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EVALUATION OF THE SOLAR INCOME FOR BRAŞOV URBAN AREA

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Abstract: *Energy is an essential factor in overall efforts to achieve sustainable development. In this regard it is necessary a revaluation of each energy system in order to plan energy strategies according to sustainable development objectives. For a good design of the solar collectors, the main objectives that need to be considered are: the maximization of the systems energy performance and the overall costs minimizing. 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.*

Key words: *Renewable Energy Systems, Solar Potential.*

1. Introduction

Braşov city is located in eastern-central Romania at 25°36' Est 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 [2].

Considering the architecture of Braşov, both in old and in the new areas, implementation of solar collectors is difficult. It has the Saxon style of buildings, their roofs crowding close, leading to an unwanted shading both morning and evening (at sunrise and sunset). In these conditions, solar collectors receive energy only when the sun is at high altitudes, around 12 hours.

New buildings and those built after 1970, which have flat roofs, make possible solar orientation, their tilt angle (considering the operation period is from January to April and from October to December) is 55 degrees, facing south.

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Given these characteristics, the paper proposes an analysis of solar radiation for Braşov urban area, analysis necessary for dimensioning and economical calculus of the installations destined for recovery this type of energy.

The paper proposes the analysis of the solar potential specific to Braşov area (global and direct energy and the influence of the inclination angle of the capturing surface) trying to give new perspectives over renewable energy systems for implementation in built environment and also for new buildings in the design stage.

2. Experimental Meteorological Data

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 are required.

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 (Romania). 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 [^{o}C]; wind speed [m/s]; wind direction [degrees]; relative humidity [%]; rainfall [pluviometric mm]; sunshine.

The horizontal global radiation *G*, diffuse radiation *D*, as well as all recorded data is related to 10 minutes range, in a continuous way [3].

3. Solar Income for Braşov Urban Area

Solar system 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 systems is necessary to obtain a maximum efficiency from the collector. 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. Considering that 50% of the total energy is used for heating and cooling buildings, it requires a solar collector efficiency as close to the maximum possible value.

The direct component of solar radiation on a horizontal surface B, inclined at a β angle is calculated with the relation (1), [1]:

$$B_\beta = B\cos\theta / \cos\theta_z = R_b B \, , \tag{1}$$

where: θ represents the incidence angle of the solar beam (angle between the perpendicular on the considered plane and the solar beam direction). For horizontal surface $\theta = \theta_z$.

The diffuse radiation on an inclined surface is calculated with the relation (2):

$$D_\beta = 0.5(1+\cos\beta)D = R_d\, D \, , \tag{2}$$

where: *D* is the diffuse radiation on a horizontal surface.

Consequently, by neglecting the reflected radiation, the global radiation on an inclined surface has the following expression:

$$G_\beta = R_b B + R_d D \, . \tag{3}$$

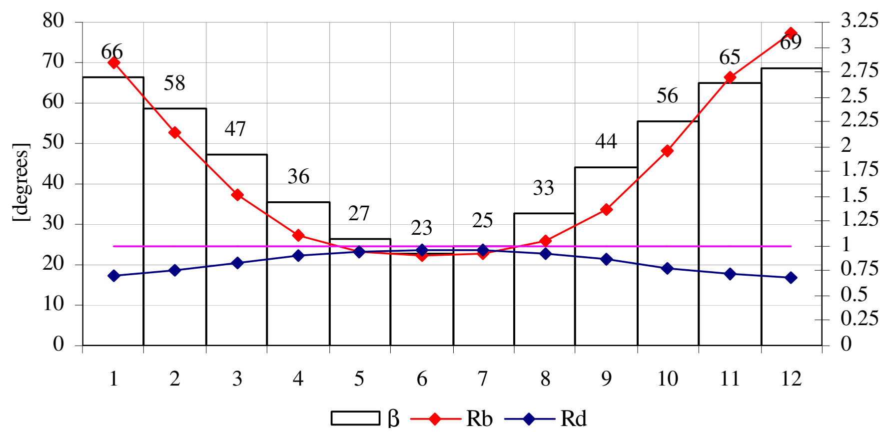
There are constructions that don't make possible - during the day - the variation of the inclination angle towards the horizontal plane (β angle modification). Considering this aspect, it is proposed to use an inclination angle constant for each month; this angle is the capture surface south oriented (arrangement, at the hour with maximum solar radiation intensity - 12 solar time - the value of cos θ is maximum).

The values of the inclination angle obtained for each month of the year are presented in Figure 1.

