ANALYSIS OF ELECTRIC POWER PRODUCTION IN SOUTH SERBIA
Recommendations for Improvement of Operation of First Mini Photovoltaic Power Plants

by

Mihailo P. MITKOVIĆ*[*], *Jelena P. DJEKIĆ, Milica Z. IGIĆ, Petar B. MITKOVIĆ, and Milena M. DINIĆ BRANKOVIĆ

Faculty of Civil Engineering and Architecture, Chair for Urbanism and Spatial Planning, University of Nis, Nis, Serbia

Original scientific paper
https://doi.org/10.2298/TSCI170531123M

Solar radiation in Serbia is for about a third higher than in Middle Europe, which represents a very favorable energy potential. Southeast Serbia is a leading area in this aspect, since the annual average of daily global radiation on a horizontal surface exceeds 4.2 kWh/m^2.
This paper compares four photovoltaic power plants installed in southeastern Serbia. Analyzes are done based on results from two years of power plant exploitation. The power plants are not located in the same area – there are differences between topography and altitude of their locations, which is also taken into account during analyzes. Photovoltaic modules have different orientation and inclination toward horizontal surface, and their capacity varies from 30-40 kW. The conclusion provides recommendations for improvement of production where it is actually possible.

Key words: *solar radiation, photovoltaic modules, renewable energy sources, south Serbia photovoltaic power plants*

Introduction

Nowadays, use of renewable energy sources (RES) for heating, cooling and electricity increases rapidly worldwide. Application of modern technologies in construction and design of different systems provides a high security production and economic profitability of investments. In order to promote electricity produced from RES on the electricity market, the European Parliament adopted Directive 2001/77/EC in 2001. The goal of the Directive was to promote use of RES in order to satisfy 12% of total energy consumption and this Directive predicted that by 2010 the share of RES in the total consumption of the EU should reach 22.1% [1]. The Directive defined referential values for each country which must be reached in order to satisfy the predicted goals. Because of a very slow progress regarding goals from this Directive, in 2009 a new Directive was adopted. Unlike the previous Directive, the goal of the new Directive was that by 2020, 20% of energy consumption in the EU must be met from the

[*] Corresponding author, e-mail: mihailo.mitkovic@yahoo.com

RES. This goal was laid out through obligatory national sub-goals, which took into account different starting points of the member states [2]. Regarding solar energy, the White book of the EU from 1997, set a goal that by 2010 the total capacity of installed photovoltaic (PV) systems should reach 3 GW [3]. The predicted PV solar system capacity was reached earlier than planned and already by the end of 2008, the total capacity was 9.5 GW [4, 5]. More than half of European PV power plants were installed in Germany, approximately 5.3 GW and about 1/3 in Spain. Since 2005, solar PV electricity generation capacity has increased from 1.9 GW in 2005 to 80.7 GW by the end of 2013, and the 2020 National Renewable Energy Action Plan (NREAP) target of 84.4 GW was exceeded, fig. 1, by the end of 2014, reaching about 88.4 GW [6]. Energy Law of the Republic of Serbia set the legal framework and the ability to use incentives in the production of electricity from renewable sources.

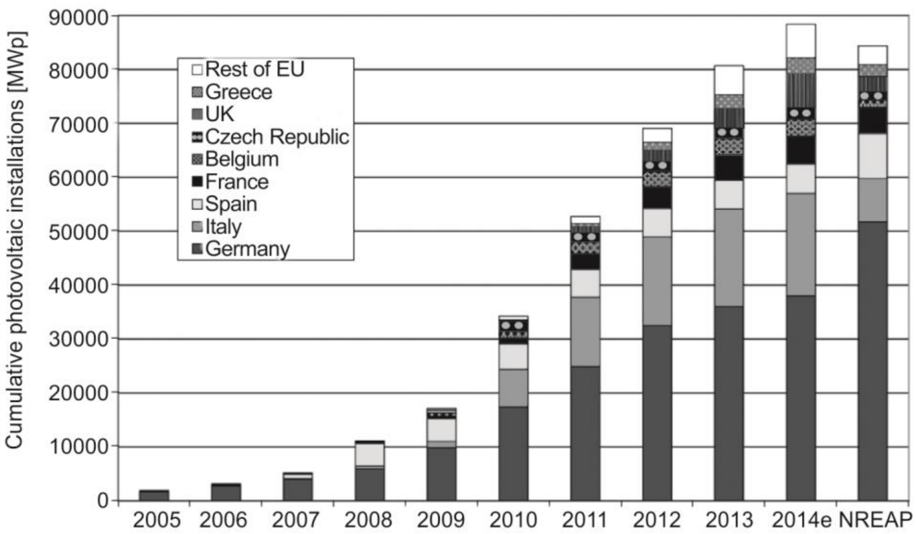

Figure 1. Cumulative installed grid connected PV capacity in EU + candidate countries compared with the NREAP target for 2020 [6] (*for color image see journal web site*)

