SOLAR RADIATION ATLAS IN TREBINJE IN THE REPUBLIC OF SRPSKA

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Abstract

The paper presents an atlas of solar radiation for the city of Trebinje in the Republic of Srpska formed by PVGIS estimation utility. The atlas contains the results of calculating global and direct solar radiation falling on the horizontal surface and global solar radiation falling on the optimally placed surface in Trebinje in the period from 2007 to 2016. In addition, the intensity of global, direct and diffuse solar radiation falling on the optimally placed surface in Trebinje is given by months. It was found that 15.93% less solar radiation falls on the horizontal surface and 51.07% less on the vertical surface as compared to the solar radiation that falls on the optimally placed surface. The basic characteristics of fixed, one-axis and dual-axis tracking PV solar power plants power of 1 MWp and the amount of electricity that can be generated by them in Trebinje, are also given. It was found that with the one-axis rotary solar power plant 32.77% more electricity can be generated, and with the dual-axis tracking solar power plant 36.42% more electricity can be generated as compared to the fixed solar power plant.

Keywords: PVGIS program, solar irradiance, solar energy, PV solar power plants.

INTRODUCTION

Quantity of sun radiation intake on the surface of earth is influenced by numerous factors such as: geographical latitude of the given place, season of the year, part of the day, purity of the atmosphere, cloudiness, orientation and surface inclination, etc. These data are very important because of their use in calculations of the cost effectiveness of equipment using sun radiation. Very reliable data can be found in data basis PVGIS (*Photovoltaic Geographical Information System*–PVGIS © European Communities, 2001–2008, http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php).

PVGIS methodology comprises solar radiation data, PV module surface inclination and orientation and shadowing effect of the local terrain features (e.g. when the direct irradiation component is shadowed by the mountains), thus PVGIS represents immensely important PV implementation assessment tool that estimates dynamics of the correlations between solar radiation, climate, atmosphere, the earth's surface and the PV technology used. Several fast web applications enable an easy estimation of the PV electricity generation potential for selected specific locations in Europe [1-5].

This paper provides the results of calculating global, diffuse and direct solar radiation by means of PVGIS estimation utility for the city of Trebinje. Moreover, the paper contains the results of calculating the electrical energy which can be generated by the fixed, one-axis and the dual-axis tracking solar power plants in Trebinje.

THE GEOGRAPHICAL LOCATION OF TREBINJE

Trebinje is a city in the Republic of Srpska. It is the economic and cultural center of the region of Eastern Herzegovina. Trebinje is located at 42° 42' 32" north latitude and at

18° 19' 18" east longitude, and at 275 m above sea level. In 2013, Trebinje had 22987 inhabitants.

Fig. 1. The geographical location of Trebinje

Trebinje is located in the very south of Herzegovina, i.e. of the Republic of Srpska. It is located below the mountain Leotar, on the edge of the Trebinje field, in the valley of the once largest European subterranean river, Trebišnjica, which flows through the city. Trebinje is about 19 km away from the Adriatic Sea, i.e. about 27 km from Dubrovnik, or about 38 km from Herceg Novi. Trebinje is said to be a "city of sun and plane trees", and it is one of the most beautiful cities in the Republic of Srpska.

GLOBAL SOLAR RADIATION

The energy of global solar radiation falling on the horizontal surface in Trebinje is given in Figure 2.

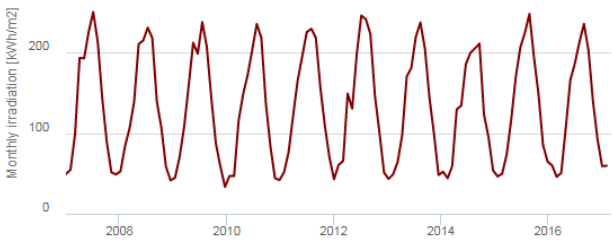

Fig. 2. *The energy of global solar radiation falling on the horizontal surface in Trebinje*

The energy of direct solar radiation falling on the horizontal surface in Trebinje is given in Figure 3.

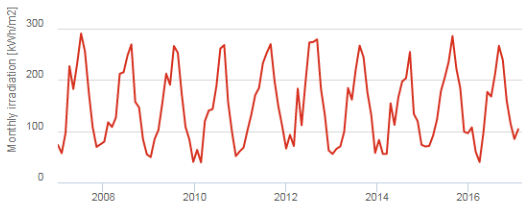

Fig. 3. *The energy of direct solar radiation falling on the horizontal surface in Trebinje*

The energy of global solar radiation falling on a surface set at an optimal angle of 35^o in Trebinje is given in Figure 4.

