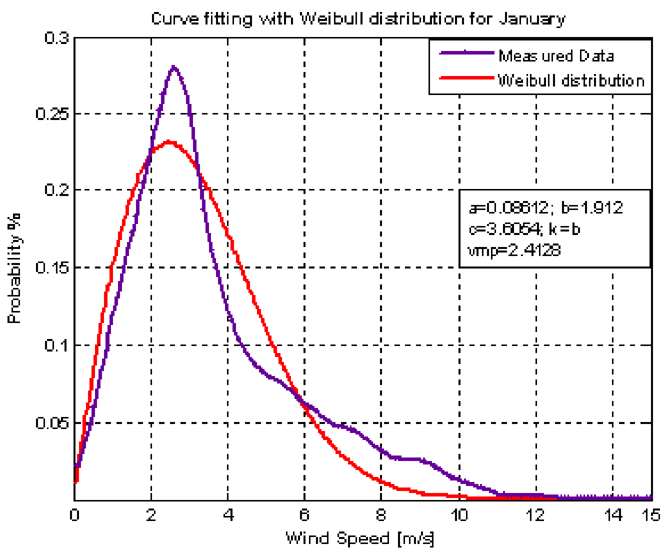
→ ***Create data set*** and it will appear in Data set → ***Close***

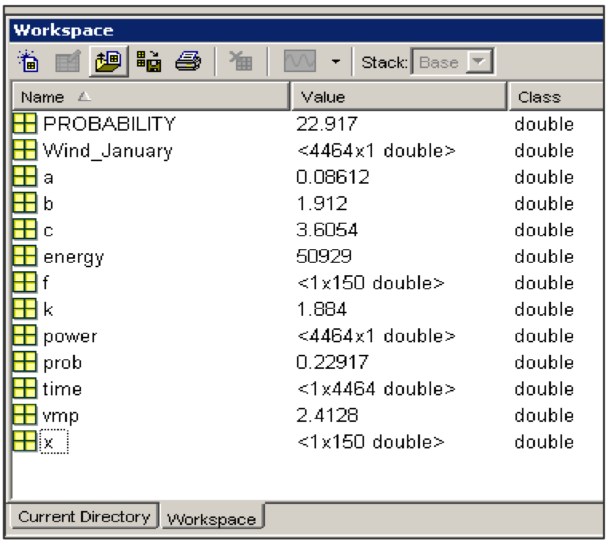
→ Now from the Curve Fitting Tool the ***Fitting*** Button has to be chosen which will open the Fitting window. In the Fit Editor area choose ***New Fit.*** In the Fit Name it is written:"fit.1-Weibull distribution", in the Data set it was chosen: "f vs. x-Measured Data" and in Type of fit Weibull.



The Fitting window contains in the result area the general function of Weibull and the calculated values for the coefficients: “a” and “b” as well as the other parameters, which can also be seen in the Table of Fits from the Fitting window.







The energy from wind speed for one month is equal with the area under power curve, multiply with the number of days for that month. In order to calculate the area under the curve, the **trapz (time, power)** function must be used.

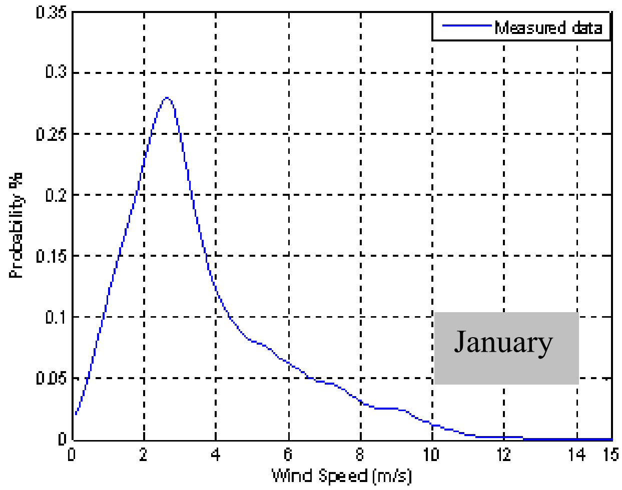
The main program from the M. file for January wind speed distribution is presented in the following table:

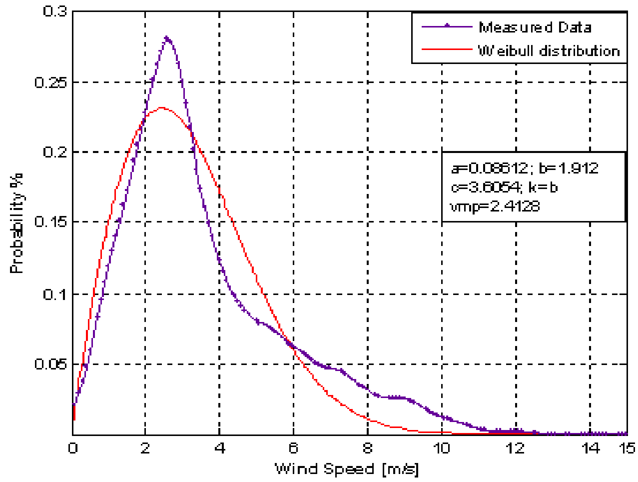
```
% the Matlab file (program) for the calculation of the model generator parameters
x =[0.1:0.1:15] %the values on the X axis for the wind speed can go until 15 m/s
[f, x] = ksdensity (Wind_January, x);
plot (x, f);         % represents the density function
grid on, title ('The density function curve for January'), xlabel ('Wind Speed (m/s)'),
ylabel ('Probability %'), legend ('Measured data');
cftool;          %make the curve fitting with Weibull distribution
a= 0.08612    % the coefficients "a" and "b" are the result in Matlab for the fitting with
Weibull fit type
b=1.912
k=b              %in Matlab the "b" parameter is equal with k for the Weibull distribution
c=(1/a). ^(1/b) %the formula for "c" parameter for Weibull function
vmp=c*(1-1/k)^(1/k); % the average wind speed
prob=(k/c)*((vmp/c)^(k-1))*exp (-(vmp/c)^k); % the most probable wind speed
PROBABILITY=prob*100;     % the probability
% creating the vector with the values of the powers
power = [1/2*1.225*Wind_January. ^3];
time=0:0.16667:744;
plot (time, power);
Energy=trapz (time, power);
```

4. The results

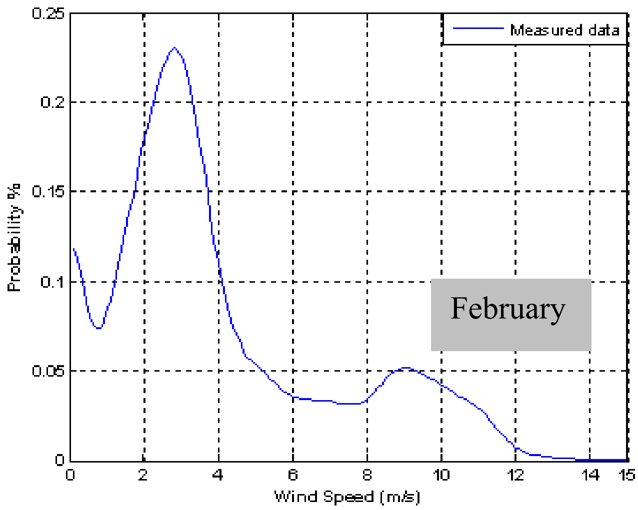
In the next pages there are presented the wind energy probability graphs and the result for each month (Year 2004, Heraklion data). The wind energy values are plotted and the wind energy variation during the whole year can be studied.

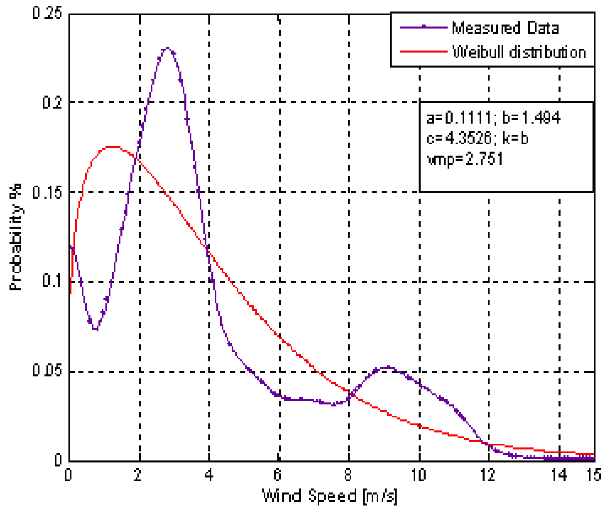
The calculated principle for each month is the same as above mentioned; just wind speed data is different according as wind potential for each month.



