Solar radiation increase over a capturing surface considering R_b factor, for Braşov urban area

C. Şerban[1] and L. Coste[1]

[1]Department of Renewable Energy Systems and Recycling
Transilvania University of Braşov
B-dul Eroilor, 29, 500036 Braşov (România) Phone/Fax number: +0040 268 412921,
e-mail: cristina.serban@unitbv.ro, andreea.coste@unitbv.ro

Abstract. The paper calculates the available solar potential for Braşov urban area and the possibility to increase this potential by using different tilt angles of the capturing surfaces (photovoltaic panels, solar collectors).

The paper also presents: the variation diagrams of the R_b coefficient considering an inclination angle during all year, respectively the values of the optimum tilt angle obtained for months March (47º), June (23º), September (44º), and December (69º); the daily means of the direct and global energy, depending on the tilt angle of the capturing surface; the annual variation of the direct and global energy depending on the tilt angle.

Key words

Direct irradiation, global irradiation, solar potential, tilt angle, R_b factor.

1. Braşov urban area – Geographic and Climatological description

Braşov city is located in eastern-central Romania at 25°36' East longitude and 45°39' North latitude. Placed in Braşov basin, in Carpathians internal curvature, Braşov urban area is about 790 m above the sea level.

This region exhibits some typical features with respect to the topology, the climatology and the environment. The build-up area is low in comparison with that of the neighbouring mountains, which circles the basin area.

The lowest atmospheric layers in the basin are – especially in winter – under the influence of temperature gradient inversions that restrict the atmospheric conversion and, therefore the vertical dispersion of air pollutants and dust. The slope winds that alternatively move up and down along the basin are too weak (the wind speed monthly mean is lower than 2 m/s) to carry the pollutants completely out of the basin. Consequently, crucial situations of atmospheric pollution are frequently observed in winter when cloudy air masses persistently stay in the bottom of the basin, stopping solar radiation and incidentally increasing temperature inversion [1].

In order to calculate the performance of an existing system or to estimate the energy generated from a system in the design stage, appropriate weather data must be required. In this regard, both an analysis of the influence of the measurement interval of solar radiation and wind speed, and a good fit for the data measured in a typical hybrid energy system are of paramount importance, not only with regard to technical reliability but also in the minimization of total system cost (kWh costs).

Most of the times, we record information concerning the solar radiation onto a horizontal surface. However, it is necessary to know the direct and diffuse components of the radiation onto the plane of a solar collector or a PV system. In all primary solar systems, solar radiation can be adsorbed by a flat collector, a PV panel or can be concentrated using mirrors and optical lenses. Optimal choice of technology (fix or tracked) depends on energy needs, area and location-specific weather conditions.

To provide the necessary information about the weather, meteorological instrumentation was used. The meteorological data measurements were carried out with a Delta-T local weather station, positioned on the roof of "Transilvania" University of Braşov. The data sets have been collected since October 2005 until now and they comprise: global solar radiation [W/m^2]; diffuse solar radiation [W/m^2]; air temperature [°C]; wind speed [m/s]; wind direction [degrees]; relative humidity [%]; rainfall [pluviometric mm]; sunshine duration [2].

2. Available solar potential

The amount of solar radiation that reaches the earth's surface is not constant; it depends on location, time of day, period of the year, and specific weather conditions.

The solar collectors are widely used because they have no moving parts and require little maintenance. They are used in various applications that include water heating, space heating and cooling, and low-temperature cycles for power generation [5].

Solar systems with flat-plate surfaces are built without tracking; they are oriented with the active side facing south and mounted under an optimum angle towards horizon, depending on the geographical coordinates of the given location; the inclination of the solar energy systems is necessary for a maximum efficiency from the capturing surface. As the incidence angle between the panels' surface and the solar beam has a minimum value (it is recommended the solar beam to be perpendicular on the panels' surface all day), the energy gain is higher.