The Republic of Serbia, thanks to its geographical location and topography, has a huge potential for use of RES. Unfortunately, at the moment hydro potential is the most exploited, while biomass, solar, geothermal, and wind energy are underused. In order to promote energy which is generated from RES, National Renewable Energy Action Plan was adopted in 2013 and as main goal is that share of energy from RES in total energy consumption amount is about 27% by the 2020. The plan predicts that by the end of 2015 the total installed capacity of PV power plants is 5 MW, and by the end of 2020 total capacity of 10 MW. Energy Development Strategy of the Republic of Serbia was done for the period until 2025 with projections until 2030 and projected capacity of PV power plants until 2025 is 100 MW, respectively, 200 MW until 2030 [7].

PV solar power plants that are integrated within the buildings are an important segment in the process of planning of zero energy cities and one of the almost unavoidable elements in design of energy efficient buildings. In combination with the utilization of other RES – solar, wind, geothermal water, it is possible to meet all the requirements in terms of HVAC (heating, ventilation, air conditioning) and technical characteristics and to obtain zero energy buildings. By combining all the possibilities of use of RES, as well as three generation approach with the help of co stimulus (CS), it is possible to meet energy efficiency standards zero. The advantage of use of the PV modules is that there is a wide range of materials that can be used and the development of technology can integrate the panels into the design of existing buildings or completely redesign the old façade, in order to meet aesthetic requirements. [8]

Use of solar energy in Serbia

Serbia has a great potential for usage of solar energy all year round and this potential is high above European average. Figure 2 shows the values of the annual sum of global radiation energy in Germany and Serbia where it can be seen that average value of global radiation for the German territory is around 1.000 kWh/m^2, while the average value of global solar radiation energy in Serbia ranges between 1.200 kWh/m^2 a year in the north-west and 1.550 kWh/m^2 in the southeast, while in the central area it is around 1.400 kWh/m^2 a year. The highest value of annual sum of global solar radiation in Germany (1.130-1.240 kWh/m^2), coincides with the lowest vale in the north of Serbia (<1.240 kWh/m^2). The average solar energy of global radiation on the flat surface during the winter season ranges between 1.1 kWh/m^2 in the north of the country and 1.7 kWh/m^2 in the south, and during the summer season between 5.4 kWh/m^{2}in the north and 6.9 kWh/m^2 in the south. [5, 9].

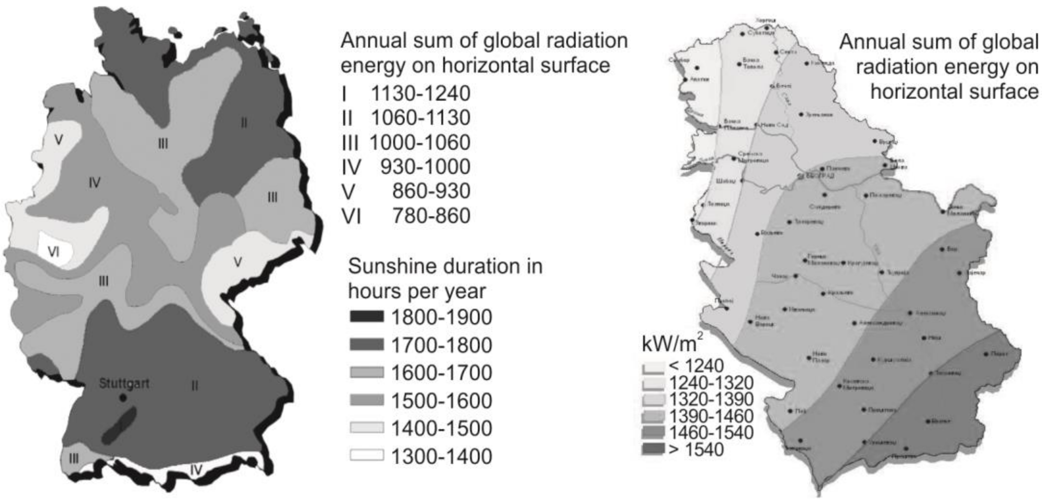

Figure 2. Values of annual sum of global radiation energy in Germany (left) and Serbia (right) [10]
(*for color image see journal web site*)