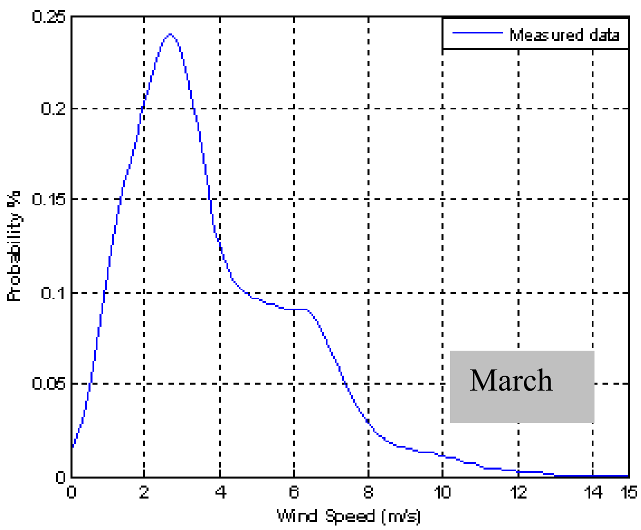


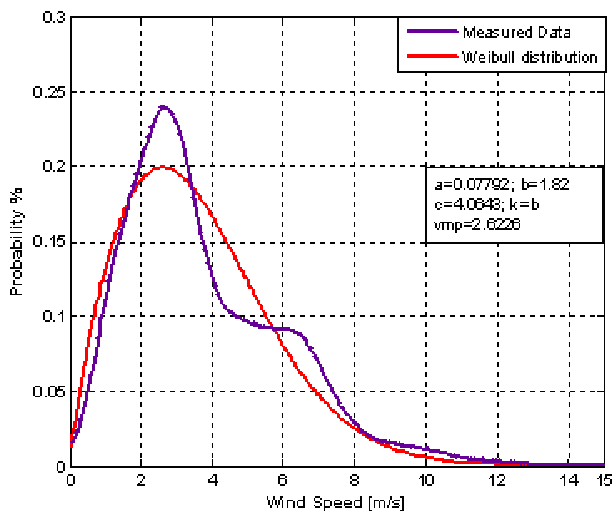
The wind potential energy for January is 50.929 kWh.



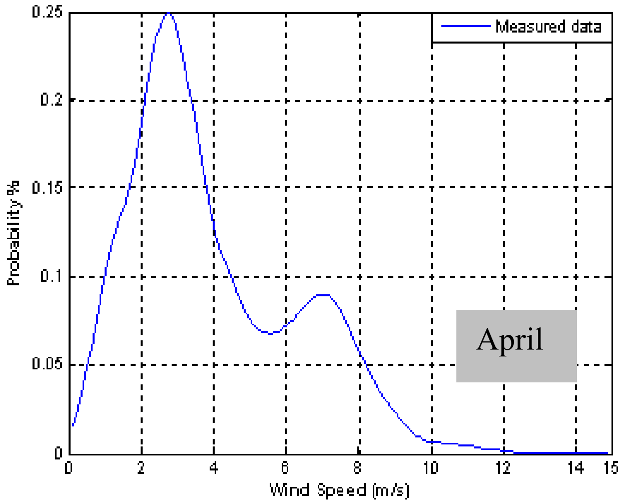


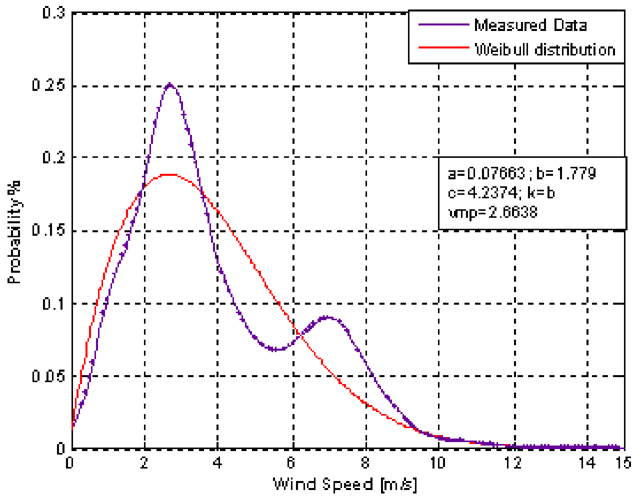
The wind potential energy for February is 81.059 kWh.