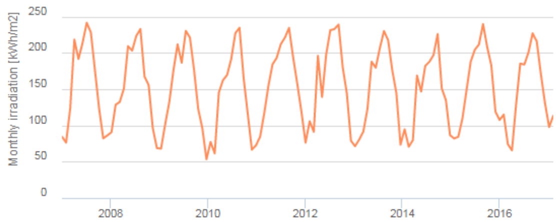

Fig. 4. *The energy of global solar radiation falling on a surface set at an optimal angle of 35^o in Trebinje*

Based on the previous figures, it can be concluded that in the period 2007-2016 there was no significant deviation of the energy of global and direct solar radiation falling on the horizontal and optimally placed surface.

GLOBAL, DIRECT AND DIFFUSE SOLAR RADIATION FALLING ON AN OPTIMALLY TILTED SURFACE

The intensity of global, direct and diffuse solar radiation that falls on the optimally placed surface by months, during the year in Trebinje is shown in Figures 5-16.

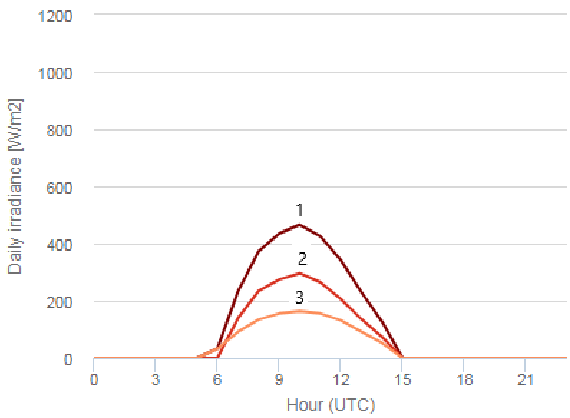

Fig. 5. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in January in Trebinje (35^o)*

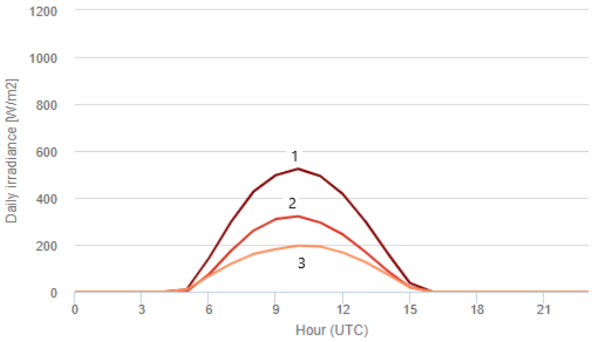

Fig. 6. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in February in Trebinje (35°)*

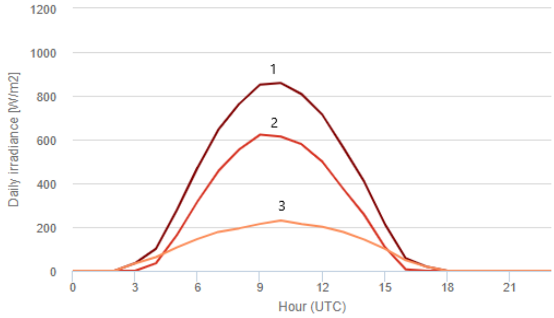

Fig. 10. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in June in Trebinje (35°)*

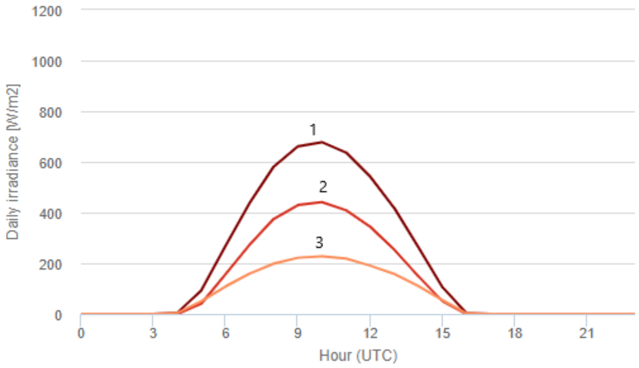

Fig. 7. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in March in Trebinje (35°)*

