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THE HELIO-ENERGY RESOURCES IN THE REGION OF KRUSHARI

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Abstract

The present work is aimed at evaluating the solar energy potential of Krushari region in Bulgarian territory. The results obtained have a scientific-theoretical importance for the verification of the approach, based on the PV-GIS satellite database. These results can complement the macroclimatic picture for the Bulgarian territory and can be compared with results from other solar radiation databases – SODA, NASA, METEOTEST, etc. The obtained values for solar energy production in the particular region of investigation are of practical-applied importance too. They represent valuable basic information for the planning and design of solar power plants, the choice of their technological equipment, the evaluation of their financial returns, etc.

***Key words**: duration of sunshine, intensity of solar radiation, helio-energy capacity, production of solar energy power, North-east Bulgaria*

Introduction

The Sun is the most powerful source of renewable energy and the transformation of solar radiation to electric energy is one of the most ecological variants for electric power production. The position of Bulgaria in the so-called “sun belt” of the planet is an advantage in terms of solar-energy potential compared to a number of countries with higher geographic latitudes. Therefore, years ago, the government of the country adopted a proposal from the European Commission (EC) to include a new activity in the measure “Access to sustainable and effective energy resources” within the EU financial programme for Bulgaria till 2013. This activity concerns the construction of installations for using renewable energy sources and it is a priority in the EU programmes.

In this context, one of the priority tasks of applied climatology in the recent years is to make an up-to-date assessment of the potential of climatic renewable energy sources in Bulgaria. The parameterization of the territory of the country is of major importance both in small-scale, macroclimatic plan, and large-scale, mesoclimatic plan, with respect to particular localities.

The present work[1] is aimed at evaluating the solar energy potential of one region of Bulgarian territory. In this way the study realizes two useful tasks simultaneously: (1) scientific theoretical – to verify one of the approaches to solar energy estimation, as well as to add a segment to the macroclimatic solar-energy assessment of the territory of the country; (2) scientific-applied – to estimate the solar-energy potential in a particular locality, revealing in more detail mesoclimatic parameters at the background of the macroclimatic solar characteristics of the country.

The object of investigation is the area of the Krushari municipality in Northeast Bulgaria. The choice of this site is based on the results from our previous studies [3], showing in more general aspect a rather good solar potential within the region. The combination of this potential with the proven good wind potential makes the area a place of raised interest on behalf of practice and an attractive center for investments in wind-solar power generation. This has been also proved by a particular customer request, in response to which we have also focused our choice to the region of Krushari. Last but not least, the selection of this area was substantiated by the fact that it is characterized by good parameters of transport, electric power transfer and ecological accessibility.

The Krushari municipality is situated in the northern part of the Dobrich district, part of its northern border coinciding with the state border of Bulgaria with Romania (Figs. 9 and 10). The average altitude of the terrain in the municipality is about 200 m. Lower places below 100 m are observed only in the narrow incised river valleys. The western part of the municipality coincides with part of the Suha Reka Natura 2000 protected area.

1. Sunshine duration

The average annual duration of sunshine in the region of Krushari is about 2200 h, with a maximum in July – 324 h, and a minimum in December – 68 h (Fig. 1). These values are around the average for the country. In the summer months the proportion between the possible and actual duration of sunshine reaches 71% and decreases to 24% in winter (Table 1).

Table 1. Relative sunshine duration (% of the astronomically possible sunshine)

Месеци												Год.
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
27	30	34	45	53	62	70	71	61	52	31	24	49

[1] The research contributions in this work are distributed as follow: analysis of sunshine duration, intensity of solar radiation, processing of the initial bases of climatic data, methodology approach, table and graphic presentation - Z.Mateeva; field investigations, physical-geographic characteristic, protected areas, skyline overshadow, optimal inclination of the receptioning surface, energy capacity, satellite data, computer simulation of power production, and GIS-interpretation&mapping – A.Filipov.

