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Wind Characteristics and Wind Potential Assessment for Braşov Region, Romania

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Abstract-Nowadays, the raised interest for reducing fossil fuel consumption and therefore of pollution led to the development of new technologies for exploiting renewable energy sources. One of the important directions in the use of renewable energy sources is represented by the conversion of wind energy into electricity. Knowledge of wind energy resources of an area is important for the determination of its capitalizing possibilities. In this respect, the paper proposes a case study on the estimating the wind energy potential of the Braşov region, two areas being subjected to analysis. Taking into account the proposed objective, there were necessary: meteorological data processing that represents the average wind speed and frequency for each station; calculation of the average values of wind speed; the estimating of wind speed profiles; the representation of wind roses; the graphical representation of the probability density distribution of wind speed; the calculation of Weibull parameters; the approximating the probability density function using Weibull function. Tacking into consideration the fact that the wind regime is described statistically by Weibull distribution derived from the reference data, this paper also proposes an algorithm for determining the Weibull coefficients. To obtain the most accurate possible prediction of energy, the paper proposes regressions to determine the Gamma function and the shape coefficient for Weibull distribution.

Keywords- *probability distributions of wind speed, wind potential, wind speed*

I. INTRODUCTION

Among the advantages of capitalization of local renewable energy sources (the wind power) for the energy production, there are remembered:

- the environment protection by significantly reducing emissions,
- the diversification of energy production sources for the electricity / heat production,
- the creation of possibilities for the introduction into the economic circuit of some energy independent remote areas.

The main objective of this paper is to assess the wind resource in the area of Braşov, both in the urban area of the city and near (extra-urban) this.

In order to determine the wind potential of an area it is insufficient only the knowledge of average wind speed; for its correct evaluation there are required both knowledge of wind power density for the analysed area as well as the probability distribution of the wind.

In addition, for the determination of Weibull distribution for the area of interest, there are required direct measurements of wind parameters for at least one year.

II. MATERIALS AND METHODS

A. *Geographical and Climatic Description of the Site*

The objective of this study consists of the measurements analysis of the wind characteristics for the Braşov area. Braşov is located at the junction of three major natural units: the Eastern Carpathians, Southern Carpathians and the Transylvanian Plateau, from where it results a pronounced complexity and diversity of geological and geomorphologic features, reflected in climate. Mountainous terrain covers about 40% of the county of Braşov, and the lowland and hilly about 60% [1], [2].

Braşov Depression is an intra-Carpathian depression, bordered by the Bodoc Mountains and the Baraolt Mountains to the North, the Ciucaş, Bârsa, Bucegi and Piatra Craiului Mountains to the South, Vrancea Mountains to the East and to the West by Perşani Mountains; the juxtaposition of mountain massifs and depression plains creates altimetric and clinometric contrasts.

On the outskirts of Braşov Depression, there are a series of mountains with low height (with a maximum altitude of 1200m) as a border; these low mountains together with the high mountains that border the depression, act as a barrier, limiting the wind speed.

The relief features induce major changes in the character of wind, the movement of air currents (the wind regime) being determined primarily by the development of different baric systems (due to air temperature, landforms, water surfaces) [1], [2].

Braşov area is characterized in climatologically terms by a climate of refuge due to the geographical placement that is in a largely in the interior of Carpathian arch. The climate of this area is significantly influenced by the existence of western winds that blow from the Atlantic Ocean and that have a character of climatic moderator.

Wind regime, the expression of general horizontal circulation of air masses, is significantly influenced by the orography of the analyzed area. In this regard, it was noted that in general the local orography determines the wind action deviation on the direction of valleys and deepest corridors. Thus, in the county of Braşov, in Bran corridor and in lowland of Bârsa, the North-West wind is dominant [3].

The annual average wind speed is directly influenced by orography and the thermal stratification of the air, which can enhance or attenuate it. The mountain area is characterized by annual average speeds that decrease with altitude from 8-10m/s on the Carpathians heights (2000-2500m) up to 6m/s in areas with altitudes of 1800-2000m; on sheltered slopes, the annual speeds decrease to 2-3m/s, and in the intra-mountain depressions these are of 1-2m/s. In the interior of Carpathian mountains, the average annual speeds range among 2-3m/s, the lowest annual average values (1-2m/s) being recorded in the intra-Carpathians closed depressions [4].

B. Wind Climatology Statistics and Weibull Distribution

The calculus of the mean power of a wind turbine requires the knowledge of generalized expression for the probability density distribution [5]. A good approximation of the distribution of probability density function of wind speed is given by the Weibull function, [5], [6], [7], [8]:

$$F(v) = k / A(v / A)^{k-1} exp\left(-(v / A)^{k}\right), \tag{1}$$

where k and A are the Weibull distribution parameters, respectively the shape factor of the distribution (k) and the scale factor (A).

Returning to equation (1), this can be written in terms of the Gamma function, respectively [5]:

$$\begin{aligned} F(v) = k\,\Gamma(1+1/k)(v\,\Gamma(1+1/k))^{k-1} \cdot \\ \cdot exp\left(-(v\,\Gamma(1+1/k))^{k}\right), \end{aligned} \tag{2}$$

where $\Gamma(1+1/k)$ is the Gamma function for $(1+1/k)$.

Thus to determine Weibull function, in the first stage it is necessary to determine the two parameters A and k.