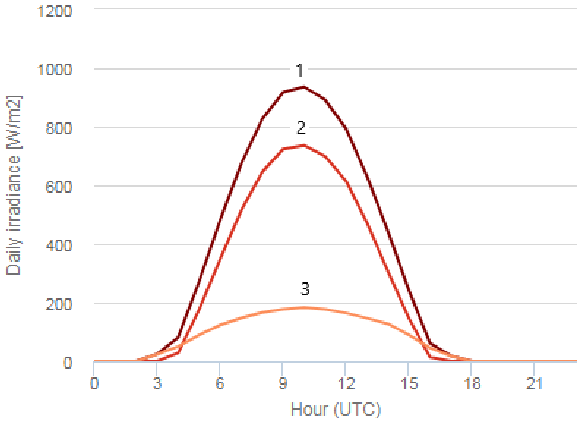

Fig. 11. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in July in Trebinje (35°)*

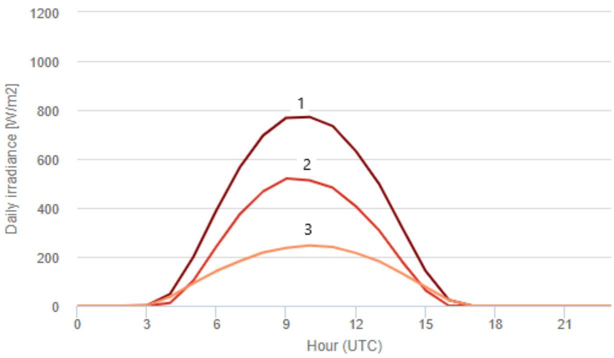

Fig. 8. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in April in Trebinje (35°)*

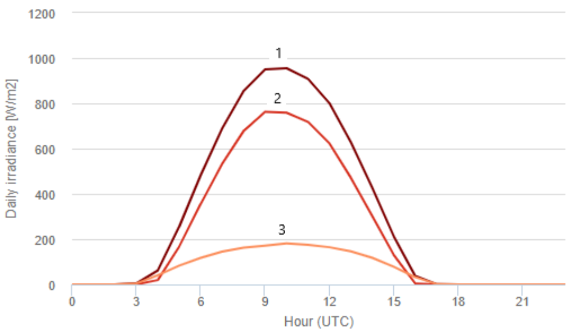

Fig. 12. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in August in Trebinje (35°)*

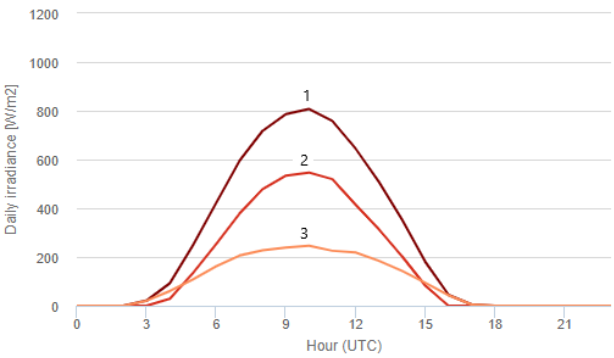

Fig. 9. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in May in Trebinje (35°)*

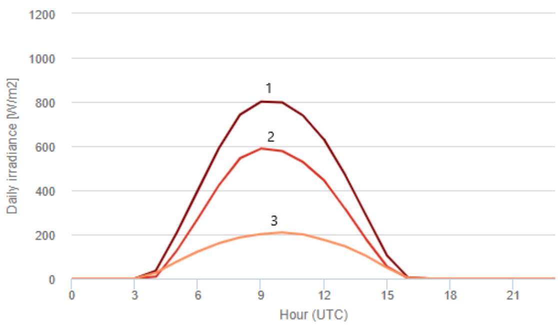

Fig. 13. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in September in Trebinje (35°)*

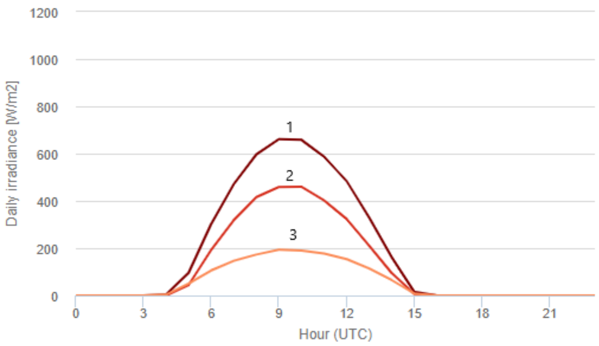

Fig. 14. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in October in Trebinje (35^o)*