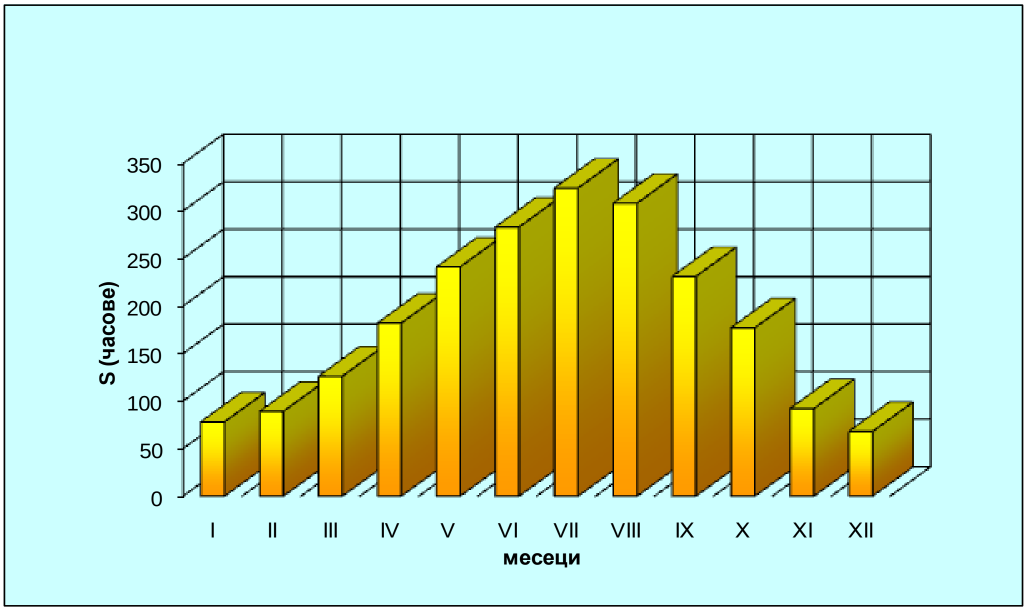

Fig. 1. Annual course of sunshine duration (S)

The minimum and maximum number of hours with sunshine gives additional detail to better understand the situation in the region. On the territory of Krushari municipality this parameter fluctuates in time within relatively narrow range – from 2022 to 2330 h/yr, which is an indication for low chorological variability and hence – stability of sunshine duration. Only 71 days without sunshine are recorded in this part of the country (Fig. 2) and it has to be taken into account that electric power is also generated from the PV modules, although less effectively, during the days without sunshine.

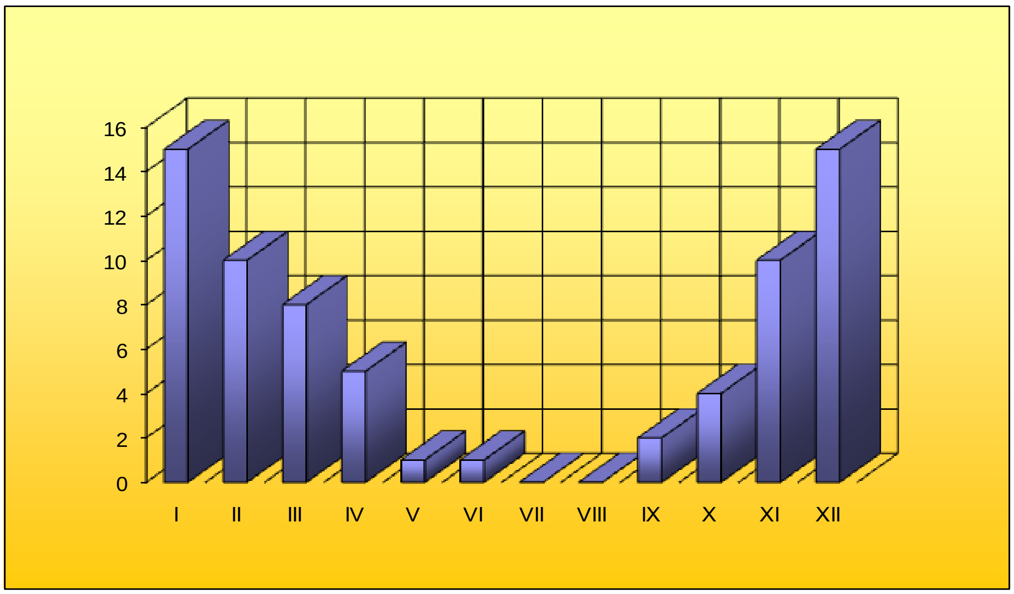

Fig. 2. Number of days without sunshine

The daily course of sunshine duration in the region, illustrated in Fig. 3, starts its realization from 3-4 a.m. in summer months (7-8 a.m. in winter months) and ends in the period 7-8 p.m. in the summer months (4-5 p.m. in winter months). With respect to its probability the duration of sunshine varies from 2871 h for probability of 5% to 1458 h for probability of 95% (Fig. 4).

