THE ANALYSIS OF THE PHOTOVOLTAIC SYSTEM INVESTMENT PROFITABILITY IN THE AP VOJVODINA

Nemanja Milekić [1]
Stanko Corić [2]
Zoran Perović [3]
Dragoslav Šumarac [4]

UDK: 621.311.243(497.113)
DOI: 10.14415/konferencijaGFS2021.12

Summary: *Green energy has become an essential piece of any sustainable development analysis. Furthermore, renewable energy must be recognized as an area with the greatest potential for reducing the overall pollution in the Republic of Serbia. The goal of this paper is to show the benefits of the investment in solar energy use and to determine the economic justification of the photovoltaic system implementation on the roof of houses in the AP of Vojvodina.*

Keywords: *Energy efficiency, active solar systems, photovoltaic systems, sustainability, pollution*

1. INTRODUCTION

Modern society has late developed an awareness of the severity of the consequences that come with the destruction of nature and its resources. Excessive use of fossil fuels, in addition to the energy crisis of the 1970s, has threatened the survival of many animal species whose ecosystem has been disrupted by global warming. Throughout history, people have repeatedly shown their selfishness and negligence for other species, so the concern for global warming began only when we endangered our future.
Motivated by the desire to reduce pollution and preserve fossil fuel stocks, the idea to reduce energy consumption was developed, which has further grown with the development of technology. Menkind started looking for ways to maintain the quality of life, and on the other hand to do so with minimal energy consumption. From this aspiration, energy efficiency as we know it today has been developed.

[1] MSc Civil Engineering, University of Belgrade, Faculty of Civil Engineering, Bulevar kralja Aleksandra 73, Belgrade, Serbia, tel: +381 11 3218 586, e – mail: nmilekic@grf.bg.ac.rs
[2] PhD assistant prof., University of Belgrade, Faculty of Civil Engineering, Bulevar kralja Aleksandra 73, Belgrade, Serbia, tel: +381 11 3218 586, e – mail: cstanko@grf.bg.ac.rs
[3] PhD assistant prof., University of Belgrade, Faculty of Civil Engineering, Bulevar kralja Aleksandra 73, Belgrade, Serbia, tel: +381 11 3218 544, e – mail: zperovic@grf.bg.ac.rs
[4] PhD full prof., University of Belgrade, Faculty of Civil Engineering, Bulevar kralja Aleksandra 73, Belgrade, Serbia, tel: +381 11 3218 544, e – mail: sumi@grf.bg.ac.rs

In addition to more efficient use of energy, it was also important to find ways to use inexhaustible energy sources whose use will not endanger nature and its resources.
These reasons increased human focus on renewable energy sources. The use of such sources protects the planet and leaves it for future generations as it saves natural resources and minimizes the harmful impact on nature. When we talk about renewable energy sources we primarily mean solar, wind, hydro energy, but also sea-wave energy, biofuel, and geothermal energy.
The beginning of the 21st century was marked by the strong expansion of new technologies for the use of solar energy. The two techniques that are at the forefront of the solar systems technology prevalence and application are vacuum-thermal systems and photovoltaic-electrical systems.
Serbia has many more hours of sunshine per year than most European countries thanks to its geographical position. Through the monitoring of the annual statistics, we can notice a growing trend in the number of sunny days even during the winter. Current estimates are that solar energy represents about 15% of the potential of renewable energy sources in Serbia. [1] For this reason, we can state that there is a potential for the use of solar energy in our area. However, due to the low price of electricity, there is no motivation to invest in solar systems whose initial costs are still high. For that reason, we are far behind the countries of the European Union in terms of the use of solar energy.
In this paper, the analysis of the implementation of the photovoltaic system on the roof of the existing building shows the benefits of such solution from the energy efficiency and environmental protection point of view.

2. SOLAR ENERGY POTENTIAL IN THE AP VOJVODINA

Serbia has an average of about 272 sunny days and about 2300 sunny hours, which is more than the European average. The average value of solar energy on the territory of the Republic of Serbia ranges from 1.1 kWh/m^2 /day in the north to 1.7 kWh/ m^2/day in the south - during January, and from 5.9 to 6.6 kWh/m^2/day - during July. The average value of total global radiation for the territory of the Republic of Serbia ranges from 1200 kWh/m^2 per year in northwestern Serbia to 1550 kWh/m^2 per year in southeastern Serbia, while for the middle part it is about 1400 kWh/m^2 per year. The energy that the Sun radiates during the year to 1 m^2 of the roof of an average house in Serbia is equal to the energy obtained by burning 130 liters of oil - and it is completely free. [1]
The number of sunny hours in the AP Vojvodina ranges from slightly less than 2,000 hours (western part) to 2,100 hours (eastern part). Annual global radiation for the horizontal surface ranges between 1,294 kWh/m^2 in the northern part and 1,335kWh/m^2 in the south, and 1,281 kWh/m^2 in the west to 1,294 kWh/m^2 in the east of the AP Vojvodina. The annual sum of global solar radiation on the horizontal plane at the AP Vojvodina is shown in Figure 1. [2]