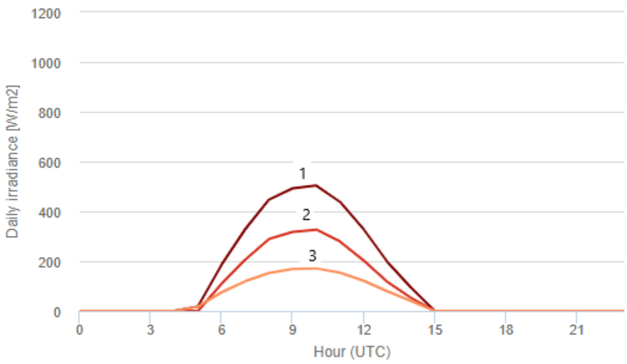

Fig. 15. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in November in Trebinje (35^o)*

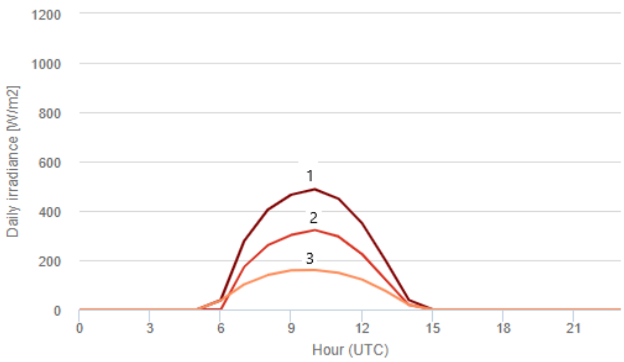

Fig. 16. *Intensity of global (1), direct (2) and diffuse (3) solar radiation in December in Trebinje (35^o)*

Figures 5-16 show the following:

- the intensity of global solar radiation increases from 480 W/m^2 in January to 970 W/m^2 in August and it decreases from August to December when it is 490 W/m^2;
- the intensity of direct solar radiation increases from 300 W/m^2 in January to 780 W/m^2 in August and it decreases from August to December when it is 320 W/m^2;
- the intensity of diffuse solar radiation increases from 180 W/m^2 in January to 190 W/m^2 in August and it decreases from August to December when it is 180 W/m^2;
- the values of the intensity of direct and diffuse solar radiation are almost the same in January, February, November and December, respectively;
- in the period from March to November, the curves of direct and diffuse radiation intensity do not coincide, whereby the intensity of direct radiation is always higher than the intensity of diffuse radiation.

The geographical position, optimal angle and the energy of the solar radiation falling on the horizontal, optimally tilted and vertically placed surface in Trebinje are given in Table 1.

Table 1. *Geographical position, optimal angle and the energy of the solar radiation falling on the horizontal, optimally tilted and vertically placed surface in Trebinje*

Optimal angle (^{o})	**Energy of solar radiation falling**		
	on the horizontal surface (Wh/m^2)	**on the optimally tilted surface (Wh/m^2)**	**on the vertically placed surface (Wh/m^2)**
35	4324,69	4983,58	3298,86

Based on the data shown in Table 1 it can be seen that the largest amount of solar radiation energy falls on the optimally placed surface, slightly less on the horizontal, and the lowest on the vertically placed surface. The horizontal surface receives 15.93%, and the vertical 51.07% less energy of solar radiation in relation to the optimally placed surface [1-9].

SOLAR POWER PLANTS

The calculation results of the amount of electricity that can be generated using the fixed, one-axis and dual-axis tracking PV solar power plants in Trebinje, using the PVGIS program are given below.

Fixed solar power plant

PVGIS characteristics of a fixed solar

power plant power of 1 MWp that would be installed in Trebinje are given in Table 2.

Table 2. PVGIS characteristics of a fixed solar power plant power of 1 MWp that would be installed in Trebinje

Location	Trebinje
Power of photovoltaic solar power plant (MWp)	1
Power plant losses (%)	14
Tilt angle (°)	35
Azimuth angle (°)	0
Annual electricity production (kWh)	1425934,39

PVGIS data for monthly electricity production by a fixed solar power plant with monocrystalline silicon solar modules total power of 1 MWp in Trebinje are shown in Fig. 17.

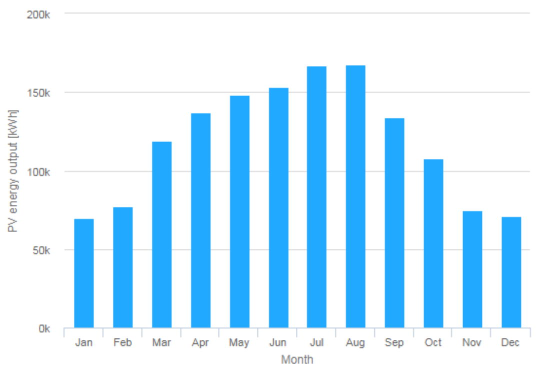

***Fig. 17.** PVGIS data for monthly electricity production by a fixed solar power plant with monocrystalline silicon solar modules total power of 1 MWp in Trebinje*

One-axis tracking PV solar power plant

PVGIS characteristics of the one-axis tracking PV solar power plant power of 1 MWp that would be installed in Trebinje are given in Table 3.