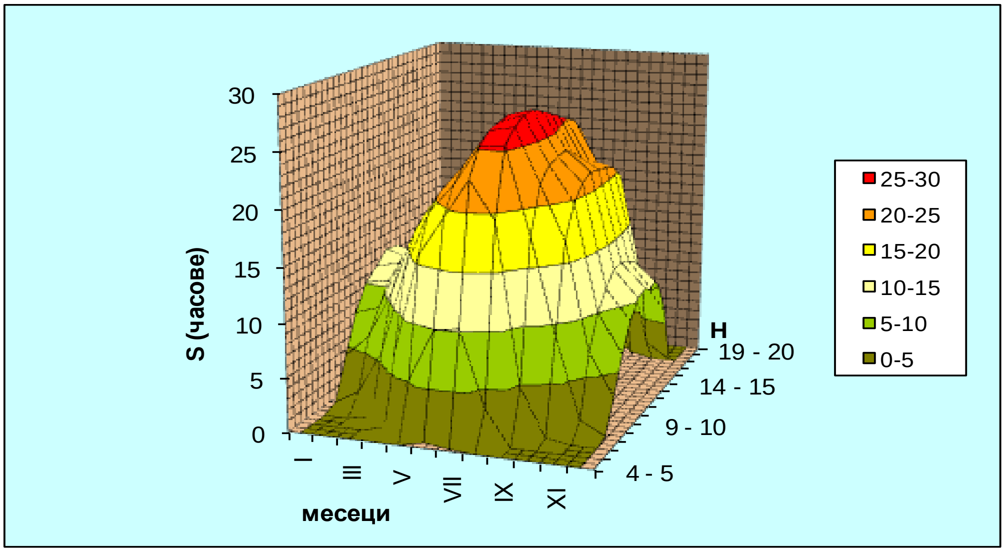

Fig. 3. Daily course of sunshine duration (S) in the time intervals of the day (H)