Using relations (1) and (2), the scale parameter A can be determined from (3),

$$v_{med} = A\Gamma(1+1/k). \tag{3}$$

A method for the determination of wind speed instability consists of determining the standard deviation σ and the ratio of the standard deviation of the average speed.

In this stage it must be mentioned the fact that the turbulence of the wind speed can be characterized by the dispersion of speed fluctuations from its mean value, or by the square mean value of the fluctuations.

More simply, the turbulence characterizes only the instant speed fluctuations on the wind direction (longitudinal turbulence).

Thus, the ratio between the standard deviation of the gust fluctuations in the longitudinal direction and the average wind speed characterizes the longitudinal turbulence intensity and this has the significance of the coefficient of variation of gust fluctuations compared to average speed [9], [10].

In this regard, it is noted that the standard deviation is calculated using the Gamma function using the relationship (4):

$$\sigma^2 = A^2\left(\Gamma(1+2/k) + \Gamma^2(1/k)\right), \tag{4}$$

for the ratio between the average speed and the standard deviation (turbulence intensity) resulting the following relation:

$$\sigma / v_{med} = \sqrt{\Gamma(1+2/k)/\Gamma^2(1+1/k) - 1}\,. \tag{5}$$

Determination of the polynomial expression for approximation of Gamma function was performed taking into consideration the following considerations [6]:

$$\begin{aligned} &\Gamma(1) = 1, \\ &\Gamma(0.5) = \sqrt{\pi}, \\ &\Gamma(a+n) = (a+n-1)(a+n-2)\ldots a\Gamma(a), \end{aligned} \tag{6}$$

where a is a real value and n, a positive integer.

Thus by the calculation of the Gamma function values, for the values of the argument *(1+1/k)* between 1 and 2, and by graphic representation of these (Fig. 1), it can also be determined the regression expression that best approximates these values.

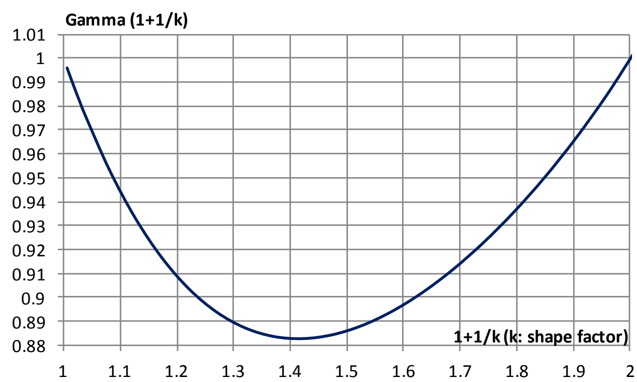


Figure 1. Determination of the Gamma function depending on the values of the shape factor *k*

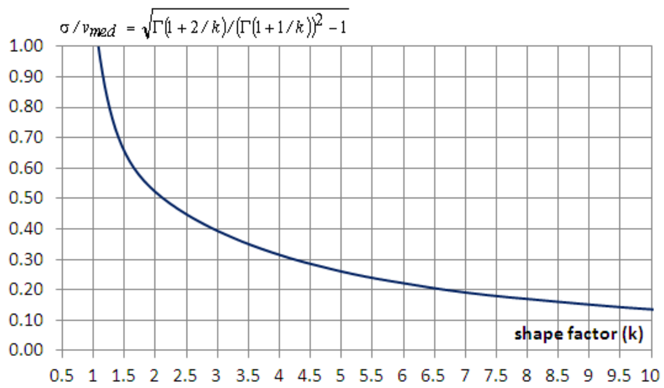


Figure 2. The determination of the shape factor depending on the ratio of standard deviation values and the average speed

This paper proposes the determination of Gamma function values using a polynomial regression of fouth degree, respectively:

$$\Gamma(x) = 0.279x^4 - 1.972x^3 + 5.487x^2 - 6.8483x + 4.054. \quad (7)$$

In this stage, knowing the regression expression for the Gamma function, it can be calculated the right term of relation (5) for different values of shape factor (k). Plotting these values (Fig. 2), it can be established the regression expression for determining the shape factor k.

Therefore, by calculating – on the basis of the measured data – the ratio between the standard deviation and the average speed, the shape factor value of the Weibull distribution may be obtained.

Thus for the shape factor (k), this paper proposes the relation (8):

$$k = (\sigma / v_{med})^{-1.089}, \quad (8)$$

or for a more precise determination, you can use one of the regressions (9), (10), or (11), regressions determined for different variation limits of the ratio between standard deviation and average speed:

$$k = 1.1376(\sigma / v_{med})^{-1.104}, \text{ for } \sigma / v_{med} \le 0.3, \quad (9)$$

$$k = 0.8454(\sigma / v_{med})^{-1.354}, \text{ for } 0.3 < \sigma / v_{med} \le 0.7, \quad (10)$$

$$k = 1.0804(\sigma / v_{med})^{-0.705}, \text{ for } 0.7 < \sigma / v_{med}. \quad (11)$$

C. *Determination Stages of the Weibull Parameters*

So, if there is a database containing measurements on wind speed, the determination the Weibull distribution is achieved through the following steps:

- the wind speed histogram is plotted;
- the following values are determined: the average speed, v_{med}, standard deviation, σ, and the ratio σ/v_{med};
- the value of the shape factor (k) is determined, using regression (8), or depending on the values of the ratio σ/v_{med}, using one of the regressions of relations (9), (10), (11) ;
- the scale parameter A is determined, using equation (3);
- the Weibull probability density distribution is plotted, equation (1).

