ENERGY INCOME FOR BRAŞOV URBAN AREA – SOLAR AND WIND POWER

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Abstract: For a good design of the solar and wind systems, the main objectives that need to be considered are: minimizing overall costs and maximize the energy performance of systems. In order to calculate the performance of an existing system or to estimate the energy generated by a system from the design stage, appropriate weather data are required. The paper presents an analysis of the meteorological data recorded with a Delta-T weather station, over a time span of four years, 2006-2009. In conclusion, the paper presents some deductions derived from the comparative analysis of the solar and wind potential, values recorded for Braşov urban area for two years, 2008-2009.

1. INTRODUCTION

Energy is an essential factor in overall efforts to achieve sustainable development. Countries striving to this end are seeking to reassess their energy systems with a view toward planning energy programs and strategies in line with sustainable development goals and objectives.

Implementation of renewable energy systems is a solution for providing assistance to consumers, reducing greenhouse gas emissions (carbon) and dependence on fossil fuels which are endangered. RES Directive (European directive on renewable energy) aims that by 2020, 20% of total energy demand in Europe will be supplied from renewable energy. Also it is mentioned that, from the total energy demand, 50% of the energy is used for heating and cooling buildings. During 2008-2012, Romania pledged to reduce greenhouse gas emissions (CO2) by 8%. Solar energy is free, its supply is unlimited and using solar energy produces no air or water pollution. To obtain maximum efficiency of solar collectors, they must be oriented so that the angle of incidence between the solar panel surface and solar ray to have a minimum value, even zero.

Also the wind is an important renewable energy source, which is currently exploited to produce electricity. The biggest disadvantage of using wind power is that electricity can not be got when the wind does not blow or blows too weak, so there must be provided an alternative source of electricity. In addition, implementation of wind turbines in the proximity of urban areas has disadvantages in terms of visual and noise pollution, because wind turbines have not a very pleasant aesthetic design and they produce noise (approx. 45 dB (A)).

2. THE SOLAR INCOME

Most of the times, we record information concerning the solar radiation onto a horizontal surface. However, it is necessary to knowing the direct and diffuse components of the radiation onto the plane of a solar collector or a PV system.

The solar systems with plane surfaces are not of the solar tracking type; they are south oriented and set at a certain angle towards horizon. This angle must have an optimum value for a certain location.

Considering the direct solar radiation onto a horizontal plane B, the radiation, perpendicular to a surface inclined towards horizon at a b angle, has the expression [1]:

$$B_\beta = B\frac{\cos(\theta)}{\cos(\theta_z)} = R_b B, \quad (1)$$

where: θ represents the incidence angle of the solar beam – the angle between the perpendicular and the solar beam direction. For a horizontal surface $\theta_z=\theta$.
For an arbitrarily positioned surface, the functions cos(θ) and cos(θz) are expressed by the following relations:

$$\cos(\theta_z) = \cos(\varphi)\cos(\delta)\cos(\omega) + \sin(\varphi)\sin(\delta), \quad (2)$$

$$\cos(\theta) = \cos(\varphi-\beta)\cos(\delta)\cos(\omega) + \sin(\varphi-\beta)\sin(\delta), \quad (3)$$

where: φ - represents the location latitude; δ - the declination angle; ω - the hour angle.
The diffuse radiation on an inclined surface D_b is calculated with the relation:

$$D_\beta = D\frac{1}{2}(1+\cos(\beta)), \quad (4)$$

where *D* is the diffuse radiation onto a horizontal surface.
Consequently, the global radiation onto an inclined surface has the expression (the reflected radiation is neglected):

$$G_\beta = R_b B + \frac{1}{2}(1+\cos(\beta))D\,. \quad (5)$$

The optimum inclination angle of a solar collector is thus chosen in the months of March and October, the amount of energy on the PV system to be maximum.
Referring to Braşov area, with an inclination angle of the PV system β = 45°, Tables 1 and 2 present the recorded values for the global irradiation onto the collector surface in 2008 and 2009, respectively.
The highest values of the solar power were registered in July 2009.