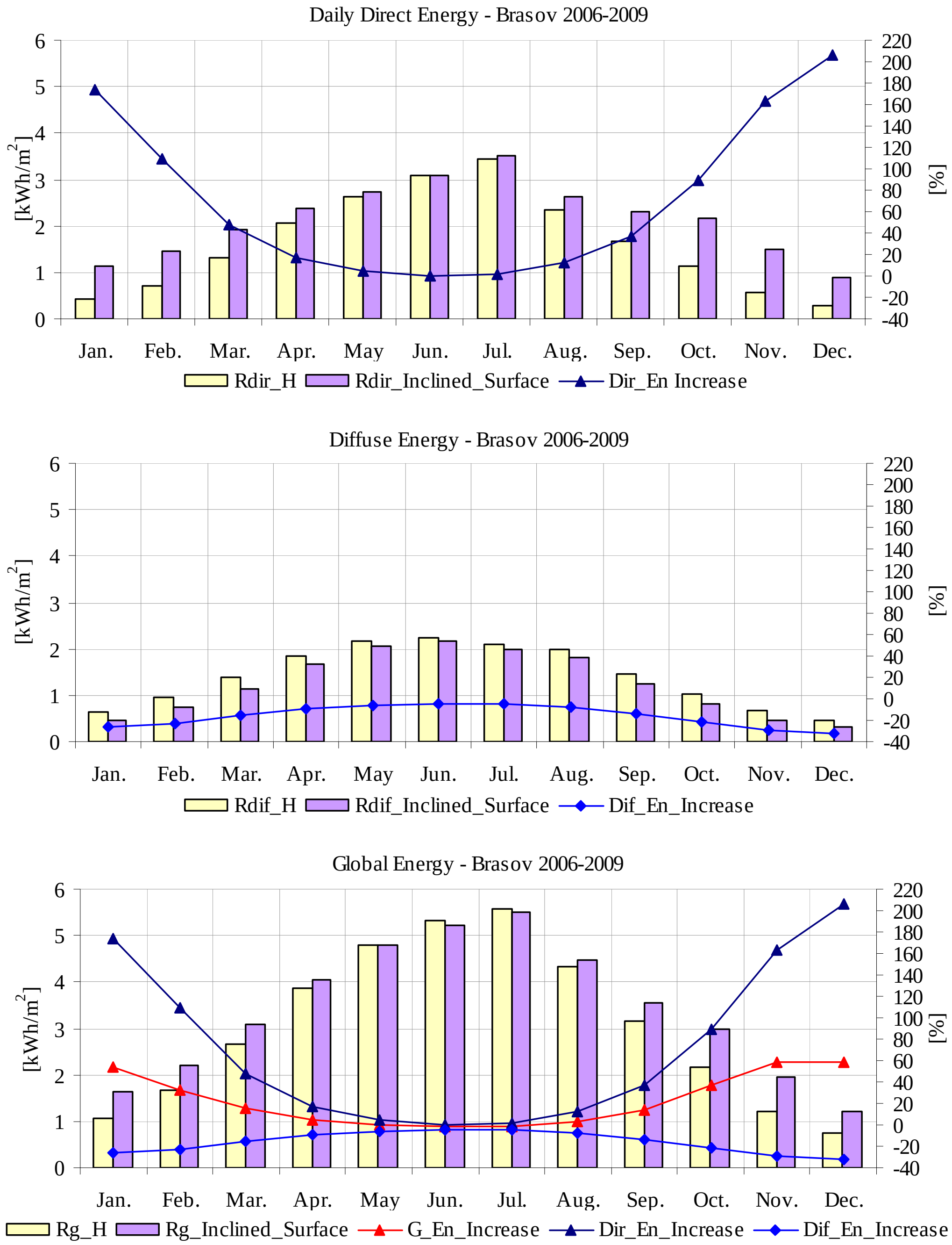

Fig.1. Direct, diffuse and global irradiations

Figure 1 represents the variation of the global, diffuse and direct energies on a horizontal surface and on surfaces inclined at different angles depending on the month.

It can be observed that the maximum of direct and global energy is registered in the month of July and it does not coincide with the month when the day time has maximum duration and the altitude angle has maximum value (June).

The diagrams represent also the energy increase percentage, due to the inclination of the capturing surface (the highest gain value is obtained for the winter months).

3. R_b coefficient influence over the solar potential

The coefficient R_b is defined as the ratio between the direct solar radiation received by a horizontal surface (B) and the direct solar radiation over an inclined surface (B_β) [3].

The real R_b factor was determined for five years (2006 – 2010) period of time for different tilt angles of the capturing surfaces using the meteo database. The paper presents the optimum values of tilt angle obtained for each month of the studied years.

The optimum tilt angle for Braşov area varies from 22^o (for summer period) to 69^o (for winter period) [2], [4]. Analyzing the diagram from Figure 2, it results that for an increase of the direct energy quantity during the winter time it is recommended to assume higher tilt angles, which also leads to a decrease of the diffuse radiation.

The maximum value of the R_b coefficient is registered in December, a value of 3.14 for a tilt angle of 69^o.