It is mentioned that for the calculation of average power, a value of 52% of the ratio between the standard deviation and the average speed is used, value that corresponds to a value of shape factor (k) of 2; this case corresponds to a particular shape of the Weibull distribution, that is Rayleigh distribution.

The high values of the ratio σ/v_{med} (70%) lead to low values of the shape factor (k<2), and these describe a zone characterized by turbulence.

III. EXPERIMENTAL. CASE STUDY

A. *Meteorological Data*

To carry out the study on wind potential in Braşov area, there have used data on the main meteorological parameters (wind speed and direction), meteorological data that have been recorded using two weather stations located in two different areas.

The first area subjected to analysis, for the case study, is located in the urban area of Braşov. The choice of this area was determined by the fact that, here it is located Weather Station of the Department of Renewable Energy Systems and Recycling, from Transilvania University of Braşov. Data on wind speed and wind direction are recorded from October 2005, which allows energy analysis.

The second area subjected to analysis is an area in the vicinity of Braşov urban area, in this area anemometric measurements are made from January 2013.

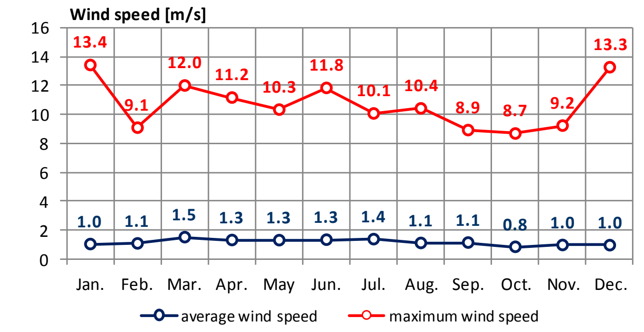
Anemometers installation was done at 15m above ground for both locations. Information – for both weather stations – was recorded every ten minutes by the data loggers; these values represent the average wind speed and wind direction for the ten minute period [11].

B. *Monthly Average and Maximum Speeds*

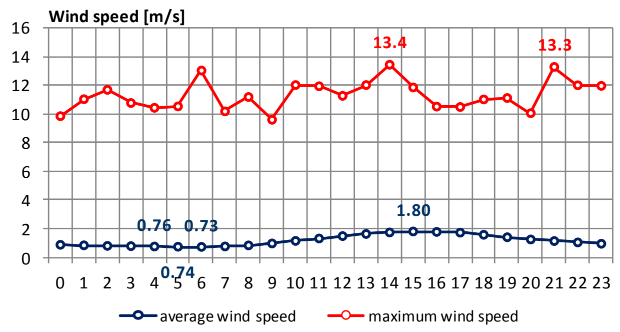
Fig. 3 presents the monthly variation diagrams of the average and maximum wind speed for the two measurement areas using the entire available database for them.

For urban areas, maximum speeds were recorded during the cold season of the year (13m/s), December, January.

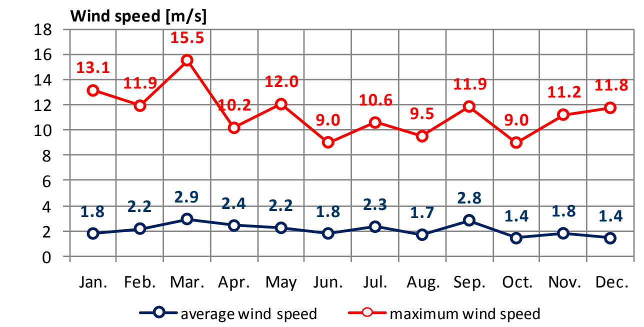
During the year 2013 (Fig. 4), the maximum wind speeds were recorded during the month of March, both in urban area (10.9m/s) and in extra-urban area (15.5m/s).



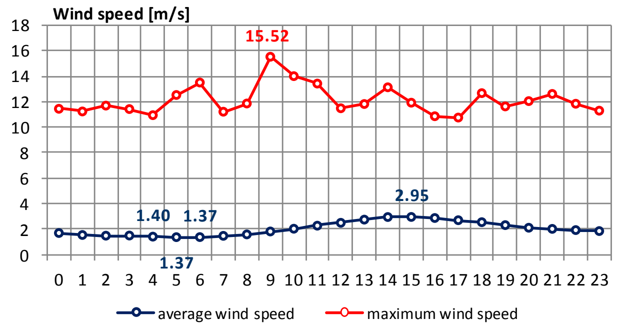
a. the urban area – the period January 2006 - March 2014



a. the urban area – the period January 2006 - March 2014



b. the extra-urban area – the period January 2013 – March 2014



b. the extra-urban area – the period January 2013 - March 2014

Figure 3. Variation of the monthly average wind speed and monthly maximum speeds

Figure 5. Diurnal variation of the average speed and maximum diurnal speeds

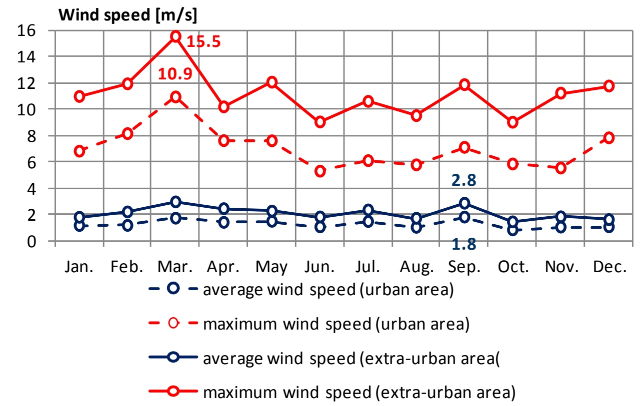


Figure 4. Variation of the monthly average wind speed and monthly maximum speeds recorded during the year 2013

