EVALUATION OF SOLAR ENERGY POTENTIAL IN DOBRUDJA

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ABSTRACT: Evaluation of solar energy potential in Dobrudja. This study aims to bring an original contribution in the assessment as accurate and complete as of the characteristics of solar radiation as accurate and comprehensive estimate of solar potential in Dobrudja. In light of the results obtained from processing a significant background measurements at the 18 points analyzed and significant determinant in assessing the potential of space solar studied, it can be concluded that the coastal zone and the Danube Delta are areas with the highest solar energy potential. Comparison of solar potential values obtained in this work with solar potential values of other countries belonging to the European Union reflects the fact that Dobrudja has potential as good as în many other places on the European continent.

Keywords: Dobrudja, solar potential, net radiation, sunshine

1. INTRODUCTION

This study aims to make an original contribution in the assessment more accurate and more complete estimate of the characteristics of solar radiation as precise and complex solar potential of Dobrudja. According to the results from processing an important background measurements at the 18 points analyzed, significant and crucial in assessing the potential of space solar studied, it can be concluded that the coastal and Delta are the areas with the highest solar energy potential. Comparing solar potential values obtained in this work with solar potential values of other countries belonging to the European Union shows that Dobrudja has potential as good as in many other places in Europe.

2. MATERIALS AND METHODS

In preparing this study and used climate data from weather stations in Dobrudja (Constanta, Harsova, Mangalia, Adamclisi, Cernavoda, Medgidia, Sulina, Tulcea, Jurilovca Portitei mouth, corrugated, Chilia Old Mahmudia) during 1965-2005.

Solar potential can be analyzed from the perspective of global radiation and net solar radiation (solar potential effective). Global solar radiation (Rs) is

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reflected at the earth's surface depending on several factors: the nature, color and surface slope angle of incidence of sunlight etc. Albedo, or fraction of R_S, denoted by α, which is reflected by the active surface of the earth, can reach a maximum of approx. 95% for fresh snow, or a minimum of 5% for ground naked, wet and black. Vegetal cover albedo presents a range of approx. 20-25% green grass with a value of 23%.

Net solar radiation of short wavelength (RNS) is the fraction of the Rs that is not reflected in active surface and net radiation wavelength long (RNL) is the difference between long-wave radiation emitted and received by the active surface of the earth . Net solar radiation (Rn) is the difference between radiation receiver (incoming) and the emitted or reflected (outgoing) for both wavelengths, short and long (MJ m^2/zi). Rn is the balance between the energy absorbed, reflected power and energy emitted by the active surface of the earth, or the difference between net radiation received, the short wavelength (Rns) and net radiation emitted long wavelength (Rnl). Rn is normally positive during the day or at night negative. The total per diem for Rn is almost always positive, except for very severe conditions at high latitudes. Rn is of great importance in the climate of a region, the major contribution which it contributes, among other things, the differential evaporation of water from the surface of land or water (evapotranspiration). In this respect internationally are listed Prescott (1940), which highlighted the correlation between water evaporation and solar radiation, Doorenbos and Pruitt (1977), Allen and others (1998), which showed the great importance of global solar radiation and evapotranspiration on the net.

To determine the solar potential (based on global and net radiation) were taken several steps.

Data on actual duration of bright sunshine (n, h) were converted to values of global solar radiation (Rs, MJ m2/day) with Angstrom relationship type, calibrated to the south-east of the country (Păltineanu and. al, 2002) [1]:

$$\mathbf{Rs = (0,24 + 0,50\ n/N)\ Ra} \quad (1)$$

where:

N - maximum possible duration of bright sunshine (h); Ra - extraterrestrial radiation (MJ m^2/day), calculated with relations given by Allen and others (1998). Further, Rns (MJ m^2/day) was calculated with the formula [2]:

$$\mathbf{Rns = (1 - \alpha)\ Rs} \quad (2)$$

where:

α - albedo, vegetation cover estimated situation during plant vegetation.
Rnl (MJ m^2/day) was calculated by equation (Allen et al, 1998):

$$\mathbf{Rnl=\sigma\ [(T_{max}+T_{min})/2]^4[0,34-0,14*sqrt(e_a)][1,35*(Rs/Rso)-0,35]} \quad (3)$$

where:

σ - Stefan-Boltzmann constant (σ = 4.903 * 10-9 MJ K-4 m^2/day);
T_{max} (K) - absolute maximum temperature during 24 hours, in Kelvin:

$$\mathbf{T_{max}\ (K) = (^{\circ}C + 273,16)}$$

T_{min} (K) - Absolute minimum temperature during 24 hours, in Kelvin:

$$\mathbf{T_{min}\ (K) = (^{\circ}C + 273,16)}$$

$\mathbf{e_a}$ is actual water vapor pressure (kPa) and is given by:

$$\mathbf{e_a = (RH_{med}/100)*(e_{Tmax} + e_{Tmin})/2} \quad (4)$$

where:

RH_{med} - average relative humidity (%);

e_{Tmax} - saturated vapor pressure at the maximum temperature (t_{max}, ° C) daytime (kPa);

$$\mathbf{e_{Tmax} = 0,611*exp[17,27*t_{max}/(t_{max}+237,3)]} \quad (5)$$

e_{Tmin} - saturated vapor pressure at the minimum temperature (t_{min}, ° C) daytime (kPa).

$$\mathbf{E_{tmin} =0,611*exp[17,27*t_{min}/(t_{min}+237,3)]} \quad (6)$$

Ratio Rs / Rso is given by:

$$\mathbf{Rs/Rso = 0,75 * Ra} \quad (7)$$

Where:

Rs / Rso - short wave radiation relative (≤ 1.0);

Rs - global solar radiation (MJ m^2/day);

Rso - serene daily global solar radiation (MJ m^2/day).

Finally, net radiation, Rn, the difference between the radiation received and emitted or reflected by both wavelengths, short and long, was calculated by the formula[8]:

$$\mathbf{Rn = Rns - Rnl} \quad (8)$$

The average monthly and annual data Rn and Rs schematic maps were drawn on its territorial distribution. To identify relatively homogeneous areas on Rn and Rs interpolation was performed monthly averages geostatistical method kriging (ordinary kriging) using linear variogram model without nugget and sill suitable for relatively equally distributed spatial data. For better resolution isolines calculated and plotted graphically were used cubic spline functions in the same program above. In the mountain region, altitudinal climatic Zoning exhibition from the sun, and microclimates could not be taken into account in drawing isolines this small Territory studied. It also should be noted that the resulting maps are approximations of reality based on position data and observation points used. A high density of them, especially in the northern coastal area, will improve their representation.

3. RESULTS AND DISCUSSION

3.1. Duration of bright sunshine and global radiation in Dobrudja

Black Sea is located in the largest amounts of annual mean sunshine duration in the country, exceeding 2250-2300 hours. High values of global radiation area is the largest in Southern Dobrudja, outlining the overall field of the predominant influence of the sea breeze front - the day and time inversions accompanied by clear, that, according to the thermal contrast between the high and dry trenchant penetrates deep into the earth's surface, over relatively level terrain, with lower elevations (100-200 m on average) and fragmentation densities very low (<0.1 km/km^2). Here, the action limit maximum sea breeze (30-35 km), the highest of the Valley Carasu sunny terraces, the average annual insolation is also more than 2300 hours. Due to the extended surface air damping sources in the Danube Delta, which generate specific hydrometeors (fog evaporation etc..), isolines of annual sunshine with high values (> 2240 hours) delimits a territory smaller here - most of the eastern half. Lowest annual average values of insolation (<2150 hours) are recorded in its fragmented landscape of node-west of Dobrudja, in deep valleys, shady slopes or ridges frequently shrouded by clouds. Sunshine duration is reduced in relation to the altitude and relief in southwestern region, on the Plateau Oltina, figure 1. Under these conditions, the Black Sea, upper valley terraces Carasu and generally east of South Dobrudja, which is the maximum action in sea breezes, is characterized by the highest energy potential, the mean annual global radiation being over 14 MJ/m^2/zi (123-124 kcal/cm^2) figure 2.