In the White book of the Serbian electric power company [11] the regulations of the EU related to the RES, as well as the legal framework and potential for use of RES in Serbia can be found. The decree on incentives for production of electric and heating energy (*Official Gazette of RS*, no. 99/2009) the price of 23 c€/kWh was determined for buying off of electric energy produced in PV power plants of up to 5 MW. In 2013, a new directive on incentives for privileged electric energy producers (*Official Gazette of RS*, no. 8/2013) was issued, which reduces the incentives, from 16.25 c€/kWh for ground power plants, to 20.66 c€/kWh for the power plants on structures, with installed power up to 0.03MW. For the power plants on structures with installed power (P) from 0.03-0.5 MW the price is calculated per formula 20.941-9.383·P. In the Republic of Serbia several small electric power plants connected to the electric grid were installed: on the buildings of schools and faculties: primary school Dušan Jerković in Ruma (3 kW, 2004), secondary school in Varvarin (5 kW, 2010), Electric engineering school Rade Končar in Belgrade (5 kW, 2010), secondary technical school Mihajlo Pupin in Kula (5 kW, 2010), The Faculty of Technical Sciences in Novi Sad (8 kW, 2011), Faculty of Electronic Engineering (1.2 kW, 2011), and Faculty of Sciences and Mathematics in Nis (2 kW, 2012); on privately owned companies in Leskovac (30 kW, 2012) and Cacak (55 kW, 2012); and private houses in Merošina, Zajecar, *etc*., which indicates that in Serbia, PV power plants are increasingly used for commercial purposes [12].

Electricity generated by PV modules can be stored and distributed, but it is also possible to use it for different systems within buildings. Heat pumps which are used for air conditioning, water heating systems and waste water treatment, can use electricity that was generated with the help of PV modules on the roof of the building and in this way an energy-efficient and cost-effective PV system is obtained where it is possible to recover the investment approximately per only one year [13]. Installing a PV system of PV modules is also possible on the roofs of individual houses in order to reduce the consumption of electricity for air conditioning and water heating. According to a conducted study [14] it was found that installing a PV system on the roof of the house, with the appropriate inclination of the roof slope and roof orientation, it is possible to reduce the cost of electricity for more than 51% and thus a decentralized model of generating electricity can be achieved.

Price for construction of PV solar power varies depending on the type of a plant, size, type of modules and equipment that is installed, *etc*. However, the price of PV modules (49%) has the greatest influence on the final value of the investment and depending on the material these prices vary. Within the total price, the value of building and construction works is about 29%, price of the inverter about 8% and the price of cables, switches and other electronic equipment around 7%. The remaining costs concern the documentation for the plant, the impact assessment study, connecting the local systems of electricity, taxes and utilities. On the other hand, costs for PV power plants maintenance are minimal [15].

In 2004, Study of energy potential of Serbia for the use of solar radiation and wind energy was conducted by the Institute for Interdisciplinary Research in Serbia. It is a complex multi-year study based on measurements and data on local climate conditions and based on the database for Typical Meteorological years (TMY) whose data is contained within the European atlas of solar radiation (*The European Solar Radiation Atlas*). According to the study of solar and wind energy potential of Serbia [10] the highest amounts of energy on the northern hemisphere are available in the period between April and September, and the energy influx on a certain surface depends on its inclination and orientation in respect to the sun rays. Calculation of the differently oriented inclined surfaces is performed starting from the basic formula – primarily through calculation of the irradiance (radiation intensity) for direct radiation. Research of the Institute for Interdisciplinary Research gives the following results.

– The highest annual energy gains are realized if the surface is oriented towards south and has a 30° angle, which is optimum of the periods March-April and August-September.
– The highest monthly energy gains are in May, June and July, if the surface is oriented towards south and has an inclination of 10°.
– The highest monthly gains in the winter period from October to February are realized if the surface is oriented towards south and has an inclination of 60°.

This paper presents the characteristics of four mini PV power plants in south-east Serbia and the results of the electric power output measured during two years. In three power plants, the panels are installed at the angle of around 30°, and on one of them the roof pitch of around 10° was used.