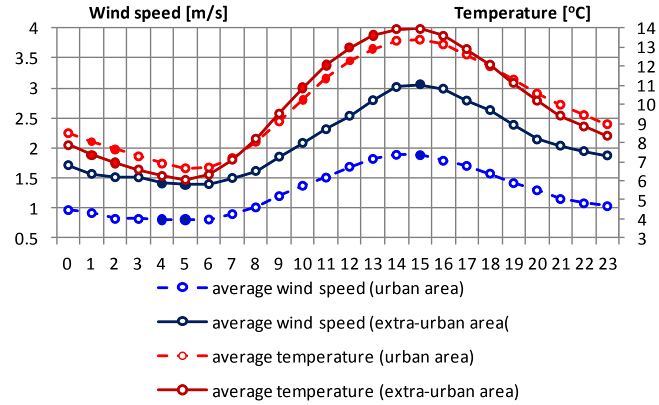


Figure 6. Diurnal variation of the average speed and average temperature recorded during 2013

But, it must be noted that the maximum values of the monthly average speeds have not been recorded in the cold season; so, during the period 2006 – March 2014 in the urban area for the monthly average speeds were recorded maximums during March-July, and during 2013 – both for urban and extra-urban areas - the highest monthly averages were recorded for March and September.

C. Diurnal Speeds

Daily variation of wind speed is determined mainly by the different warming of the air and it can be influenced by turbulent exchanges and local orographic conditions.

Diurnal variation of wind speed presents a simple oscillation, with a maximum recorded during the afternoon, when the terrain warming is more intense and a minimum recorded on the night to morning (Fig. 5 and Fig. 6). For the comparison of the average wind speeds in urban area and in extra-urban area, in Fig. 6 are presented diurnal variations of wind speed during the year 2013.

The above observation is confirmed, for both measuring areas, the maximums of average speed being recorded between 14 and 15 o'clock and the minimums of this between 4 and 6 o'clock in the morning.

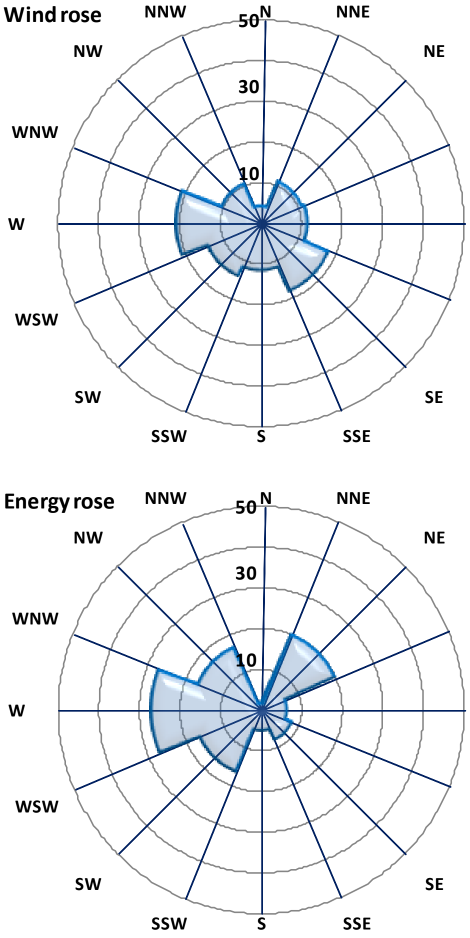
It is also noted a similar variation of the diurnal average temperature with the variation of average speed. Although these cyclic variations of diurnal average speeds and the diurnal average temperature are similar both for the urban and extra-urban area, it should be noted that both the thermal gradient and the speed gradient are higher for extra-urban areas (1.67m/s and 7.9°C in extra-urban area compared to 1.08m/s and 6.74° C in urban area).

For urban areas, the presence of buildings and urban traffic, produce modifications of the radiative characteristics that influence the thermal structure of urban air. The maxim differences between the diurnal temperatures were registered between 1 and 2 o'clock respectively between 11 and 13 o'clock (≈ 0.7°C), and maxim difference of diurnal speed was recorded between 14 and 18 o'clock (≈1.2m/s).