Table 1. Global irradiation onto an inclined surface (β=45°) - 2008

Month		III	IV	V	VI	VII	VIII	XI	X
R_b	-	1.53	0.98	0.80	0.74	0.77	0.92	1.35	2.11
B	KWh/m² day	1.51	1.58	2.83	3.38	3.19	2.92	1.47	1.26
D	KWh/m² day	1.31	1.84	2.24	2.28	1.99	2.05	1.37	1.07
$B_\beta=R_bB$	KWh/m² day	2.18	1.77	2.67	2.96	2.95	3.12	1.96	2.42
$D_\beta=D/2(1+\cos\beta)$	KWh/m² day	1.11	1.57	1.91	1.94	1.70	1.75	1.17	0.91
$G_\beta=B_\beta+D_\beta$	KWh/m² day	3.30	3.34	4.57	4.91	4.65	4.87	3.13	3.34
	KWh/m² yearly	102.58	100.29	142.21	147.49	144.25	**151.08**	94.10	103.64
		985.63 KWh/m²							

Table 2. Global irradiation onto an inclined surface (β=45°) - 2009

Month		III	IV	V	VI	VII	VIII	XI	X
R_b	-	1.54	0.99	0.81	0.74	0.78	0.91	1.33	2.09
B	KWh/m² day	1.05	2.59	2.88	3.24	3.69	2.25	1.89	0.94
D	KWh/m² day	1.55	1.90	2.12	2.20	2.03	2.13	1.66	1.11
$B_\beta=R_bB$	KWh/m² day	1.53	2.96	2.75	2.80	3.43	2.42	2.61	1.71
$D_\beta=D/2(1+\cos\beta)$	KWh/m² day	1.33	1.62	1.81	1.88	1.74	1.82	1.42	0.95
$G_\beta=B_\beta+D_\beta$	KWh/m² day	2.86	4.59	4.56	4.67	5.16	4.24	4.03	2.65
	KWh/m² yearly	88.54	137.60	141.40	140.10	**160.03**	131.31	120.80	82.25
		1002.04 KWh/m²							

Figure 1 presents the annual variation of the daily means for direct solar irradiation in Braşov, specific to every month. The diagrams are plotted considering a horizontal and an inclined surface (45°).

From the analysis of the diagrams presented by Figure 1, it is ascertained that the highest values of the solar income are registered from April to September. The highest values of the direct solar irradiations were registered in July; the highest value of the direct solar irradiation was recorded in July 2009, 3.69KWh/m^2 / day.
The yearly global solar irradiation, on a horizontal surface, for the four years analysed was: for 2006 - 1055.84 KWh/m^2, in 2007 - 1091.02 KWh/m^2, in 2008 - 1180.761 KWh/m^2 and in 2009 - 1159.40 KWh/m^2.