Main location features

The paper treats PV power plants in Leskovac and Bosilegrad, in south-east Serbia, which has the most favorable conditions for solar energy harvesting. The city of Leskovac is located at 42°52' N and 21°57' E, in the center of 50 km long and 45 km wide Leskovac valley, which is framed by the mountains: Babicka gora (1,095 m), Selicevica (903 m), and Krusevica (913 m). Mountains Radan (1,409 m) and Pasjaca form the western edge of Leskovac valley, and there are Cemernik (1,638 m) and Kukavica in the south. In topographical terms, the city of Leskovac is characterized by the flatland gradually declining towards north-east. The elevation above sea level of the valley varies between 210 and 240 m, and the city lies at around 230 meters above sea level (m. a. s. l.). The climate of Leskovac is moderate-continental, characterized by moderately warm summers and moderately cold winters, with two transitional periods, spring and autumn. According to data from the Hydrometeorological Institute, tab. 1, for the period of the last ten years (2004-2013) the annual sunshine for the Leskovac area is 2,084 h, whereby the maximum sunshine in July is around 313 h, and the least sunshine in December is around 54 h. The average humidity, on annual basis is around 71%. The highest average cloudiness is in December, January, and February (75%, 68%, and 71%), while the lowest cloudiness is in July, August and September (33%, 30% and 46%). Mean annual air temperature is 11.7 ° C. The coldest month is January with an average temperature of 0.5 ° C and the warmest is July with an average daily temperature of 22.5 °C. West and north winds are the dominant winds in the city area. The area of Leskovac is located in the zone with the average daily solar radiation energy with the annual average 4.0-4.2 kWh/m^2, while in the Bosilegrad territory the daily solar radiation energy is >4.2 at the annual level.

Table 1. Average values of meteorological data for the area of Leskovac, for 2004-2013 period, obtained on the basis of Meteorological almanacs 2005-2014, Republic Hydrometeorological Service of Serbia

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Leskovac												
AAT [°C]	0.9	2.0	7.0	12.27	16.7	20.5	22.5	22.3	17.2	11.3	6.7	2.2
P [mm]	47.3	49.4	54.7	63.2	79.6	64.2	48.4	45.5	41.3	63.8	56.1	68.5
SD [h]	76.1	72.5	144.5	182.8	232.1	268.2	311.9	305.8	195.3	144.4	96.6	54.3
AH [%]	80	76	69	68	70	66	62	62	69	76	79	82
AO [%]	66	70	61	57	55	46	34	29	48	51	58	73
Bosilegrad												
AAT [°C]	–0.1	1.2	5.2	10.1	14.4	17.8	19.9	20.0	15.4	10.4	5.3	0.8
P [mm]	44.8	49.6	57.6	56.2	95.4	70.3	44.1	59.0	58.6	60.8	104.0	58.3
SD [h]	–	–	–	–	–	–	–	–	–	–	–	–
AH [%]	81	79	74	71	73	74	70	70	74	77	80	82
AO [%]	62	67	59	57	56	47	34	31	49	52	57	64

AAT –average air temperature, P – precipitation, SD – sunshine duration, AH – average humidity, AO – average overcast

Bosilegrad is located at 42°30' N and 22°30' E. The municipality is characterized by hills and mountains with the elevation above sea level between 660 and 1,922 meters. Table 1 features a comparative presentation of data for Leskovac and Bosilegrad in the period 2005-2014. Bosilegrad is located at 696 m.a.s.l, and Leskovac at 230 m.a.s.l., which affects the climate, and temperature in Bosilegrad is always for 1-3 °C lower than the temperature in Leskovac. The mean annual air temperature for Leskovac is 11.7 °C and 10 °C for Bosilegrad. January is the coldest month with an average temperature of 0.9 °C for Leskovac and –0.1 for Bosilegrad, and the warmest is July with an average daily temperature of 22.5 °C, *i. e.* 19.9 °C. There are no measurements of sunshine duration for Bosilegrad area, but sunshine increases towards south, and for the southernmost parts of Serbia is around 2300 hours per year.

Table 2 shows the results of calculation of total solar energy radiation falling on 1 m^2 of PV modules positioned at the optimum angle to the horizontal plane at a fixed PV power plant during the year. The calculation, which included 23 cities in Serbia, is done using PVGIS program. Results for Leskovac (1530 kWh/year) and Vranje (1500 kWh/year), nearest to Bosilegrad, are much better than results for areas of northern Serbia (for example Subotica with 1430 kWh/year) which confirms that southern Serbia is suitable area for construction of PV power plants.