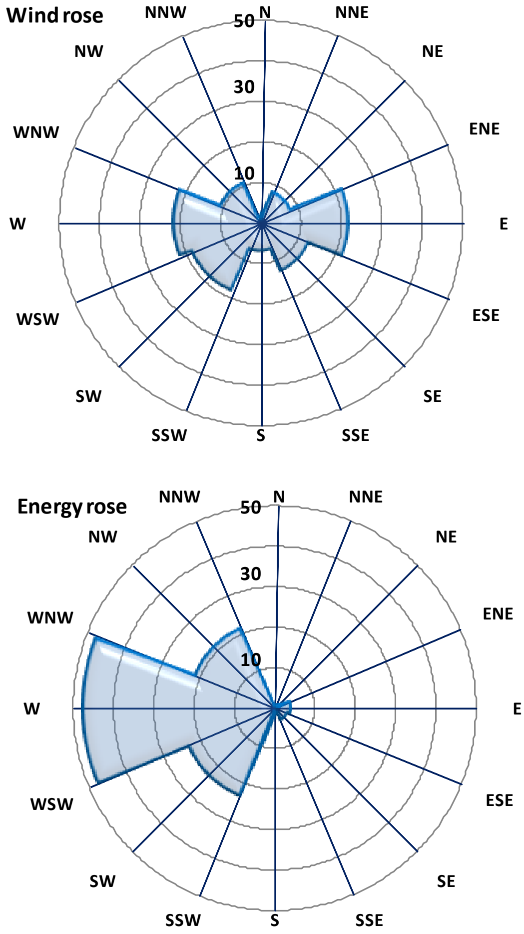
It is noted, however, that during the 2013 year, the highest difference between hourly temperatures recorded in the extra-urban and urban areas was 7°C and the difference of hourly speed of 8.6m/s.

D. Wind Rose and Turbulence Intensity

Regarding the wind direction, for the urban area, the wind direction is very much in accordance with the built depression area, the winds from West being mostly recorded (Fig. 7,a).



a. urban area (2006-2013 period)



b. extra-urban area (2013 period)

Figure 7. Wind rose and energetic rose

For the extra-urban area the winds from East are mostly recorded but also the percentage of those from West is very close (Fig. 7,b).

Also, for the two analysed areas the winds from South-West, South-East and North-West are frequent (more that 10%).

Much more important is the distribution of wind energy depending on direction. In this regard, there were plotted the energy roses characteristic to the two areas under study. Since it was considered that each sector of direction covers 45° degrees, the largest wind energy comes from:

- West and North-East for urban area, respectively about 27% from the West and about 20% from North-East, and about by 16% of the energy is captured from each of directions, North-West and South-West;
- West, about 47%, North-West, about 21% and South-West, about 23% in the case of extra-urban area.

Although for the urban area the weight of wind speed from the West is the largest, the significant value of wind energy from North-West is due to the high values of the wind speeds recorded on this direction (Table1).

TABLE I. THE WEIGHTS OF WIND SPEEDS FOR EACH SECTOR [%] - URBAN AREA

	Sector	N	NE	E	SE	S	SW	W	NW
	%	4.03	10.78	11.43	17.83	11.44	13.84	**20.50**	10.16
Wind Speed [m/s]	0-1	4.91	10.22	12.29	**20.36**	15.00	13.48	16.57	7.17
	1-2	3.01	8.80	12.66	18.93	9.29	14.04	**23.03**	10.24
	2-3	2.63	10.74	10.70	12.65	3.61	14.05	**28.54**	17.08
	3-4	1.81	13.91	7.68	9.46	3.79	13.43	**28.25**	21.67
	4-5	1.64	17.28	5.24	6.89	4.18	12.99	**30.63**	21.15
	5-6	1.24	21.92	3.56	5.72	4.19	16.71	**30.69**	15.96
	6-7	0.86	25.13	2.01	4.25	3.67	24.33	**28.92**	10.84
	7-8	0.33	**35.03**	2.14	5.10	3.62	27.30	20.56	5.92
	8-9	0.00	**37.94**	1.19	1.58	5.93	20.95	19.37	13.04
	9-10	0.00	**42.45**	0.94	0.00	9.43	13.21	22.64	11.32
	10-11	0.00	**34.88**	0.00	0.00	30.23	6.98	23.26	4.65
	11-12	0.00	**50.00**	0.00	0.00	36.36	4.55	9.09	0.00
	12-13	0.00	**75.00**	0.00	0.00	25.00	0.00	0.00	0.00
	13-14	0.00	**33.33**	0.00	0.00	**33.33**	0.00	0.00	**33.33**

TABLE II. THE WEIGHTS OF WIND SPEEDS FOR EACH SECTOR [%] – EXTRA-URBAN AREA

	Sector	N	NE	E	SE	S	SW	W	NW
	%	1.02	7.97	**21.60**	12.81	6.99	18.02	**21.19**	10.40
Wind Speed [m/s]	0-1	2.20	13.65	**23.43**	15.22	12.22	14.12	13.22	5.93
	1-2	0.52	9.08	**28.27**	14.44	6.66	18.28	17.20	5.54
	2-3	0.32	2.45	23.29	12.86	3.15	23.22	**24.10**	10.62
	3-4	0.47	1.24	15.92	10.28	1.98	19.84	**29.58**	20.69
	4-5	0.14	0.79	6.85	7.71	1.48	17.10	**36.99**	28.94
	5-6	0.05	0.33	1.47	3.98	0.98	19.77	**41.07**	32.35
	6-7	0.08	0.08	0.08	1.85	0.48	23.09	**45.53**	28.80
	7-8	0.00	0.00	0.10	0.21	0.72	26.52	**49.23**	23.22
	8-9	0.00	0.00	0.00	0.16	0.16	26.59	**53.51**	19.58
	9-10	0.00	0.00	0.00	0.00	0.63	26.03	**60.32**	13.02
	10-11	0.00	0.00	0.00	0.00	0.00	22.98	**60.25**	16.77
	11-12	0.00	0.00	0.00	0.00	0.00	22.54	**67.61**	9.86
	12-13	0.00	0.00	0.00	0.00	0.00	31.58	**57.89**	10.53
	13-14	0.00	0.00	0.00	0.00	0.00	25.00	**50.00**	25.00
	14-15	0.00	0.00	0.00	0.00	0.00	10.00	**70.00**	20.00
	15-16	0.00	0.00	0.00	0.00	0.00	50.00	**50.00**	0.00