Delta and most of Central and South Dobrudja territory are limited by annual izolinia MJ/m^2/zi 13.7 (120 kcal/cm^2). In the northwest Dobrudja, the potential energy decreases below 13.6 MJ/m^2/zi (<120 kcal/cm^2).

Fig. 1. ***The distribution of the average annual sunshine (hours) in Dobrudja (1965-2005)***

Fig. 2. ***The distribution of mean annual global radiation (MJ / m² / day) in Dobrudja (1965-2005)***

3.2. The main parameters of net radiation in Dobrudja

Average annual net solar radiation have similar values in Dobrudja, from approx. 7 MJ m^2/ day in the northwestern high, up to 7657 MJ m^2/ day Black Sea, isolines are roughly parallel to the shore, figure 3. Distribution of the total annual net solar radiation, summed (MJ/m^2) has a form similar to the previous one, reaching values of 2580 in the northwestern part of the area Horia village and approx. 2800 seaside figure 4.

Fig. 3. ***The distribution of average annual net solar radiation (MJ / m² / day) in Dobrudja (1965-2005)***

Fig. 4. ***The distribution of average annual net solar radiation summarized in Dobrudja (1965-2005)***

In DECEMBER, net solar radiation have minimum values, isolines are oriented mainly in the direction parallel, east-west, with the exception of Delta, where they remain north-south direction. Reach maximum values in DECEMBER, about 1.04 MJ m^2/day in southern Dobrudja territory, while its northern part there is 0.86 MJ m^2/ day, figure 5.

Fig. 5. ***The distribution of average net solar radiation in DECEMBER in Dobrudja (1965-2005)***

The hottest month, JULY, net radiation while the maximum values and ranges from 15.5 MJ m^2/day seaside Delta, up to 14 MJ m^2/day in the north-west, figure 6. Configuration of curved isolines are approximately parallel north-south, thus illustrating the great influence of the Black Sea on net radiation.

In the cold season, from november to march, net solar radiation is spread in a similar territorial DECEMBER, with isolines oriented approximately east-west direction, figure 7. In the south are around 2.62 to 2.64 MJ m^2/day values, while in the north, net solar radiation amounts to approx. 2.38 to 2.36 MJ m^2/day.

Unlike the above range, the warm period that totals the months from APRIL to OCTOBER, including distribution of net solar radiation values have a similar form JULY. Now isolines are parallel to the Black Sea, thus illustrating horizontal gradients generated by its influence on the climate region, figure 8. Net radiation values from 11.2 to 11.3 MJ m^2/day reach the Black Sea from the west gradually decrease, reaching ca. 10.4 to 10.5 MJ m^2/ day the mountainous area north-west of Dobrudja.

Fig. 6. ***The distribution of average net solar radiation in JULY (MJ / m² / day) in Dobrudja (1965-2005)***

Fig. 7. ***The distribution of average net solar radiation (MJ / m² / day) during cold (NOVEMBER-MARCH) in Dobrudja (1965-2005)***

Fig. 8. ***The distribution of average net solar radiation (MJ / m² / day) during warm (APRIL-OCTOBER) in Dobrudja (1965-2005)***

3.3. Estimation of solar energy converted in Dobrudja

Another issue addressed is that of estimating energy converted the territory of Dobrudja, which is a practical application of solar potential assessment conducted in this chapter.

Given those shown in the previous paragraph can be calculated annual energy converted from Dobrudja stations. For this, the practical requirements, expressed in MJ/m^2/ day solar potential, has been transformed into potential energy expressed in kWh/m^2/year. For the following steps were:

- International unit for measuring electrical energy is the joule (1J = W • S) - Another unit (used in practice) is kWh, it turns into joule as follows: 1J = W • S, 1 kW = 1000 W, 1 hour = 3600 seconds, hence that 1 kWh = 1.000 watts • 3600 and so 1 kWh = 1.000 watts • 3600 J ↔ 1 kWh = 3.600.000 J.