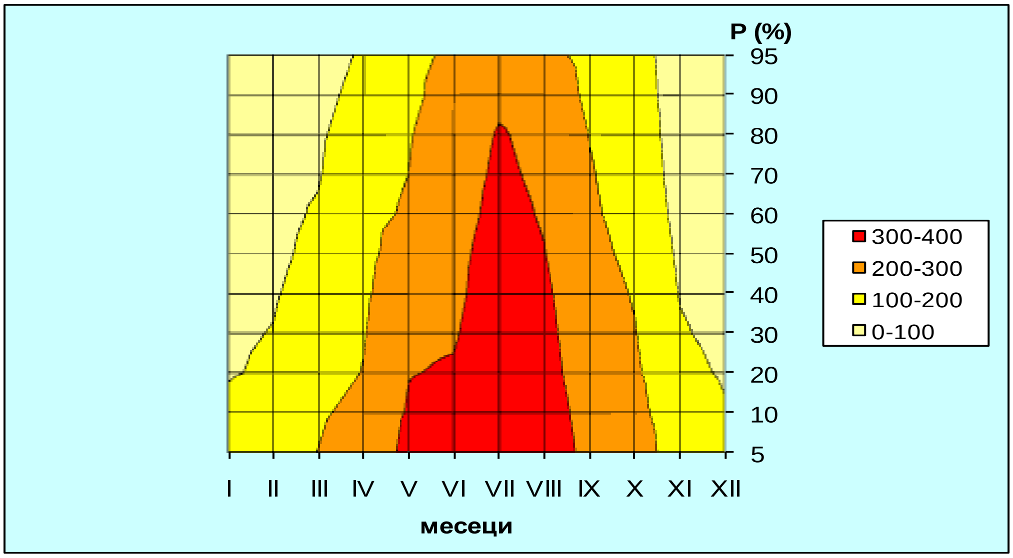

Fig. 4. Annual course of the probability (P) of sunshine

The average annual general cloudiness is the other important parameter related to the influx of solar radiation to a given site. This parameter amounts to 5 degrees for the region of the Krushari municipality, which is normal and typical for a territory with moderate-continental climatic conditions (Fig. 5). It should be pointed out that in terms of helioenergy generation the existence of partial cloud cover of the cumulus type can increase the solar radiation influx to the earth's surface due to additional reflection by the lower side of the clouds. The annual number of clear days (less than 2 degrees of general cloudiness) in the studied area is predominant compared to the number of dark days (more than 8 degrees of total cloudiness), exceeding it about 1.3 times (Figs. 6 and 7).

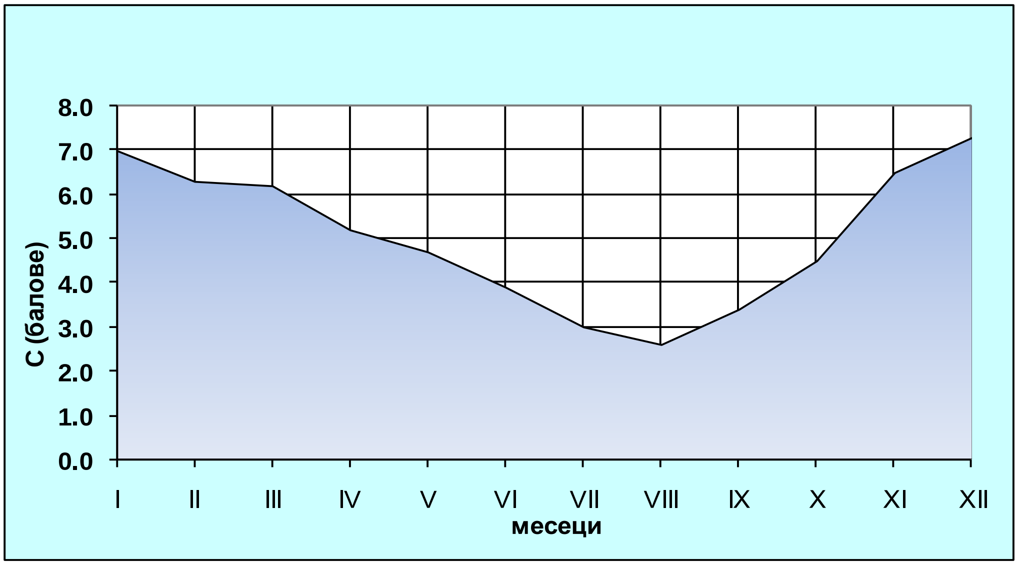

Fig. 5. Annual course of general cloudiness (C)

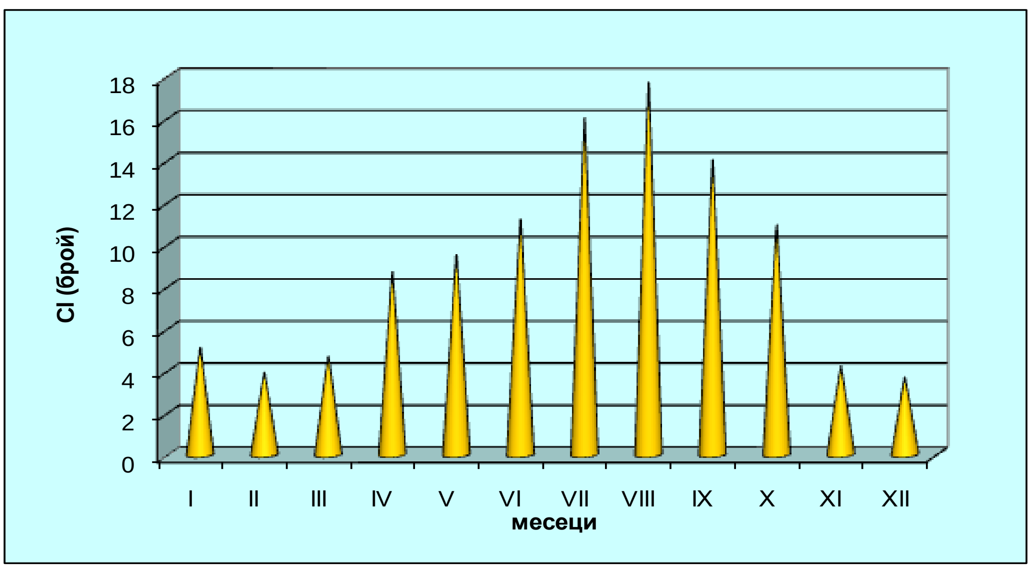

Fig. 6. Annual course of clear days (by general cloudiness, Cl)