In the case of extra-urban area, although the weights of wind speeds from the West and East have very close values, however the differences between the values of wind energy recorded on these directions are considerable (about 47% on the Western direction compared with about 4% on East direction); this is due to the high weights of winds with speeds greater than 4m/s recorded after West direction (Table 2). In extra- urban area, the winds characterized by low values of speed are recorded on an Easterly direction, the winds with high speeds having a Westerly direction.

Analysis of the dominant direction of the wind depending on months leads to the conclusion that for the urban area the dominant direction is West; although for the months of April, October and November the wind weight in South-East direction is high, however the differences compared to West direction are less than 2%.

In the extra-urban area, the dominant direction for the months January to April, August, October and November is South-East, for the other months, the dominant wind directions being South-West, West.

TABLE III. DOMINANT DIRECTION OF WIND DEPENDING ON MONTH - URBAN AREA

	%	N	NE	E	SE	S	SW	W	NW
Jan.	9.59	3.03	11.86	15.24	**20.71**	8.88	9.24	**20.44**	10.61
Feb.	7.94	4.95	10.52	14.80	**20.10**	9.12	10.50	**20.50**	9.51
Mar.	9.22	4.98	9.31	11.12	16.41	9.46	14.02	**24.33**	10.36
Apr.	8.27	3.95	11.47	10.48	**19.25**	12.71	15.44	18.25	8.45
May	8.54	4.36	11.15	9.32	17.53	12.39	16.77	**19.63**	8.87
June	7.92	2.82	8.98	8.64	16.18	12.71	16.99	**22.38**	11.29
July	8.03	3.65	12.91	8.69	14.82	11.43	15.21	**21.33**	11.97
Aug.	8.53	4.20	11.64	8.61	15.55	13.40	16.26	**19.68**	10.68
Sep.	8.27	3.99	12.25	10.13	15.26	12.63	14.46	**20.92**	10.36
Oct.	8.30	1.90	5.05	15.16	**21.25**	14.31	13.77	18.94	9.62
Nov.	7.09	4.37	12.45	14.14	**20.20**	11.07	11.22	18.47	8.08
Dec.	8.31	4.98	9.12	13.39	19.64	9.63	11.40	**20.39**	11.45

TABLE IV. DOMINANT DIRECTION OF WIND DEPENDING ON MONTH – EXTRA-URBAN AREA

	%	N	NE	E	SE	S	SW	W	NW
Jan.	13.92	1.39	8.60	**22.59**	14.96	7.54	14.39	20.39	10.14
Feb.	10.52	0.70	6.86	**26.74**	15.72	9.14	18.83	15.56	6.45
Mar.	11.54	0.49	5.30	**26.69**	14.02	5.50	14.82	23.61	9.58
Apr.	6.73	1.06	7.20	**24.88**	12.78	5.30	20.93	19.47	8.38
May	6.96	0.69	6.21	19.40	14.87	9.25	**22.07**	18.77	8.74
June	6.73	1.02	7.96	15.00	9.21	7.50	**23.54**	23.47	12.29
July	6.96	0.49	7.75	15.73	7.46	5.29	19.69	**24.69**	18.91
Aug.	6.96	1.23	9.77	**23.01**	13.98	7.68	16.80	19.60	7.93
Sep.	6.73	0.65	5.05	11.88	6.99	4.91	18.73	**33.89**	17.92
Oct.	6.96	1.16	10.53	**24.13**	14.58	6.45	19.78	14.90	8.47
Nov.	6.73	1.02	7.85	**28.01**	14.54	7.13	17.73	17.01	6.71
Dec.	9.25	2.07	12.57	15.87	10.65	7.28	15.45	**24.28**	11.81

TABLE V. MONTHLY VALUES OF THE WIND TURBULENCE INTENSITY

Month	**Standard deviation**		**Turbulence intensity**	
	urban area	***extra-urban area***	***urban area***	***extra-urban area***
Jan.	1.31	1.80	1.27	1.01
Feb.	1.16	1.65	1.10	0.96
Mar.	1.57	2.40	1.03	0.86
Apr.	1.33	1.89	1.02	0.78
May	1.21	1.73	0.92	0.77
Jun.	1.16	1.25	0.86	0.69
Jul.	1.24	1.77	0.90	0.76
Aug.	1.02	1.25	0.92	0.74
Sep.	1.17	2.19	1.03	0.77
Oct.	1.02	1.45	1.21	1.01
Nov.	1.17	1.65	1.20	0.91
Dec.	1.33	1.93	1.39	1.35
Annual value	1.25	1.88	1.07	0.92

The analysis of the monthly values of wind turbulence intensity leads to the conclusion that the two areas subjected to analysis are characterized by high values of standard deviation (σ) compared with low average wind speed, respectively the two areas are characterized by turbulent wind. In the extra-urban area although the wind intensity values are lower than in urban areas, the turbulence intensity still remains high (values higher of 07).