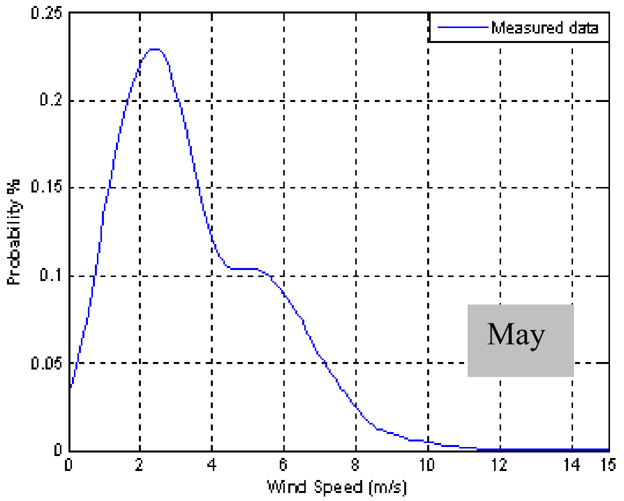


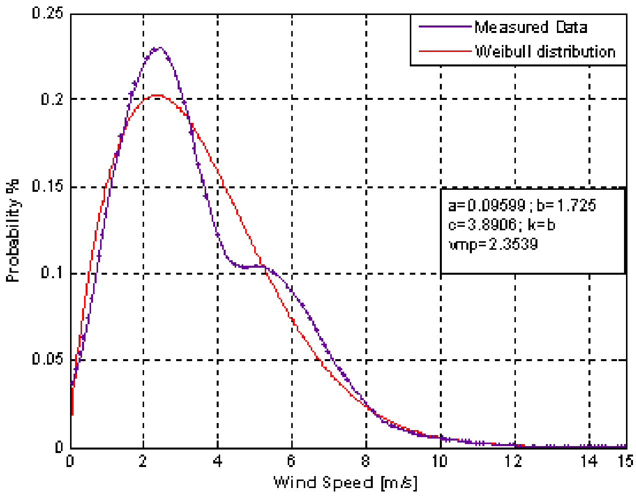
The wind potential energy for March is 54.631 kWh.



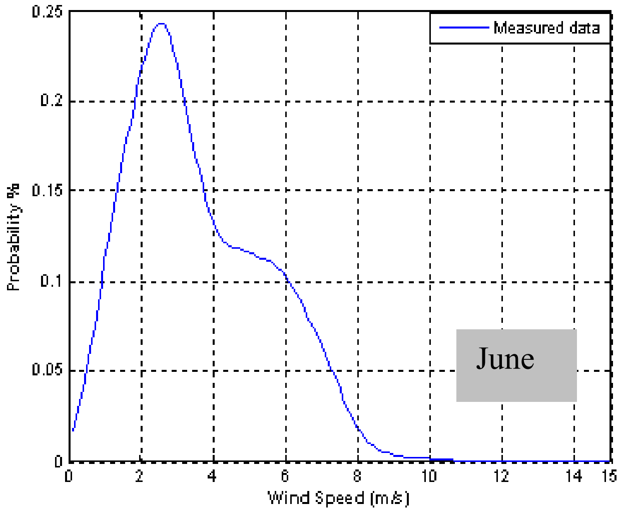


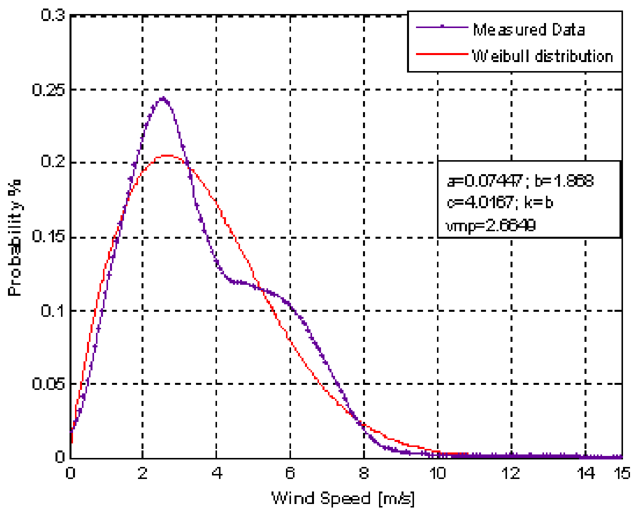
The wind potential energy for April is 57.933 kWh.