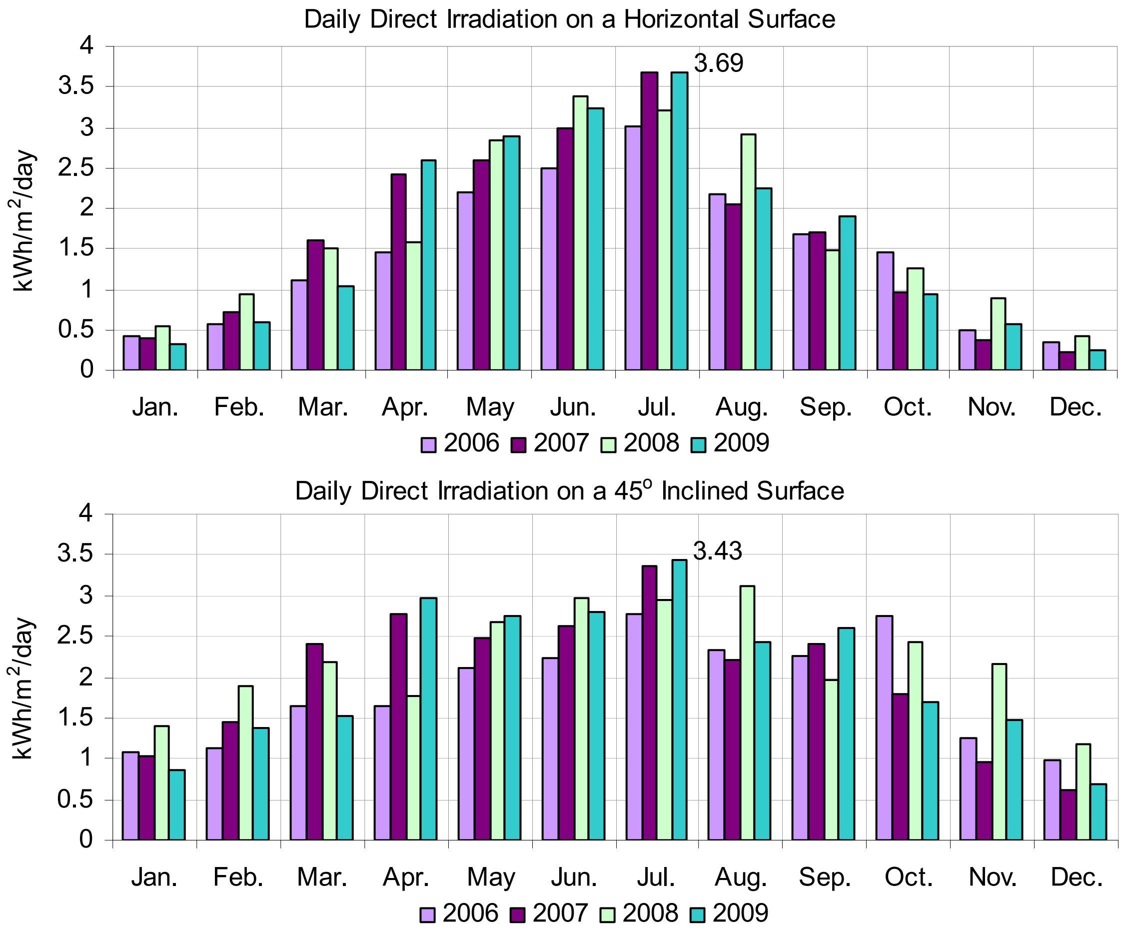

Fig. 1. The solar power variation for Braşov city area (2006, 2007, 2008, 2009)

Figure 2 presents the comparative diagrams of the global and direct solar irradiation for 2009 (the diagrams are presented for a horizontal and an inclined surface). It can be noticed that from January to April and September to December, the irradiation onto an inclined surface with 45^o, is higher. This increase of the irradiation onto a 45 degrees inclined surface is caused by the variation of the R_b coefficient during a year (Figure 3), coefficient that has sub-unit values from April to August if the inclination angle is 45 degrees.
For the year 2009, the highest value of global irradiation, on a horizontal surface, was registered in the month of July: 177.45 KWh/m^2; the direct irradiation was 114 KWh/m^2.
The highest value of global irradiation, for an inclined surface, for the year 2009 was registered in the month of July: 160.03 KWh/m^2 and the direct irradiation 106 KWh/m^2.