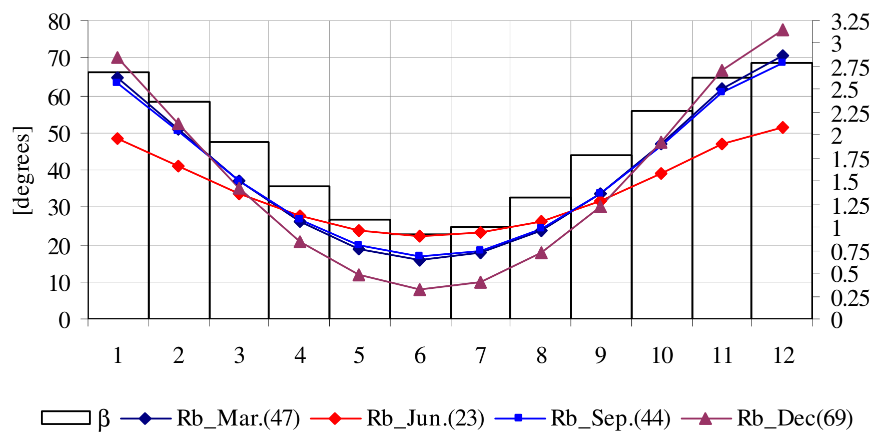
The optimum inclination angle for Braşov area varies from 23 degrees to 68 degrees.

Figure 1 presents also the variation of the direct and diffuse radiation multiplication coefficients (R_b and R_d) depending on the monthly inclination chosen angle. Analysing the diagram in Figure 1a it results that for an increase of the direct energy quantity during the winter time it is recommended to assume higher inclination angles, which also leads to a decrease of the diffuse radiation. The maximum value of the R_b coefficient is registered in the month of December, a value of 3.14 for an inclination angle of 69 degrees.

Also in Figure 1b are represented the variation diagrams of the R_b coefficient considering a inclination angle during all year, respectively the values of the inclination angle obtained for months March (47°), June (23°), September (44°), and December (69°).



a)



b)

Fig. 1. *Monthly variation of the R_b and R_d coefficients depending on the inclination angle:*
a) R_b and R_d coefficients variation for monthly constant inclination angles;
b) R_b and R_d coefficients variation for different inclination angles

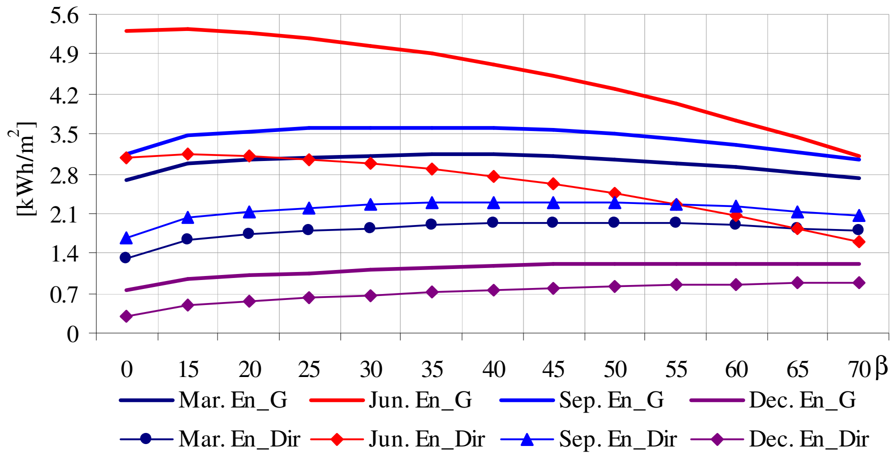


Fig. 2. *R_b variation depending on the inclination angle*

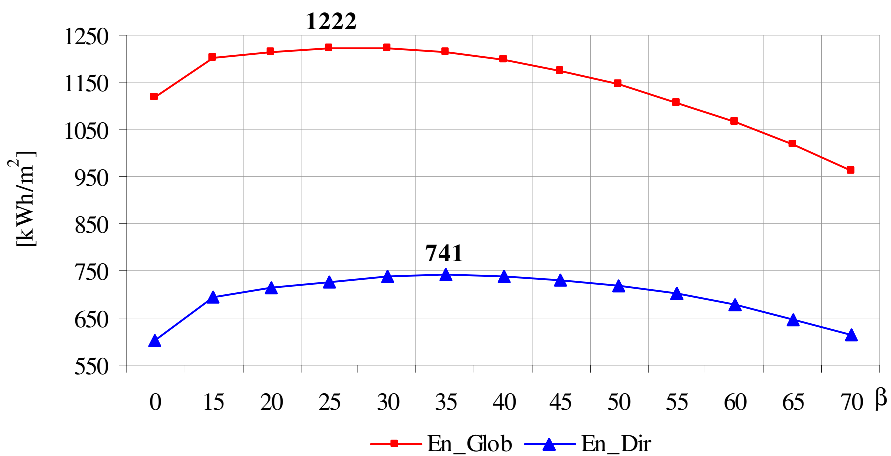


Fig. 3. *Yearly Average of the Direct and Global Energy - Braşov 2006-2009*

Figure 2 presents the daily means of the direct and global energy, depending on the inclination angle of the capturing surface. The diagrams are presented for the months March, June, September and December and it can be noticed that the maximum values of these are obtained for inclination angles with small value during summer, while for winter it is recommended to adopt inclination angles with high values.