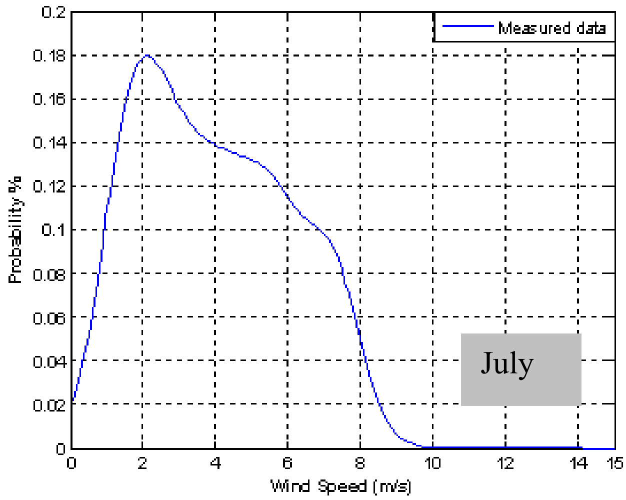


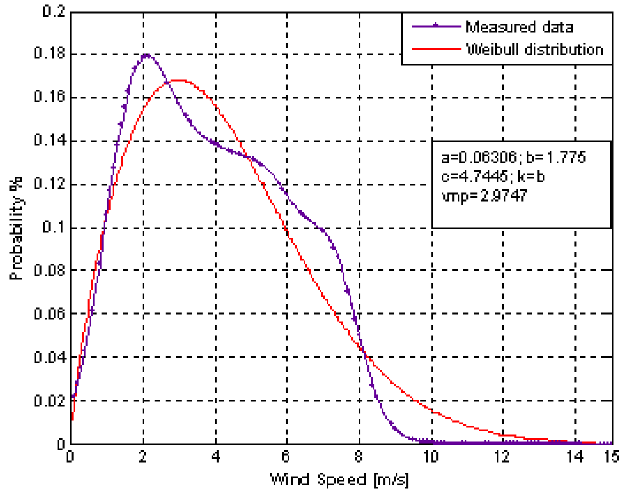
The wind potential energy for May is 42.281 kWh.



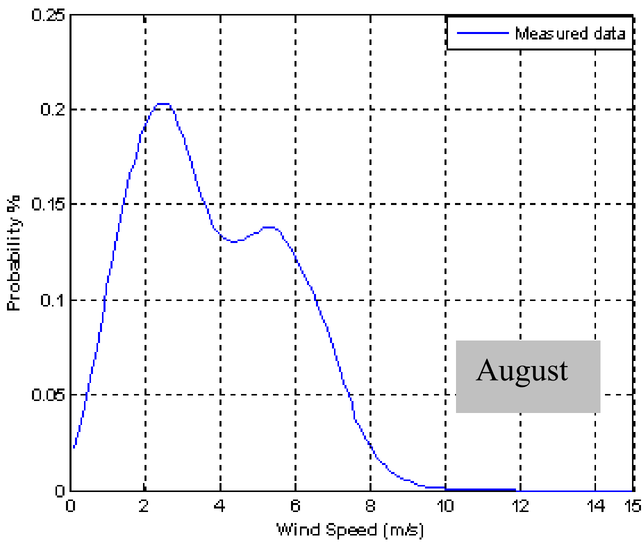


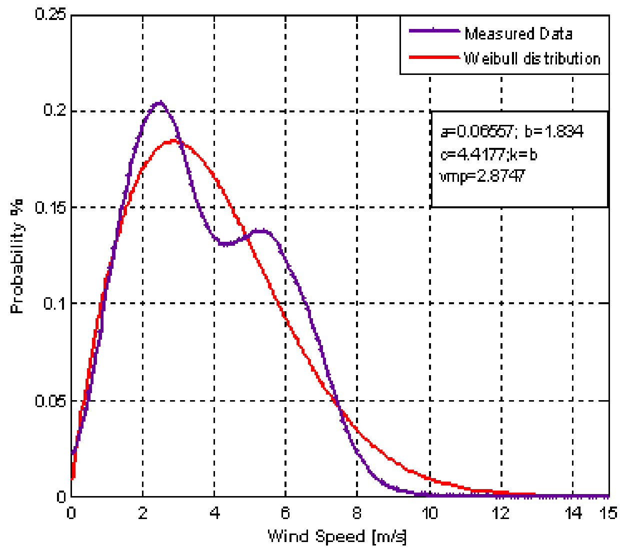
The wind potential energy for June is 38.649 kWh.