Table 2. The energy of total solar radiation falling on 1 m^2 of PV modules positioned at the optimum angle to the horizontal plane at a fixed PV powerplant during the year [16]

Cities (Serbia)	Energy of solar radiation (kWh/year)	Cities (Serbia)	Energy of solar radiation (kWh/year)	Cities (Serbia)	Energy of solar radiation (kWh/year)
Subotica	1430	Uzice	1540	Kragujevac	1540
Sombor	1390	Zajecar	1490	Pirot	1460
Novi Sad	1470	Cacak	1490	Leskovac	1530
Vrsac	1520	Krusevac	1550	K. Mitrovica	1620
Belgrade	1510	Nova Varos	1540	Vranje	1500
Negotin	1460	Nis	1510	Djakovica	1670
Pozarevac	1510	Kursumlija	1570	Prizren	1650
Valjevo	1520	Novi Pazar	1630		

For the territory of Serbia, the optimum angle of the panels is in the range 32-35° while the average value of solar radiation for optimal inclination ranges from 3.810 Wh/m^2 to 4.580 Wh/m^2. The values of solar radiation on the horizontal plane are in the range of 3.370 Wh/m^2 to 4.000 Wh/m^2, while for a vertical surface from 2.530 Wh/m^2 to 3.010 Wh/m^2. Annual average ratio of diffuse to global irradiation is in the range 0.43 to 0.51. According to these data and PVGIS software calculations, the average value of the annual radiation per m^2 optimal inclined panel at fixed solar PV systems of 1 MW power is in the range from 1.390 Wh/m^2 to 1.670 Wh/m^2. For different cities, depending on location and type of PV module, as well as different types of systems, there are different values of global radiation [16]. The increase of the solar radiation induces increase of the ambient and PV modules temperature which leds to PV plant efficiency decreases. Local climate conditions significantly affect the amount of generated electrical energy and before any energy planning it is very important to have measured energy output of PV system at the site and all the location characteristics must be taken into account [17].

Model for data interpretation

A building integrated photovoltaic (BIPV) system consists of PV modules which are integrated into the building envelope, such as the roof or the façade. This technology provides architects with completely new possibilities to incorporate solar technology into the buildings. During designing process, it is important to consider orientation of the facade or the roof where the PV modules will be installed in order to have the most favorable inclination. The most of electrical energy was generated by a PV module oriented toward the south at the angle of 32° [18]. The analyzed PV power plants, two of which are located in Leskovac (E1-Domit and E2-Fortuna), and two in Bosilegrad (E3-Anitex and E4-Kodal), are shown in fig. 3. Table 3 provides the comparative display of characteristics of four PV power plants, and the data for the designed model of a PV power plant for the area of Leskovac. All the power plants were built as a fixed system on a structure. The calculation of potential production was performed using PVGIS software, and the optimum inclination and panel orientation for the given area were used (inclination 32°, orientation –2°). The designed model was displayed with the goal to determine in what way the deviation from the proposed inclination and orientation affects the electric energy production.

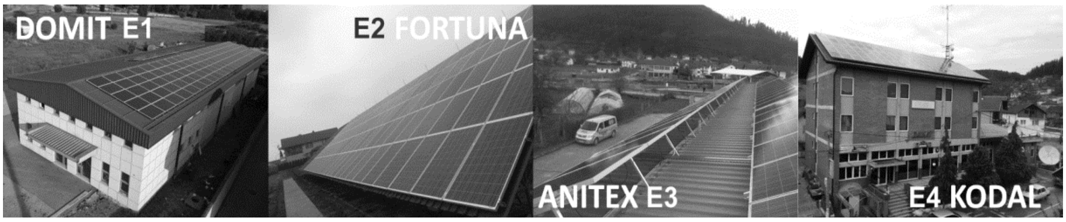

Figure 3. Photos of analyzed PV power plants

Table 3. The PV power plants characteristics and data for the designed models

	E1	E2	E3	E4
Location	Leskovac		Bosilegrad	
Power plant type	Fixed system on a building			
Panel type	Moocrystal	Polycrystal	Polycrystal	Polycrystal
Panel inclination [°]	10	30	30	30
Orientation	SW	S	S	S
Installed capacity [kW]	30	30	40.32	23
Annual unshine	2.084 hours		2.300 hours	
July sunshine [hours]	313 hours		-	
December sunshine [hours]	54 hours		-	
Solar radiation January	1.5-1.6 kWh/m^2		-	
Solar radiation July	6.4-6.5 kWh/m^2		>6.5 kWh/m^2	
Solar radiation annual	4.0-4.2 kWh/m^2		>4.2 kWh/m^2	