For a more complete analysis regarding the available solar potential for Braşov urban area, Figure 3 proposes the annual variation of the direct and global energy depending on the inclination angle. So, it can be observed that the maximum value of global energy corresponds to an inclination value of $\approx 25^{o}$ and the direct energy to $\approx 35^{o}$.

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 inclination angle of the surface. This represents one of the reasons why the maximum of global and direct energy are not obtained for the same inclination 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°).

Although the maximum values of the direct and global energy are registered for small values of the inclination angle (angles corresponding the warm season), in the case of fix systems, during the year, choosing the inclination angle is made considering that, when dimensioning these systems the total maximum quantity of energy is not always a decisive factor. The annual value of the inclination angle will be chosen so that the energy quantity to be maxim during the periods of interest (usually the cold periods) and during the warm months the energy does not become excessively high.

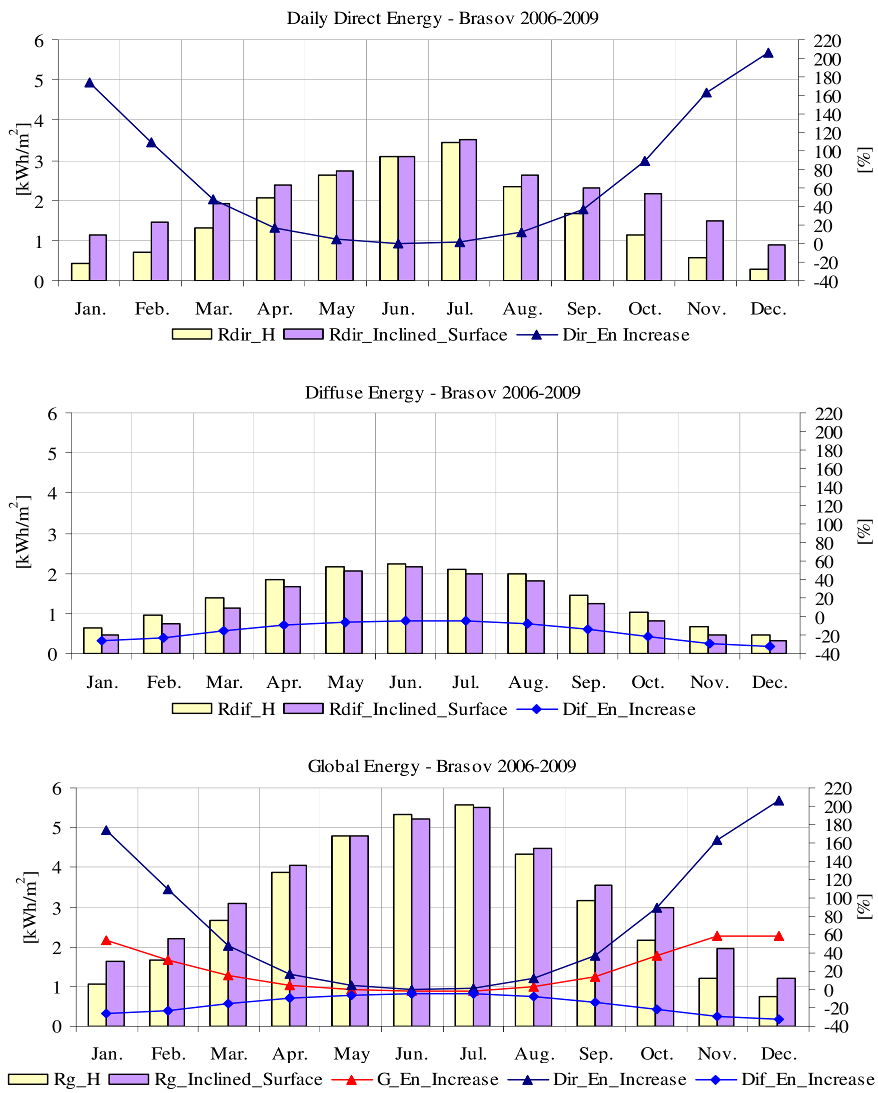


Fig. 4. *Direct, diffuse and global radiations*

Therefore, the selection of the inclination angle will be made as being the average of inclination angles obtained for the period of interest. Figure 4 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 (Figure 1).

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.

As shown in Figures 1 and 2, from the percentage point of view, the highest energy increase for direct energy is registered during the cold periods (January-February and November-December). The direct energy on an inclined surface during these periods can be with 100-200% higher than on a horizontal surface.

Considering the fact that the inclination of the surface leads to a decrease of the diffuse radiation (once with the increase of the inclination 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.

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% (Figure 3). In the case of monthly oriented surfaces (Figure 4) 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 (Figure 3). 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.

4. Conclusions

Considering the above, the following conclusions can be worded:

- the months with the highest values of registered solar radiation are April-September;
- the months December and January are the months with the smallest registered solar potential.

Acknowledgement

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