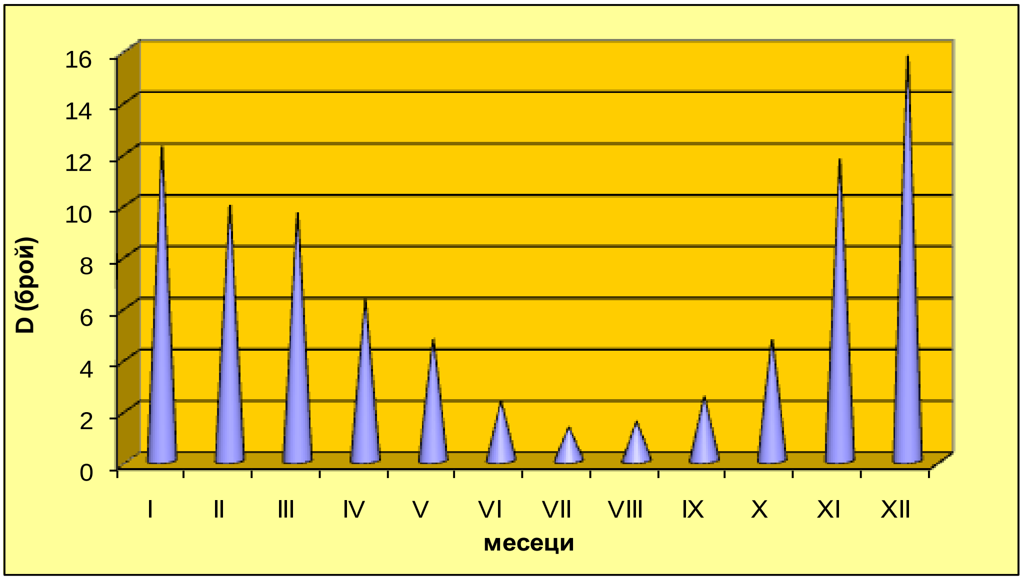

Fig. 7. Annual course of dark days (by general cloudiness, D)

Solar Radiation

The assessment of the influx of solar radiation to the region of Krushari is based on satellite data for the period 2000-2006 [2; 7; 8]. This is a sufficiently recent period to assume that it reflects adequately the current state of the climate system, including its altered status during the last decades. The internal-annual course of solar radiation on a flat surface is clearly outlined, with a value of 1170 Wh/m^2 in December to 6250 Wh/m^2 in July. For an optimal angle of the irradiated surface solar irradiation increases significantly. According to the calculations for the particular region of study, the average value of this angle in December is 65^0 and in July –14^0. The values of solar radiation for such angles of the surface reach respectively 1940 Wh/m^2 in December and 6030 Wh/m^2 – in July. In fact, during some of the months of the warm season of the year (May, June and July), when the sun passes high in the sky and sunrise and sunset are respectively to the northeast and northwest, the day duration for a horizontal surface is longer than for a surface, oriented to the south at an optimum angle. For this reason the solar radiation values for a horizontal surface in these months are slightly higher than these for a surface with an optimum inclination to the south. But as an average annual value the solar radiation on an optimally inclined surface is considerably higher than that on a horizontal surface (Fig. 8). With respect to the territory of Bulgaria the studied region exhibits rather high levels of solar radiation.

Air temperature is an important factor for the photovoltaic transformation of solar radiation into electric power. In the area of Krushari this climatic element changes during the midday observations from 0,6^{o}C (average monthly for January) to 23,6^{o}C (average monthly for July). These values refer to the period corresponding to the solar radiation satellite database used in this study.