Because the study is for an urban area, it can be noticed that the diffuse radiation, for horizontal surfaces, is about 40% of the global radiation. This percentage can be diminished with the increase of the tilt angle of the surface. This represents one of the reasons why the maximum of global and direct solar energy are not obtained for the same tilt angle of the capturing surface (for an inclined surface with 25°, the diffuse energy is higher than in the case of one inclined at 35°).

Considering the fact that the inclination of the surface leads to a decrease of the diffuse radiation (once with the increase of the tilt angle), from a percentage point of view the increase of global energy is lower than in the case of the direct energy. Thus, in the same winter period the growth of global energy on an inclined surface can be with 40-60% higher than on a horizontal surface.

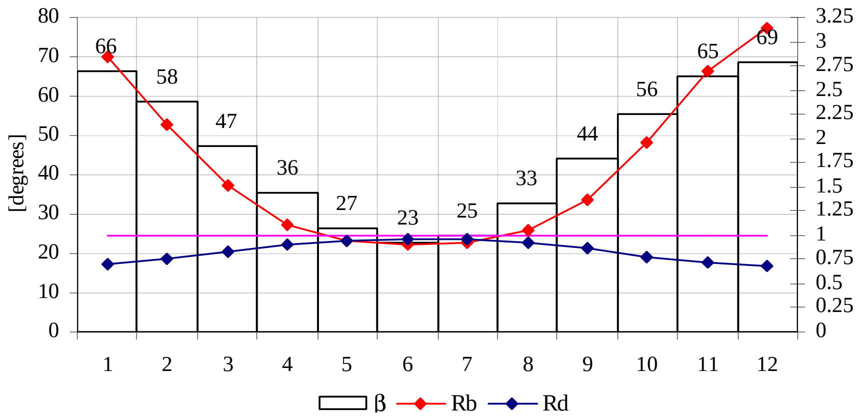

Fig. 2. Rb and Rd coefficients variation for monthly constant tilt angles

Table I. – Hourly Global Radiation increase [%] for Braşov urban area 2006-2010

Month	H_rad kWh/m^2]	Tilt angle											
		15°		25°		35°		45°		55°		65°	
		[kWh/m^2]	[%]	[kWh/m^2]	[%]	[kWh/m^2]	[%]	[kWh/m^2]	[%]	[kWh/m^2]	[%]	[kWh/m^2]	[%]
Jan.	0,13	0,33	160	0,39	204	0,43	239	0,47	265	0,49	281	0,49	287
Feb.	0,17	0,36	116	0,40	142	0,43	162	0,45	175	0,46	180	0,46	178
Mar.	0,25	0,43	69	0,46	79	0,47	85	0,47	85	0,46	81	0,44	72
Apr.	0,31	0,43	39	0,43	40	0,42	38	0,40	31	0,38	22	0,34	10
May	0,35	0,44	26	0,43	22	0,41	16	0,38	7	0,33	5	0,28	19
Jun.	0,39	0,42	30	0,40	25	0,37	18	0,33	15	0,28	27	0,23	41
Jul.	0,39	0,45	34	0,43	30	0,40	23	0,36	14	0,31	21	0,26	35
Aug.	0,34	0,40	41	0,40	41	0,39	38	0,37	33	0,34	25	0,30	15
Sep.	0,28	0,38	67	0,40	74	0,41	77	0,40	76	0,39	71	0,37	64
Oct.	0,26	0,43	108	0,47	128	0,51	143	0,53	152	0,54	156	0,53	153
Nov.	0,16	0,44	166	0,51	211	0,57	247	0,62	274	0,64	290	0,65	295
Dec.	0,11	0,30	177	0,36	228	0,41	270	0,44	302	0,47	322	0,48	331

In Table I, the hourly horizontal global radiation is presented for each month of the year [kWh/m^2] and the percentage of radiation increase due to the different tilt angles. Regarding the annual quantity of the direct energy obtained on a horizontal surface, for Braşov urban area, this is of ≈600 kWh/m^2. For an inclined surface with a constant annual angle of 35^o, this quantity increases to ≈741 kWh/m^2, respectively with ≈23%. In the case of monthly oriented surfaces (Figure 1) the annual quantity of direct energy is ≈783 kWh/m^2, respectively with ≈30% compared with horizontal surfaces. From a global energy point of view, there were obtained for a horizontal surface ≈1115 kWh/m^2 and for an inclined surface with 25^o, ≈1222 kWh/m^2, respectively with ≈9% more. In the case of monthly oriented surfaces, the annual global energy obtained is ≈1236 kWh/m^2, which represents an increase of ≈11% compared to horizontal surfaces.