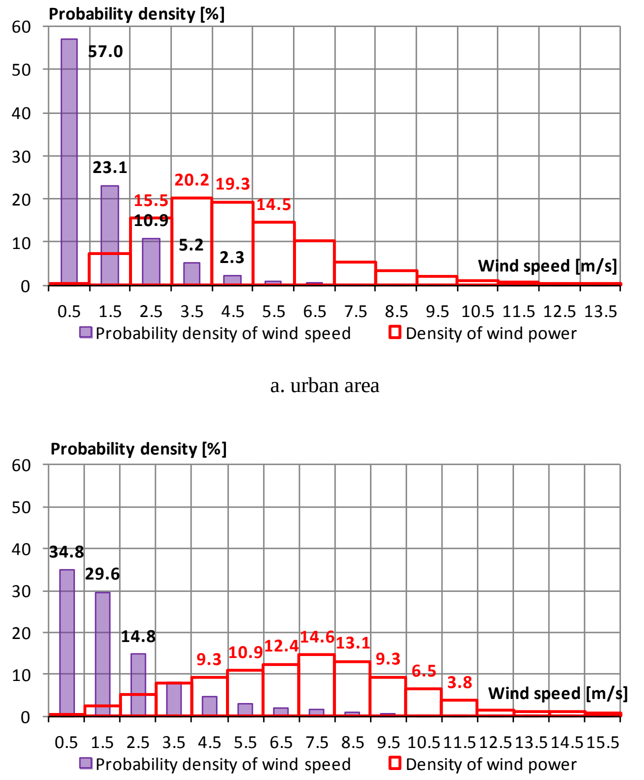
For the urban area, it resulted an annual standard deviation of σ=1.25m/s and for the extra-urban area a value of σ=1.88m/s; also for Braşov urban area it resulted an annual value of wind turbulence of σ/v_{med}=1.07 and for the extra-urban area a value of σ/v_{med}=0.92.

IV. RESULTS AND DISCUSSIONS

The wind speed is a meteorological parameter with a random deep character, for the determination of the average power delivered by a wind turbine being required the knowledge of the probability density distribution of the wind speed.

Using the databases corresponding to the two areas under analysis, further there are proposed the determination of Weibull parameters, plotting the diagrams of wind energy relative to the average (depending on the month) and the comparative analysis of wind energy values obtained for the two areas.

The average wind speed in urban area is 1.16m/s and according to the histogram in Fig. 8,a, it is noted that this value do not correspond to the most frequent value of wind speed (but it is close); the average wind speed in the extra-urban area is 2.03m/s (Fig. 8,b).



a. urban area

b. extra-urban area

Figure 8. Probability density of the wind speed and wind power, on the wind speed ranges

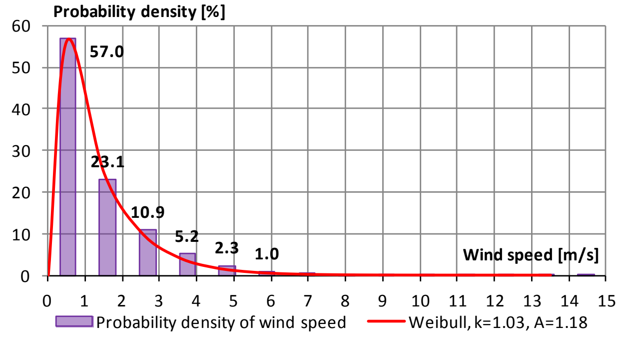
In urban areas, buildings can have a significant influence on the wind characteristics. This influence is reflected not only on the average wind speed, that will be reduced in urban areas, but also on the ratio of the standard deviation and average speed, that can be have too high values.

In the case of urban area the highest weight of power density is obtained for the speed range between 3m/s and 4m/s, which represents approximately 20%.

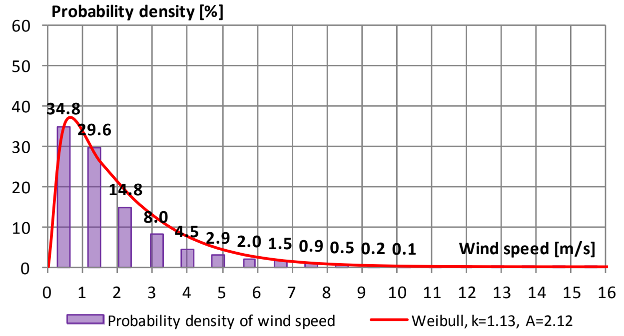
In the extra-urban area, the distribution of power density registers a maximum value of 14.6% for the speed range between 7m/s and 8m/s; it is however noted that values higher of 9% of the power density weight are obtained for the range of speeds between 4m/s and 10m/s

Taking into consideration the fact that for the wind speed modelling, including of the function of probability density distribution, the Weibull distribution is often used, following the algorithm and the regressions proposed by this paper, for the two areas subjected to analysis, there were obtained the following values of the Weibull parameters: for the urban areas, k=1.03, A=1.18 and for the extra-urban area, k=1.13, A=2.12 (Fig. 9).