The calculation of potential production was done using the PVGIS, online software for the energy production calculation of solar PV systems. PVGIS has its own database which consists of monthly average values of diffuse and global radiation on a horizontal plane from about 8,000 stations around the world. As for the calculations for the territory of Europe, PVGIS collects data from 566 stations on Earth and has a database for the period of the last 10 years [19]. PVGIS offers the option PVGIS Climate-SAF database that refers to the database for the last 12 years, which is obtained on the basis of recording Meteosat satellites. The database consists of measuring the period 1998-2005 and June 2006-December 2011. The most important information for the calculation is value of solar radiation that the program automatically calculates based on data of power plant location – latitude and longitude, which are defined using google maps applications within the program. MSG satellites send average values of solar radiation on a horizontal surface every hour so that the satellite sends to the base one picture every hour. Although PVGIS database uses average values for a period of ten years, compared with monthly measurements of temperature and radiation, there is a minimum deviation, which has proven that PVGIS application is highly reliable which allows calculation of values that are relevant for further financial and technical calculations [20].

Results and discussion

On the fig. 4, the results of two years of measurements of energy production are presented. Measurements were taken by reading the electricity meters by the Serbian electric power company for 2014 and 2015 and results are shown in kWh. According to data obtained by measuring in 2014 and 2015, it is obvious that highest amount of energy generation is during summer months June-August and lowest in December and January. Amounts of energy generation in 2015 vary from 689 kWh in January to 5.721 kWh in July for E1; from 1.517 kWh in January to 5.390 kWh in July for E2; from 1.770 kWh in January to 6.805 kWh in July for E3; and from 1.019 kWh in January to 3.984 kWh in July for E1.

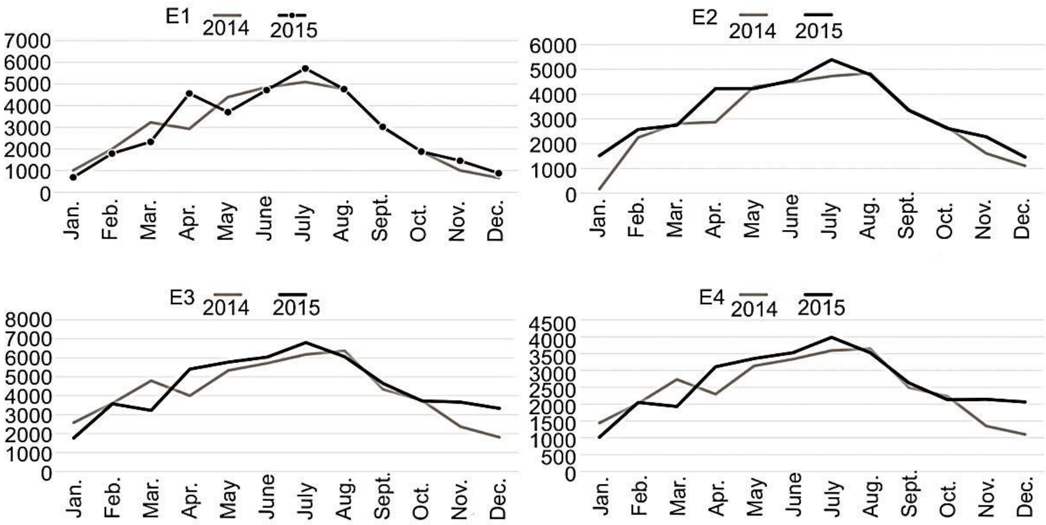

Figure 4. Results of two years of measurements of energy production in kWh for all power plants

In order to compare the results more precisely, annual electricity production per kW of installed capacity by months for all four power plants is shown in fig. 5. Even all four power plants have different characteristics, it is clearly visible that both power plants in Bosilegrad have almost the same production per unit of installed power. On the other hand, the power plants in Leskovac have mutual deviations in production. E1 power plant located in Leskovac has highest values during summer months – over 30 kWh more than E3 and 20 kWh more than E2 in July and three times less in December than E4, and 2.8 times less than E3. E2 power plant production is always between values for E3 and E4 even difference in their altitude is for almost 500 m vertically. On diagram is clearly visible that in period May to September in all four power plants production is almost the same – differences are less than 10 kWh. Completely different situation is during winter months where E3 and E4, which are on higher altitude, have 3 times greater production. In tab. 4, annual electricity production per kW of installed capacity for 2014 and 2015 are shown. Values of annual production are highest for E4 in both 2014 and 2015, while the lowest are for E1. In 2014 there were less sunny days so production in that year is proportionally lower. According to these results it is obvious that power plants on higher altitudes generate more electricity than those on lower altitudes. Location has great impact on electricity production and areas on lower elevation above sea level because of the river basin have more fog in the morning hours, and more smog and dust due to higher pollution in general which affects energy generation.