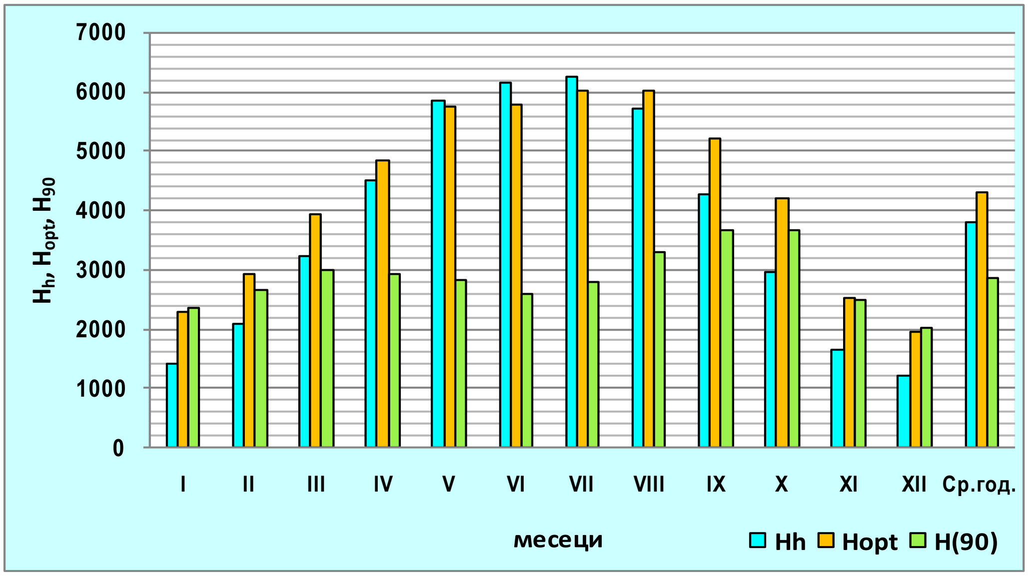

Fig.8. Monthly and annual solar irradiation (H_h, H_{opt}, H_{90})

H_h - Irradiation on horizontal plane ($Wh/m^2/day$)
H_{opt} - Irradiation on optimally inclined plane ($Wh/m^2/day$)
H(90) - Irradiation on plane at angle: 90deg. ($Wh/m^2/day$)

2. Production of solar electric power

As of the present moment the technology for transforming short-wave solar radiation to electricity is accessible at the market and numerous models of PV modules are available. There are two main groups of PV technologies: based on amorphous silicon and based on crystalline silicon. Although very cheap, amorphous silicon shows a low coefficient of efficiency, so crystalline silicon is mainly used at present. In its turn, the crystalline silicon based technology is realized in three directions: with monocrystalline silicon, polycrystalline silicon and “thin film”. Monocrystalline silicon is still a rather expensive, although most efficient, technology. The “thin film” technology is the cheapest one (in the group of crystalline silicon), but it has the shortest operational life – up to 10-12 years. The polycrystalline silicon based technology seems to be the most efficient one for the present.

In this work, based on the calculated influx of solar radiation, a field was built for the potentially produced electric energy from a PV module with a peak power of 1000 W for both assembly at a fixed inclination and modules, installed on a tracking system (Figs. 9 and 10) [5].

The predicted electric power production within the studied area from PV with polycrystalline silicon is about 1392 kWh/yr for modules assembled at a fixed angle of 32^o. The predicted electric power production increases to about 1919 kWh/yr when using a tracking system.