Regarding to the months with the highest wind energy (Fig. 10,a), in the case of the urban area, these are March, April and December, and those with the lowest wind energy are October, August, November and February.

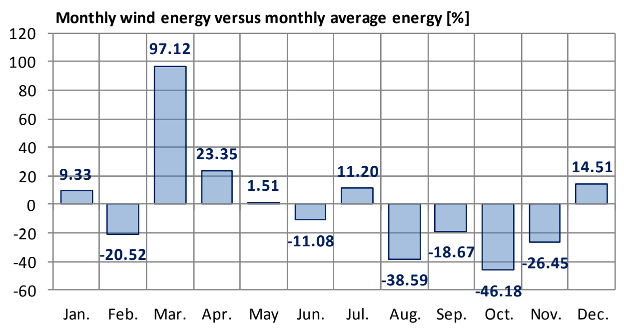


a. urban area

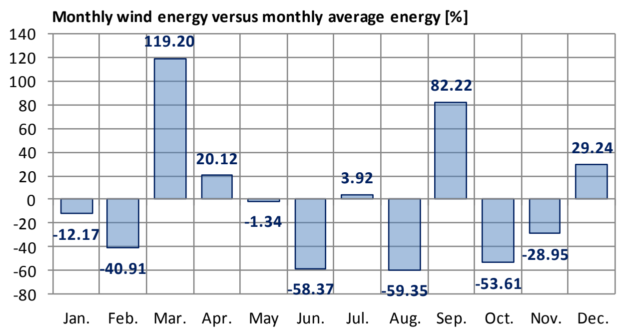


b. extra-urban area

Figure 9. Weibull distribution for Braşov area



a. Urban area



b. Extra-urban area

Figure 10. The relative wind energy compared to the average value, depending on the month

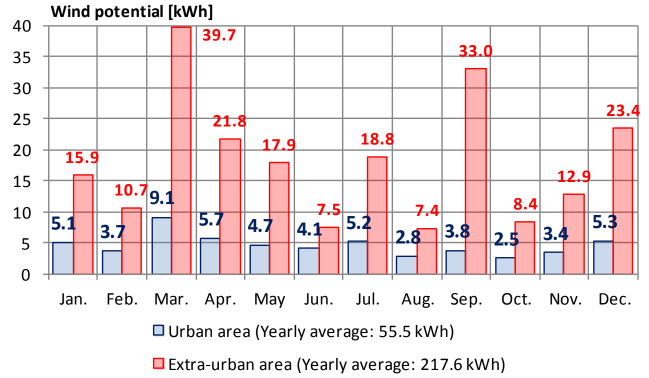


Figure 11. Monthly average of wind energy

In the case of extra-urban areas, the months with the highest value of wind energy are March, September and December and those with the lowest wind energy are June, August, October and February (Fig. 10,b).

As expected, the comparative analysis of monthly averages of wind energy obtained for the two areas, leads to the conclusion that the wind energy obtained for extra-urban area is much higher than that for the urban areas (given that the databases available for urban area contains a high number of years, there were compared the monthly averages of wind energy).

Thus, the highest differences between monthly values of wind energy were recorded for the month of September (the energy for extra-urban area is about 8 times higher than that from urban areas), March and December (about 4 times).

The annual value of wind energy obtained for the extra-urban area is about four times higher than that from urban area.

V. CONCLUSIONS

The wind may vary over time depending on climatic conditions. Wind variability also implies variability of electricity generated. This is the difference compared to most of conventional energy sources, where the fuel is usually kept constant.

The primary source of energy in producing the wind energy has not a constant flow. The climate of the location area describes the statistical variability. Different locations have different wind climates.

Since wind energy depends on the cube of the wind speed, it is obvious that the average annual power will vary from one area to another.

The proposed study emphasizes the canalisation and the effect of the surrounding obstacles on the area of Braşov.

The wind regime – in the urban area – is significant influenced by the surrounding mountains, the average values of the wind speed are low, under 2m/s and the yearly average wind potential is about 55.5kWh.

As can be seen, the Brasov city is characterized by average wind speeds between 1m/s and 1.4m/s, what makes this area may not be a candidate for the installation of wind power plants; so Braşov city area do not fall in areas with significant wind potential.

In the case of extra-urban area of Braşov is recorded an increase of the monthly average values of wind speed, these could reach up to 3m/s; it has also been recorded a significant increase in the annual average value of wind energy (217.5kWh) compared to that corresponding to urban area.

However taking into account that for wind power plant installation an area must have a minimum average speed of 4m/s at a height of 10m above the ground (this is the height at which measurements are made in the network of the National Agency of Meteorology [12]), it follows that this area does not fall under the category of areas with significant wind potential.

Regarding the wind direction, it can be said, the winds from the West are more frequent; also the maximum energy occurs on this direction except that regarding the extra-urban area, the energy rose presents this direction as dominant.

In the case of urban area, the wind energy rose is balanced; it can be distinguished four dominant sectors: West, North-East, South-West, and North-West.

The proposed study of this paper leads to the conclusion that for wind power plants installation, it is necessary to identify areas around Brasov, areas that due to local factors may lead to an intensification of wind speed on limited areas and that subsequently can be exploited in view of electricity production (emphasizing the effects of hills on the wind intensity, the location effect of these areas near an urban area, the possible local climate changes).

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