In order to compare and analyze power plants features, model in stimulation program PVGIS was made and optimal inclination of 32° and 2° for orientation were used, as well as models based on data from existing PV power plants. Comparison was made with power plants E1 and E2 in Leskovac where E1 has inclination of 10° and E2 30°. These two plants are on the same altitude and installed panels on E1 are monocrystal while on E2 they are polycrystal. PVGIS software has only three options for panel material and crystalline silicon material was selected for the analyses for one model and option "other" material was selected for other two models. Results of comparison between two years measured values of energy generation in E1 and E2 and values from three PVGIS models are shown in figure 6.

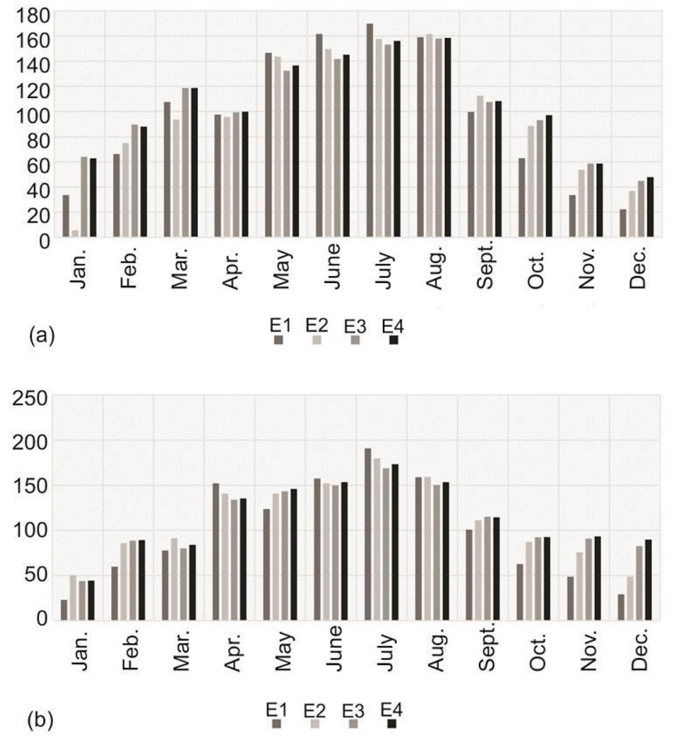

Figure 5. Annual electricity production per kilowatt of installed capacity by months; (a) for 2014 and (b) for 2015

Table 4. Annual electricity production per kW of installed capacity in kWh

	E1	E2	E3	E4
2014	1160,5	1224,2	1261,1	1277,3
2015	1184,1	1323,7	1339,8	1368,3

If we compare the values from measurements and PVGIS models, we can see that there is a difference in amount of electricity produced in power plants E1 and E2. E1 has higher values than E2 and all three PVGIS models during summer period June-August, while E2 and PVGIS optimal and PVGIS E2 model have greater values in winter months. E1 has greater values during summer months because lower inclination is most favorable for summer months and inclination of panels in E2 is more favorable during winter months. Values of E2 and PVGIS optimal model are almost the same in few winter months. Power plant E2 has a more favorable southerly orientation, while power plant E1 has a *less favorable* south-west orientation. If we observe annual values for E2 energy production, it is obvious that E2 production has less rises and falls in production and production in July is four times greater than

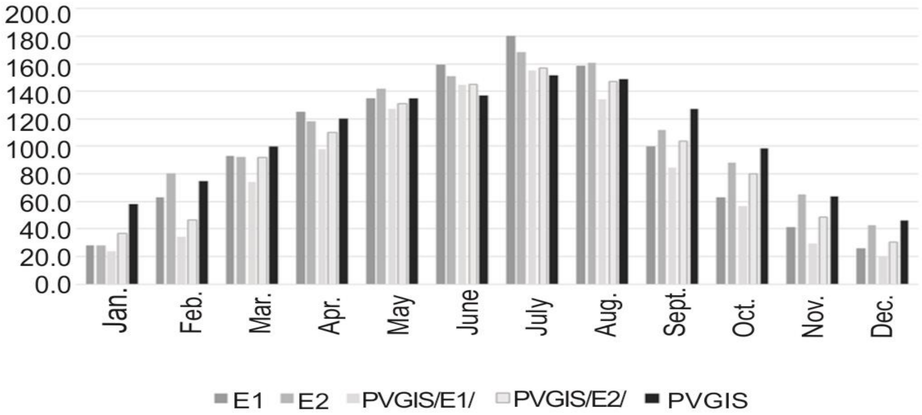

Figure 6. Results of energy production measurements on terrain compared with PVGIS models