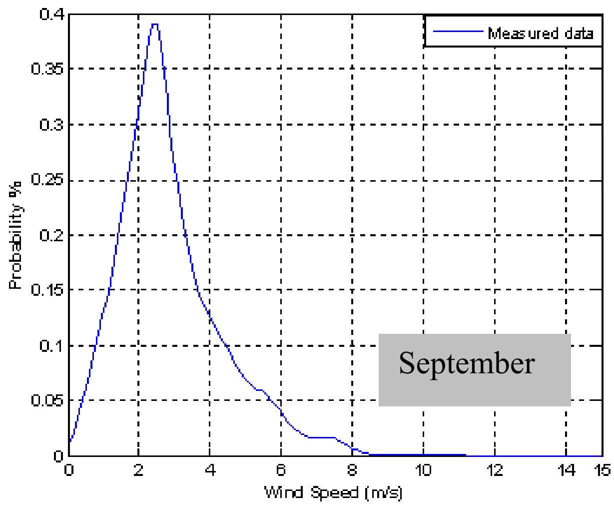


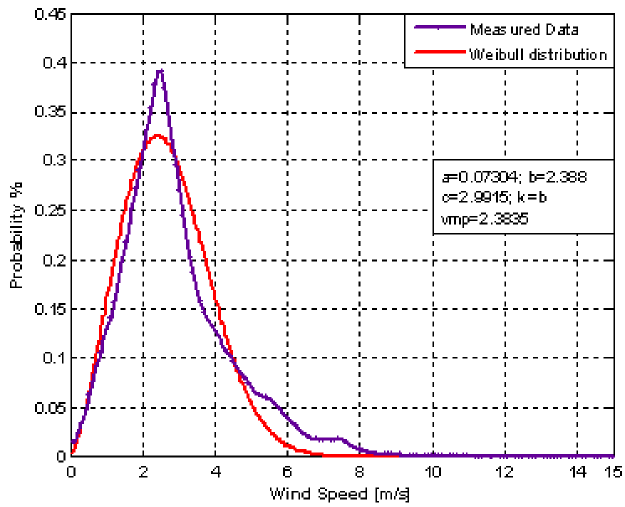
The wind potential energy for July is 53.912 kWh.



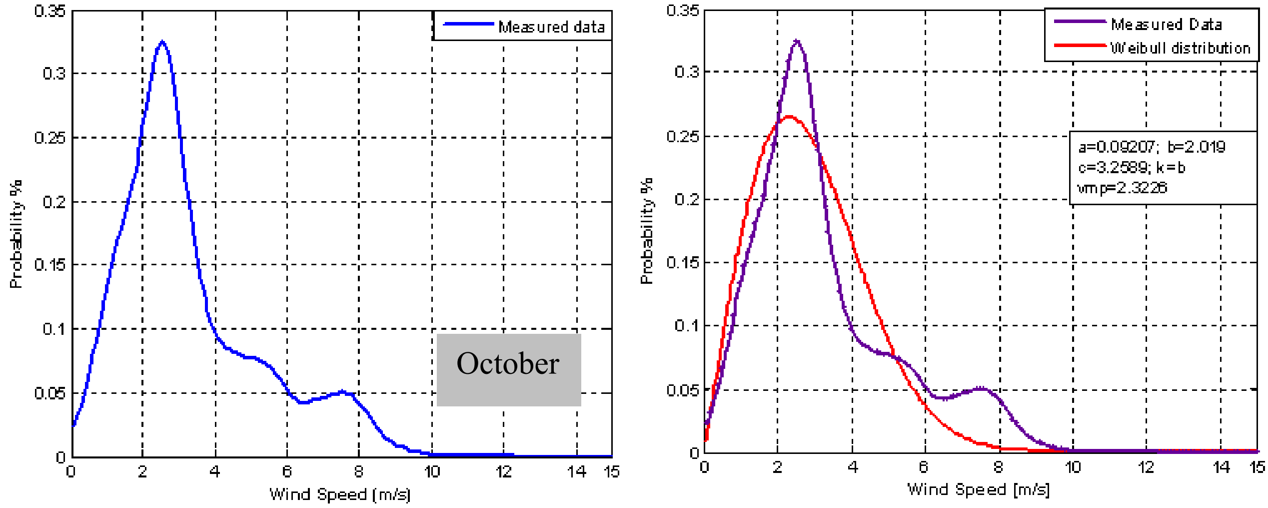


The wind potential energy for August is 44.830 kWh.