In Table II, the hourly global radiation [kWh/m^2] is presented for the five years studied (for the year 2010, the recorded data are until November). Also the mean percentage radiation increase for all five years was calculated. As shown, the tilt angle of 35^o constant for all year is the angle with the biggest energy increase for Braşov urban area.

Table II. – Hourly Global Radiation [kWh/m^2] for Braşov urban area 2006-2010

Year	**H_rad** [kWh/m^2]	**Tilt angle**											
		15°	**[%]**	**25°**	**[%]**	**35°**	**[%]**	**45°**	**[%]**	**55°**	**[%]**	**65°**	**[%]**
2006	0.25	0.42	67.1	0.44	77.3	0.45	82.9	0.46	83.7	0.45	79.6	0.42	70.8
2007	0.26	0.43	63.4	0.45	71.2	0.46	74.5	0.46	73.2	0.44	67.3	0.42	57.1
2008	0.28	0.48	73.3	0.51	84.3	0.53	90.4	0.53	91.4	0.52	87.3	0.49	78.2
2009	0.26	0.41	58.9	0.42	65.2	0.43	67.2	0.42	64.9	0.40	58.2	0.38	47.4
2010	0.29	0.26	-10.5	0.27	-7.1	0.27	-5.8	0.27	-6.7	0.26	-9.8	0.25	-14.9
Mean Radiation increase [%]			50.4		57.0		60.6		60.0		55.3		46.6

4. Conclusion

The tilt angles of a capturing surface (PV panels, solar collectors) affect the amount of incident solar radiation exposed on this. These modules surfaces must be oriented and tilted to gain the maximum solar radiation.

For solar energy applications, the optimum orientation is usually suggested to be south-facing in the northern hemisphere, and the optimum tilt angle depends only on the local latitude.

The R_b factor is very useful to RES designers in order to choose the optimum tilt angle for a capturing surface according to the systems requirements (heating, cooling or electric energy), specially if the surface is to be implemented in an already build area. In Figure 3 the variation curve for the R_b factor depending on the tilt angle are presented, for different months of the year (March, June, September and December).

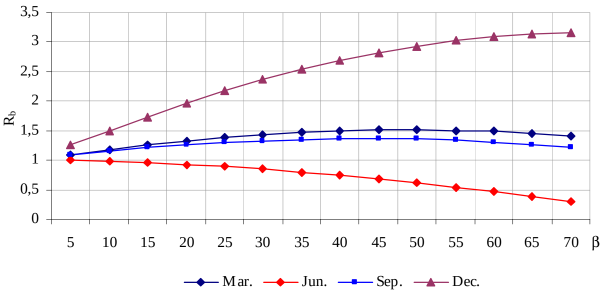

Fig. 3. R_b coefficients variation for monthly constant tilt angles

It is noted that the optimum inclination angle is different if the nature of the energy demand is different. For an application as space heating, the demand is high in the winter months (December, January and February) so an inclination angle of 69^o is optimum for this period. If the solar energy were to be used for cooling spaces, the demand of energy usage would be highest in the months of June, July and August (an inclination angle of 22^o is optimum).

Acknowledgement

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/88/1.5/S/59321 and POSDRU/6/1.5/S/.

References

[1] M. Marcu, V. Huber, Air Thermal Stratification in the Depression Area Forms, in Phytogeographical Implications, Annals I.C.A.S., 46 (2003), pp. 141-150.

[2] L. Coste, C. Şerban, Study of the PV panels tracking efficiency for Braşov urban area, Annals of the Oradea University, Fascicle of Management and Technological Engineering, Vol. IX, No. 4, (2010) pp. 4.50-4.55.

[3] I. Bostan, Conversion systems of renewable energies, ”Tehnica-Info” Publishing, Chişinău (2007).

[4] E. Eftimie, Radiative Parameters Specific to Braşov Urban Area, in the Book “Recent Advances in Environment, Ecosystems and Development”, Proce. of the 7th WSEAS International Conference EED '09, Tenerife, Canary Islands, Spain, December 14-16 (2009) pp. 208-211.

[5] S. P. Sukhatme, J. K. Nakyak, Solar Energy – Principles of Thermal Collection and Storage, Third Edition, Tata McGraw-Hill Publishing, New Delhi (2008).