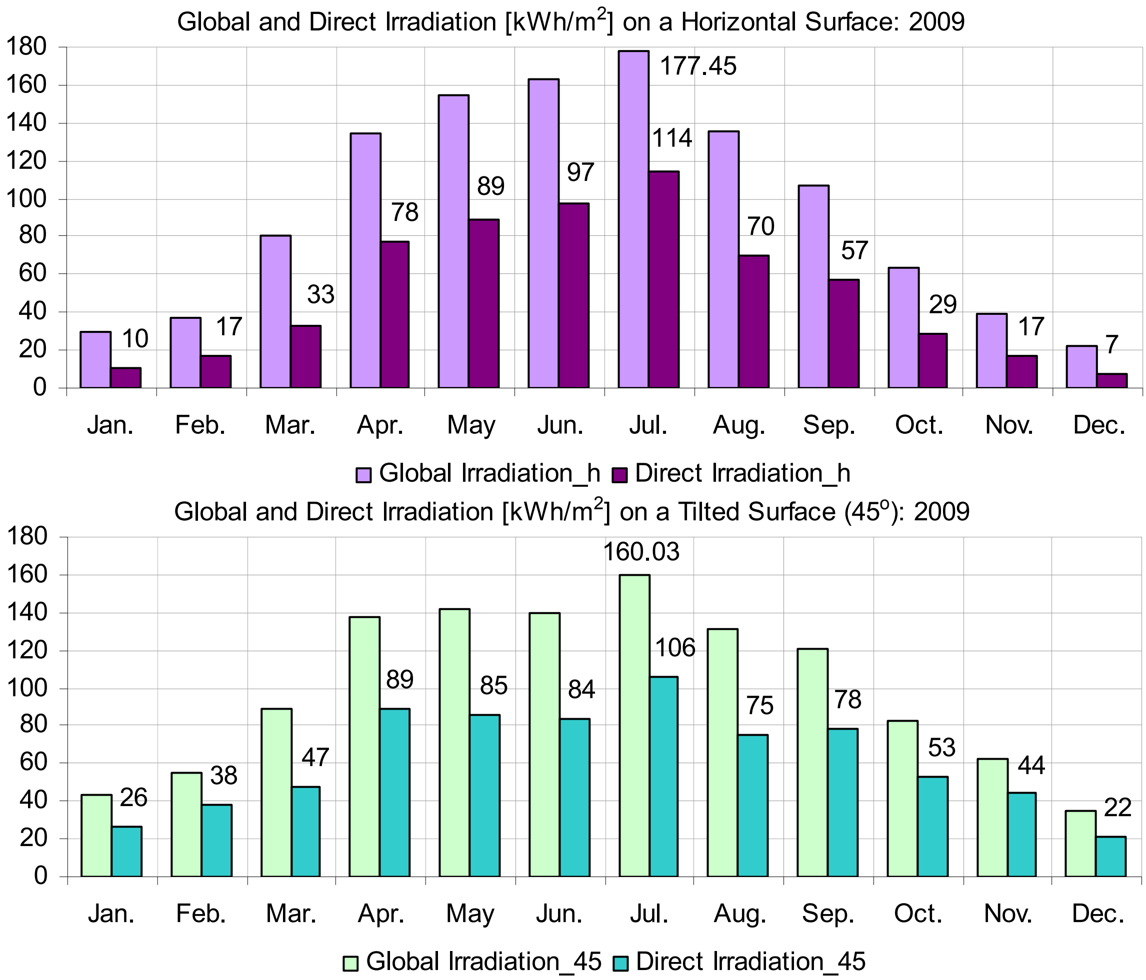

Fig. 2. Global and direct solar radiation (2009)