in January while in case of E1 it is eight times greater. The same relation also holds for the models from PVGIS for E1 and E2. If we compare these values on the annual level, E1 has total production of 1.172,3 kWh per kW of installed capacity, PVGIS model for E1 has 983 kWh on the annual level, E2 has 1.273.6 kWh, PVGIS model for E2 has 1.129 kWh and PVGIS optimal model 1.260 kWh. It is obvious that E2 has the highest value of production – almost 10% higher values than E1, where polycrystalline panels are installed which makes a great difference because monocrystalline panels generate more energy. As far as E1 and E2 models from PVGIS, relation is similar but annual values are lower than the values measured on the power plants. One of the reasons is that application does not have an option for material which is really used and also PVGIS application makes simulations based on meteorological data from its own meteorological base while values that were used were measured on the site.

According to these results, it can be concluded that PVGIS simulations are reliable and that based on results comparison and analyses for different power plants can be done. Location conditions and panel position – orientation and materials used, have the greatest impact on the amount of energy production. If panels must follow inclination and orientation of the roof or façade then the choice of panel type and performance is very important for installing panels that have better energy conversion performance. This is the case with E1 power plant where Domit panels were used with inclination of 10° as the roof slope is, orientation of these panels is southwest but they are monocrystalline. When planning a power plant, in order to have higher values of energy production and to achieve better financial income, location conditions must be considered and panels should be installed according to architectonic and spatial conditions. Economic viability for PV power plants in Leskovac can be also calculated. E1 was built in 2012 and as first PV power plant in Serbia with capacity of 30 kW and the investor signed a contract with the government according to which the tariff for 12 years was 20.66 ¢ per kW. Predicted year income would be over 7,000 € and total investment was around 45,000 €, which shows that investments will be returned after approximately 6-7 years.

Conclusions

Installing a solar PV system has high level of return on investment and it is one of the most effective systems for use of natural resources that are certainly paid off over the years. Setting plants is possible almost everywhere and level of electricity generation depends on climatic conditions and insolation. Unlike some other systems, with PV power modules setting up properly and the possibility of integrating with the facility, can reduce the need for additional investments and reduce losses. Investment for transfer of electric power of PV power plants can be reduced by selective usage of reactive power. On the other hand, if the plant is not installed in an adequate manner and generated energy is not stored according to regulations, *wasting* of energy and large losses can appear and financial and economic justification for the plant can be reduced. The government needs to stimulate and control manufacturers so that the whole system can function according to the previously agreed plans. The state should encourage small producers to connect with each other to create common PV systems that would have a higher capacity and to create a national network of solar capacity. Unlike some foreign countries, in Serbia there is no classification of plants according to location i.e. financial measures are the same for all power plants are determined by legal regulations.

Within this paper four PV power plants were analyzed, all of them are located in southeast Serbia – two in Leskovac and two in Bosilegrad. Leskovac and Bosilegrad are located at a distance of 114 km and a height difference between the two sites is 468 m. The slope of the panel at the power plants E 2, E3, and E 4 is 30° while at power plant E1 with an inclination of 10 °. The results of production of electric energy were analyzed from the town planning and architectonic aspects (inclination and orientation of roof planes and PV modules) and from the spatial aspects comprising geographic characteristics of the location and environment, *i. e*. elevation above sea level of the power plants. Panels with less inclination have less energy production and unequal production amount during year. When choosing the location for construction of power plants, in terms of space and planning, hilly and mountainous regions with better solar exposition should be chosen, since they have better ventilation and less fog.

After few years of exploitation of analyzed PV power plants, there are many guidelines that can be highlighted: increase of the number of PV modules can increase energy production; replacement of existing panels with panels of new generation that have better performance; providing better ventilation or cooling of panels with different systems, particularly systems for heating and use of hot water; development of system that has automatic adjustment of panel inclination towards sun depending on the weather conditions; constant maintenance of panel deposits; using modern technologies and software for monitoring production process for improvement of production and on time detection of malfunctions.

Analyzes showed that for approximately six years, if power plant is working constantly without downtime, initial investments can be returned and this period is just half of contract period.

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Paper submitted: May 31, 2017
Paper revised: November 19, 2017
Paper accepted: December 20, 2017