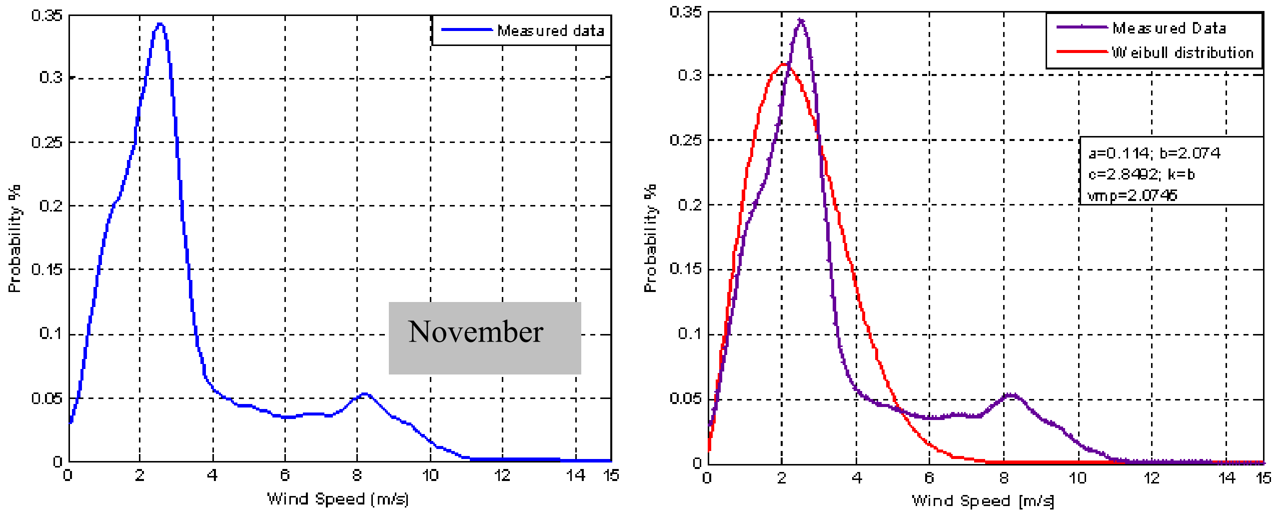




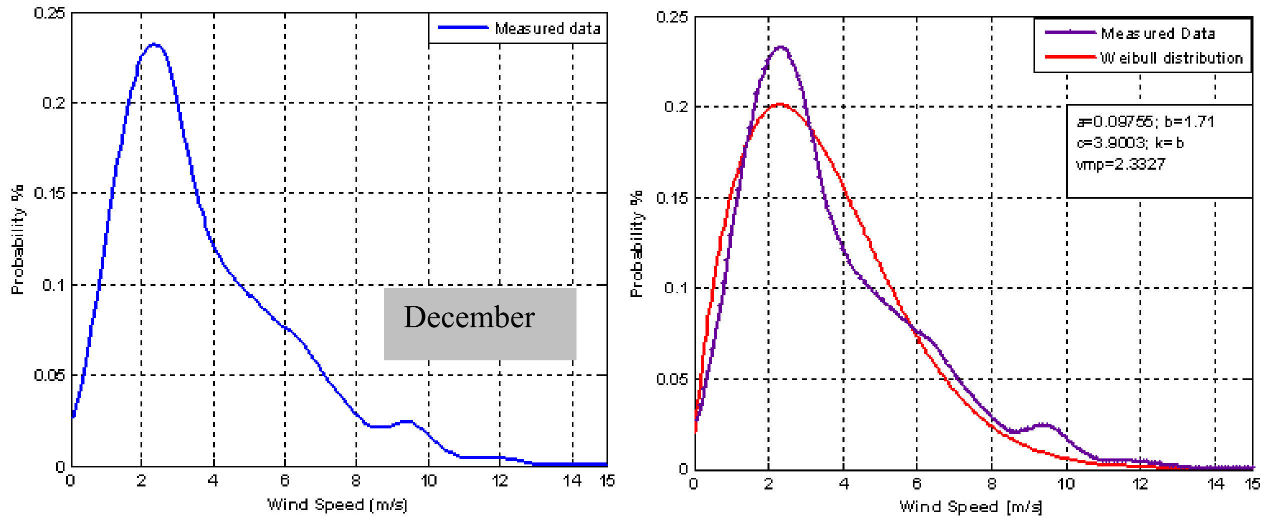
The wind potential energy for September is 20.057 kWh.