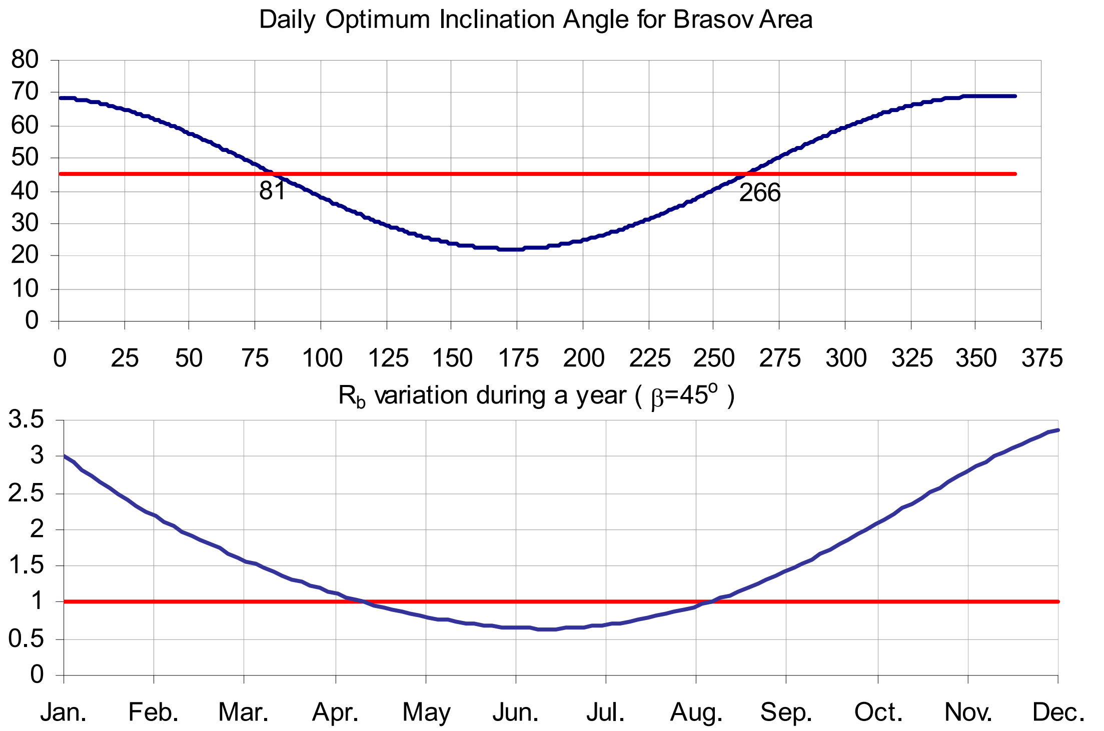

Fig. 3. The optimum inclination angle during a year and its influence on the R_b coefficient

3. THE WIND INCOME

Speed and direction are the main characteristics of wind for a certain location.

Wind is characterised by a steady variation either in speed or in direction, and therefore it takes at least ten years to get the most accurate data.

Wind acts as "fuel" for wind power stations. For a more accurate prediction of wind power for a certain location, it is very important to know its speed value and time variation.

The wind power per unit surface is calculated by the relation [1]:

$$p = 0.5\rho V^3, \quad (6)$$

where: ρ - represents the air density. For normal air pressure and a temperature of 15°C, air density has the value 1.225 Kg/m^2. Tables 3 and 4 present the wind power calculated for Brasov area within two years, 2008 and 2009.

Table 3. The wind power - 2008

Month		I	II	III	IV	V	VI	VII	VIII	XI	X	XI	XII
V	m/s day	0.74	1.08	1.97	1.46	1.31	1.24	1.49	1.08	0.96	0.84	0.79	1.55
P	kWh/m^2 yearly	4.31	3.28	**16.29**	6.40	5.22	3.04	5.68	2.75	1.93	2.73	2.22	15.06
		68.91 kWh/m^2											

Table 4. The wind power - 2009

Month		I	II	III	IV	V	VI	VII	VIII	XI	X	XI	XII
V	m/s day	0.82	0.88	1.38	1.09	1.37	1.43	1.30	0.86	0.80	1.00	1.08	1.23
P	kWh/m^2 yearly	2.58	1.90	5.93	2.90	4.60	6.18	2.37	1.47	1.38	3.74	3.40	7.50
		43.95 kWh/m^2											

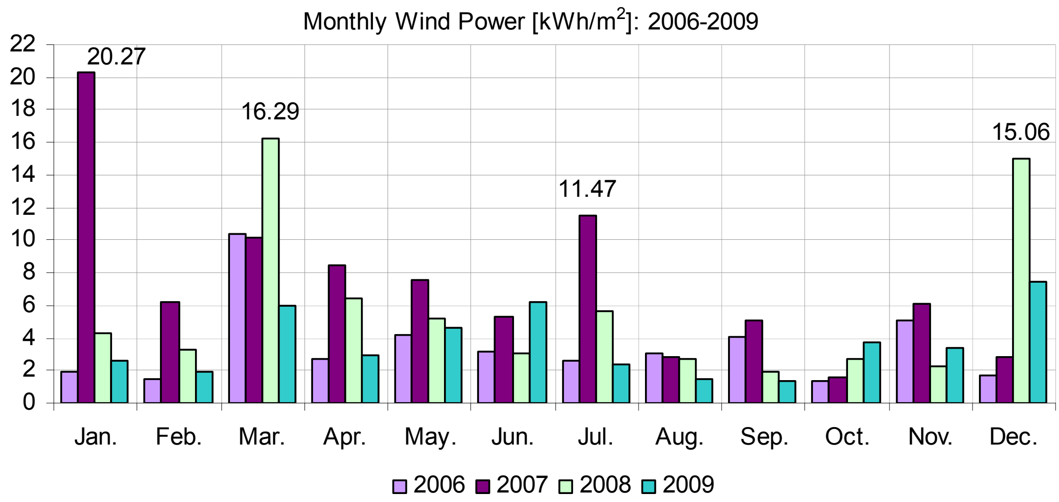

Fig. 4. Monthly wind power

4. CONCLUSIONS

In Figure 5 are presented comparative diagrams of the solar and wind potential variation recorded for Braşov urban area for two years, 2008-2009. Analysis of these diagrams leads to the following conclusions:

- the annual solar potential obtained for 2008 was 640.1KWh/m^2 (direct irradiation on a horizontal surface), while the wind potential was 68.9KWh/m^2; in 2009 were obtained 618.52KWh/m^2 for the solar potential compared with 43.95KWh/m^2 for the wind potential;
- the obtained wind power for the Braşov area is much lower than the solar power; for

the Braşov area, the PV systems are recommended (Fig. 5);

- because of the too low values recorded for the wind speed, the wind turbines' using is not recommended for this area;
- in Braşov region the highest wind potential occurs on the mountain summits and peaks, where the wind exposure is high;
- more energy will be collected by the PV if it is installed on a sun tracker; the amount of the extra generated energy due to the tracking procedure can rise up to 40%; so the sun tracking is giving a higher efficiency of the PV systems and also the required area for installing other PV modules is saved.

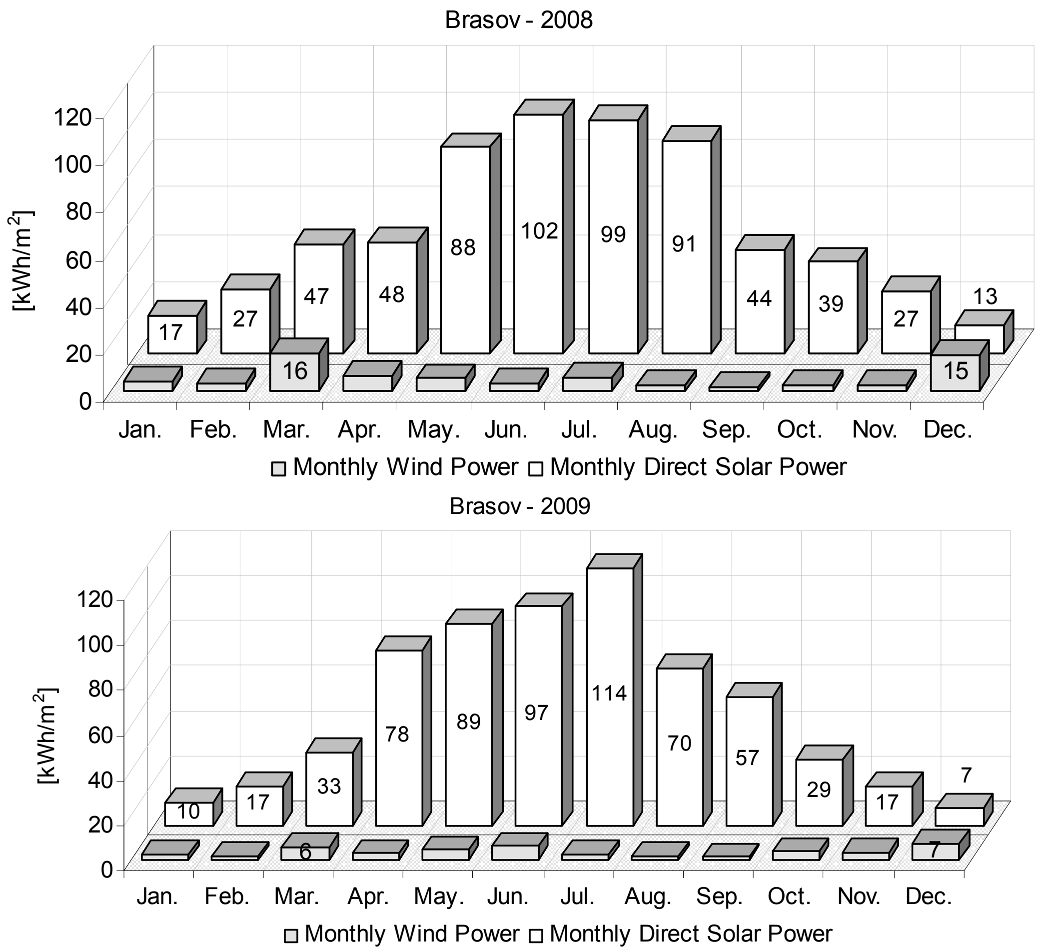

Fig. 5. Comparative diagrams regarding the solar and wind power for Braşov urban area

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