Based on these relationships could determine the solar energy potential, expressed in practical needs in kWh/m^2, total (global radiation expressed) and effective (in terms of net radiation), in december, july, the cold, the warm, and the annual average. From these figures we can conclude the following:

- In december, the month with the lowest potential energy, the most favorable areas for recovery are located in Southern Dobrudja (over 37 kWh/m^2 in central and eastern South Dobroudja - potential calculated from global radiation; over 9 kWh/m^2 in central and northwestern South Dobrudja - potential calculated based on net radiation).

- In JULY, the month with the greatest energy potential areas most favorable for recovery are located in the coastal and central and eastern Delta (over 210 kWh/m^2 - potential calculated from global radiation, over 127 kWh / m^2 - potential calculated based on net radiation).

- In the cold (NOVEMBER-MARCH), the highest values were recorded in central and eastern South Dobroudja (over 281 kWh/m^2 respectively over 110 kWh/m^2).

-In the warm period most favorable for this form of energy recovery, the highest values were recorded throughout the coastal zone and Delta (over 1147 kWh/m^2 - potential calculated from global radiation, over 659 kWh/m^2 - potential calculated based on net radiation).

- In terms of the distribution of annual mean values solar energy potential we conclude that central and eastern South Dobrudja and Danube Delta are areas where this form of energy can exploit maximum efficiency (over 1398 kWh/m^2, respectively over 750 kWh/m^2).

4. CONCLUSIONS

Global solar radiation and net distribution, which reflects solar potential of Dobroudja, presents both a clear temporal variation and spatial one, depending on month, season or period of observation.

Compared to global solar radiation, net radiation is a fraction representing about 25-40% of that in the cold season and approx. 50-60% in summer, spring and autumn with intermediate values (40-50%).

In general, global and net radiation values decrease from the coastal zone to the west, especially during the warm season, the maximum influence of the Black Sea, while in winter, net radiation varies from north to south (in if net radiation) and south-north (where global radiation).

This study aims to make an original contribution in the assessment more accurate and more complete estimate of the characteristics of solar radiation as precise and complex solar potential of Dobrudja. According to the results from processing an important background measurements at the 18 points analyzed, significant and crucial in assessing the potential of space solar studied, it can be concluded that the coastal and Delta are the areas with the highest solar energy potential. Comparing solar potential values obtained in this work with solar potential values of other countries belonging to the European Union shows that Dobrudja has potential as good as in many other places in Europe.

REFERENCES

1. Allen R.G., Pereira L.S., Raes D., and Smith M. (1998), *Crop evapotranspiration. Guidelines for computing crop water requirements*, FAO Irrigation and Drainage Paper 56, Rome,301.
2. Angström A. (1924), *Solar and terrestrial radiation*, Quart. Jour. Roy. Meteor. Soc., 50, 121-125.
3. Baker D.G. and Haines D.A. (1969), *Solar radiation and sunshine duration relatioships in the north-central region and Alaska - Basic computation,* North-central regional research publication 195. Technical Bulletin, 262, 372.
4. Bogdan, Octavia (1974), *Asupra noţiunii „Resurse climatice”*. SCGGG Geogr. XXI, 1, 89-93.
5. Cristian Păltineanu, Ion Florin MIihailescu, Vasile Torică, Anca Nicoleta Albu, (2002), *Correlation between sunshine duration and global solar radiation in south eastern Romania*, International Agrophysics, vol. 16, Nr. 2, Inst. of Agrophysics, Polish Academy of Sciences,Lublin,Polonia, 139-145.
6. Lungu, M., 2010, *Resursele climatice din Dobrogea*. Editura Universitara, Bucuresti.
7. Panoras A.G. and Mavroudis I.G. (1994), *Relation between duration of sunshine and global solar radiation in Thessaloniki Plain*, Hydrotechnica, J. Hellenic Hydrotechnical Association, 4(1), 3-15.
8. Sandoval A. and Shaw R.H. (1958), *Relation of solar radiation measurements at Ames to sunshine observations at Des Moines*, Iowa St. J. Sci., 33(2), 173-184.