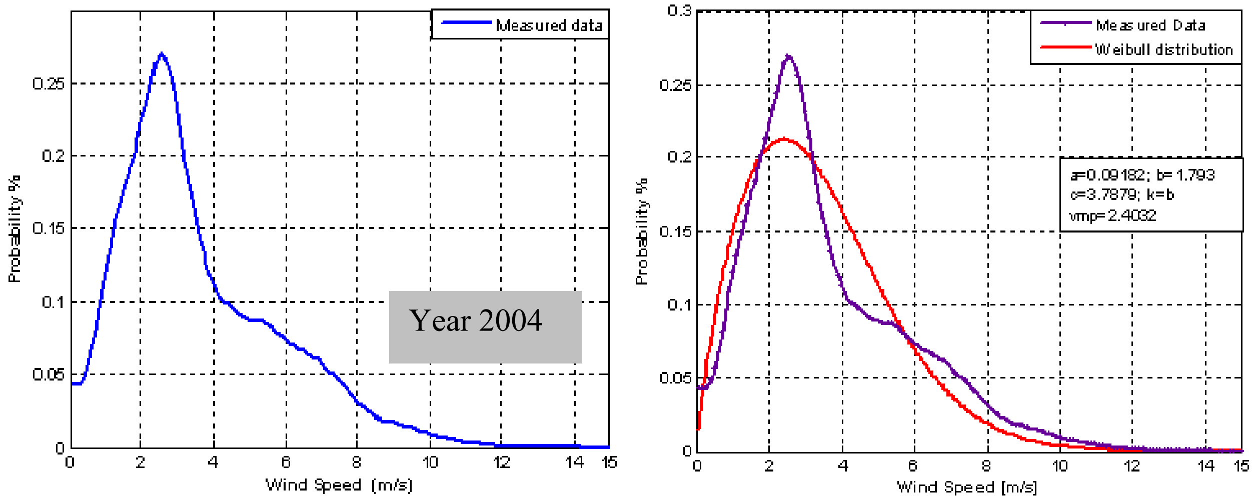
The wind potential energy for October is 36.411 kWh.



The wind potential energy for November is 48.137 kWh.



The wind potential energy for December is 57.324 kWh.



The wind potential energy for year 2004 is 585.740 kWh.

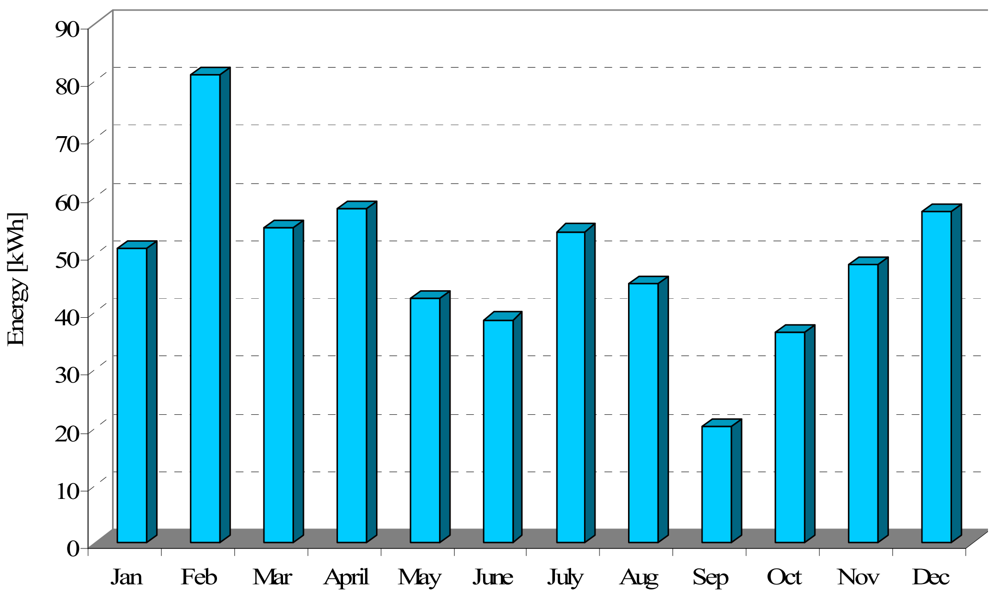


Figure 2. The wind potential energy variation for 2004, Heraklion, Crete

6. Conclusions

The annual energy that a wind turbine of 1.1kW can harvest from the wind is 585.740 kWh. The mean total consumption for the bioclimatic house is 3782, 5536 kWh, thus only 15% of the energy consumption can be provided by the wind turbine. This value can be raised by using the optimal combination between sources of energy, batteries, wind turbine and panels, allow the necessities fulfillment at the lowest cost of possible.

7. References:

[1] GENERAL DATA for the weather station-TEI of Heraklion, Crete, (website: http://meteo.epp.teiher.gr).
[2] TECHNICAL DATA for the weather station-TEI of Heraklion, Crete, (website: http://meteo.epp.teiher.gr).