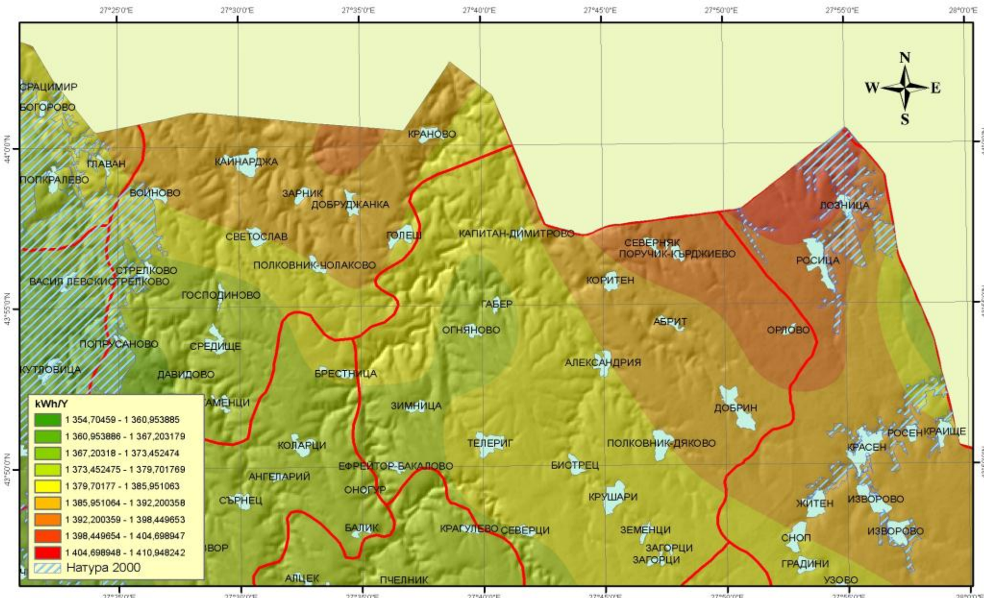

Fig. 9. Territorial variation of the potential for electric power generation from PV CRISTALLINE SILICON – a fixed system

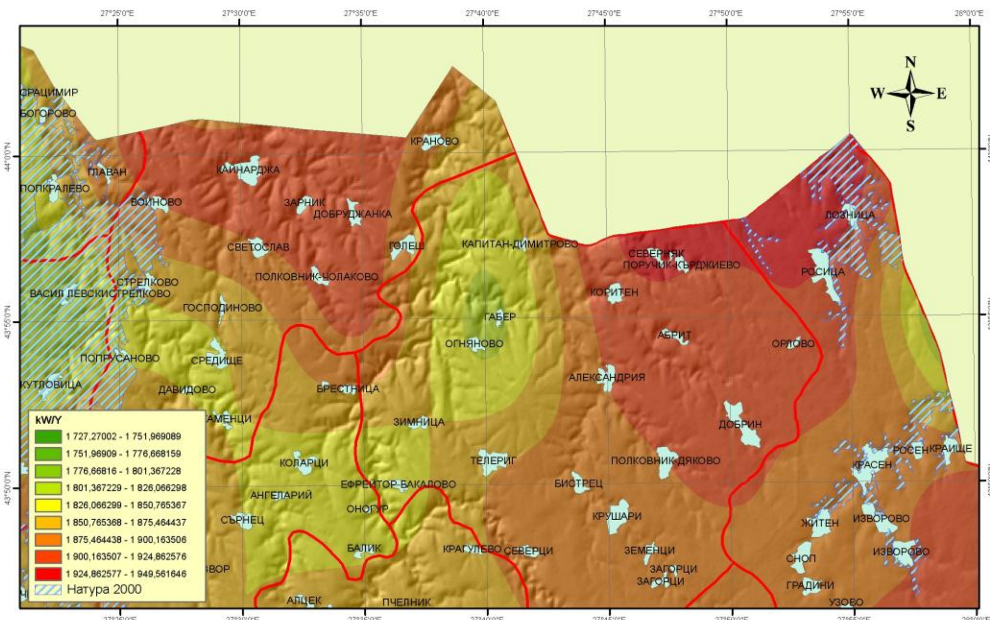

Fig. 10. Territorial variation of the potential for electric power generation from PV CRISTALLINE SILICON – a tracking system

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The results obtained in the present study have a scientific-theoretical importance for the verification of the approach, based on the PV-GIS satellite database. These results can complement the macroclimatic picture for the Bulgarian territory and can be compared with results from other solar radiation databases – SODA, NASA, METEOTEST, as well as with the databases of the National Institute of Meteorology and Hydrology (NIMH) [1; 6; 9; 10; 11].

Furthermore, the obtained values for solar energy production in the particular region of investigation – the Krushari municipality, are of practical-applied importance. They represent valuable basic information for the planning and design of solar power plants, the choice of their technological equipment, the evaluation of their financial returns, etc.

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