Table 3. PVGIS characteristics of the one-axis tracking PV solar power plant power of 1 MWp that would be installed in Trebinje

Location	Trebinje
Power of photovoltaic solar power plant (MWp)	1
Power plant losses (%)	14
Tilt angle (°)	38
Annual electricity production (kWh)	1893449,77

PVGIS data for monthly electricity production by the one-axis tracking PV solar power plant with monocrystalline silicon solar modules total power of 1 MWp in Trebinje are shown in Fig. 18.

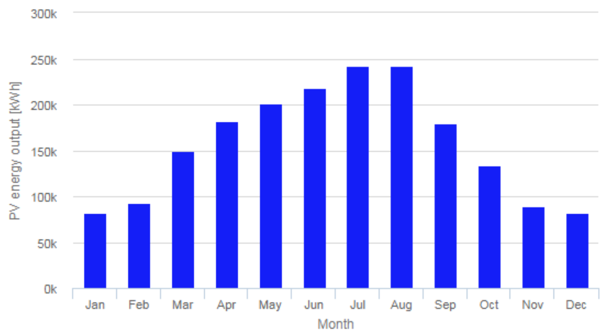

***Fig. 18.** PVGIS data for monthly electricity production by the one-axis tracking PV solar power plant with monocrystalline silicon solar modules total power of 1 MWp in Trebinje*

Dual - axis tracking PV solar power plant

PVGIS characteristics of the dual - axis tracking PV solar power plant power of 1 MWp that would be installed in Trebinje are given in Table 4.

Table 4. PVGIS characteristics of the dual - axis tracking PV solar power plant power of 1 MWp that would be installed in Trebinje

Location	Trebinje
Power of photovoltaic solar power plant (MWp)	1
Power plant losses (%)	14
Annual electricity production (kWh)	1945242,40

PVGIS data for monthly electricity production by the dual-axis tracking PV solar power plant with monocrystalline silicon solar modules total power of 1 MWp in Trebinje are shown in Fig. 19.

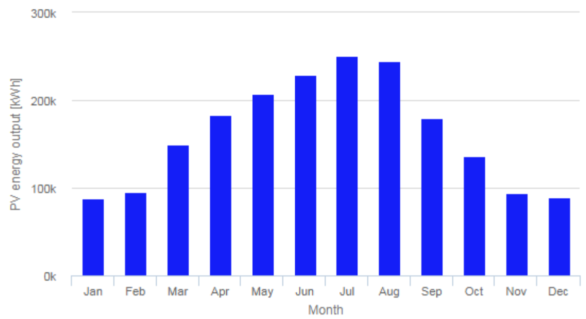

***Fig. 19.** PVGIS data for monthly electricity production by the dual-axis tracking PV solar power plant with monocrystalline silicon solar modules total power of 1 MWp in Trebinje*

Based on the data shown in Table 4, it can be seen that the one-axis tracking solar power plant generates 32.77% more electricity in relation to a fixed solar power plant. The dual-axis tracking PV solar power plant generates 36.42% more electricity as compared to a fixed solar power plant.

CONCLUSION

In the light of all said, it can be concluded that:

- in the period 2007-2016 there is no significant deviation of the energy of global and direct solar radiation respectively that falls on a horizontal and optimally placed surface;
- the intensity of global solar radiation increases from 480 W/m^2 in January to 970 W/m^2 in August and it decreases from August to December when it is 490 W/m^2;
- the intensity of direct solar radiation increases from 300 W/m^2 in January to 780 W/m^2 in August and it decreases from August to December when it is 320 W/m^2;
- the intensity of diffuse solar radiation increases from 180 W/m^2 in January to 190 W/m^2 in August and it decreases from August to December when it is 180 W/m^2;
- the values of the intensity of direct and diffuse solar radiation are almost the same in January, February, November and December, respectively;

  in the period from March to November, the curves of direct and diffuse radiation intensity do not coincide, whereby the intensity of direct radiation is always higher than the intensity of diffuse radiation.
- 15.93% less energy of solar radiation falls on the horizontally placed surface, and 51.07% less on the vertical placed surface in relation to the optimally placed surface;
- the one-axis tracking solar power plant generates 32.77% more electricity and the dual-axis tracking PV solar power plant generates 36.42% more electricity as compared to a fixed solar power plant.

Acknowledgement

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