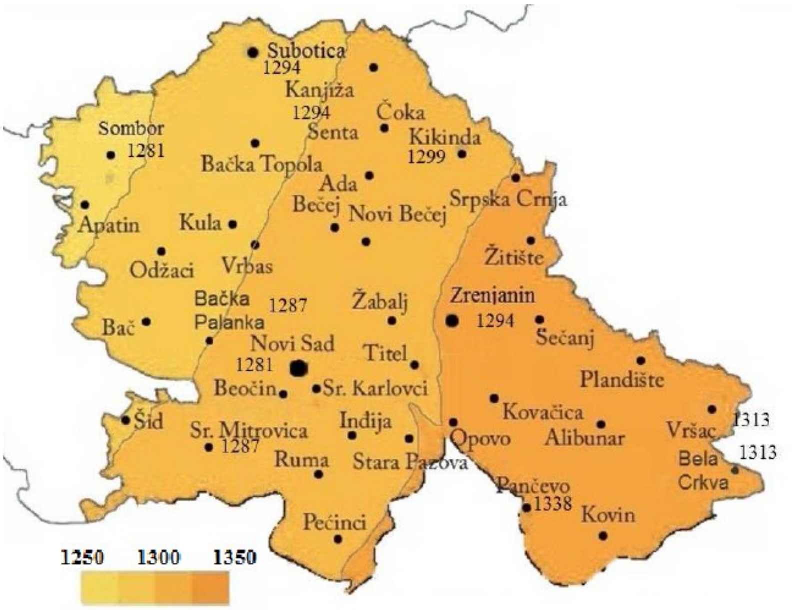

Figure 1. Total global solar radiation on the horizontal plane per year [kWh] [2]

If all the above is taken into account, it is concluded that there is a certain potential for the use of solar energy in AP Vojvodina, but the question of cost-effectiveness arises given the low price of electricity in relation to the initial costs of solar technology. Consequently, the use of solar energy lags far behind the countries of the European Union, although the average solar radiation is about 30% higher than the European average. The task of this paper is to find out whether at this moment there is an economic justification for the introduction of the use of active solar systems or it is just a more environmentally friendly solution.

3. ENERGY EFFICIENCY PARAMETERS OF THE EXISTING HOUSE IN THE AP VOJVODINA

The building used as a reference in the analysis is a ground floor residential building located in Krčedin, with an area of about 80 m^2 and was built between 1880 and 1900. Reconstruction of the building was done in 2007. when the building was expanded. It is a traditional Vojvodina house, whose walls are made of compacted earth d = 40 cm and d = 50 cm, plastered on the inside and outside with a layer of cement mortar 3.5 cm thick. The new walls which were made during the expansion of the building were made of blocks 20 cm thick, and a layer of thermal insulation in the form of 5 cm thick mineral wool was placed on the inside. The roof construction is a classic two-pitched wooden construction with a roof cover in tile. Windows and doors are made of wood, glazed with double glass 6-12-6 mm. The heating system consists of a gas boiler with an installed capacity of 24 kW, an uninsulated pipe network, and radiators that are installed on the premises.

Ventilation takes place naturally and there are no air conditioners. Sanitary hot water (SHW) is heated by electricity and boilers.

Figure 2. Building orientation

For the reference building, marked number 79 in Figure 2, full energy efficiency calculation was done. In this paper, only key results will be shown in Table 1.

Table 1. Reference building energy needs

Building energy needs	[kWh/a]	[kWh/m^{2}a]
Annual thermal energy required for heating, $Q_{H,nd}$	17013.34	216.73
Annual thermal energy required for SHW, Q_W	366.12	4.66
Annual heat losses of heating systems, $Q_{H,ls}$	5977.66	76.15
Annual heat losses of SHW systems, $Q_{W,ls}$	36.61	0.47
Annual required thermal energy, Q_H	23393.74	298
Annual energy delivered, E_{del}	24155.08	307.7
Annual primary energy, E_{prim}	28200.3	359.24
Annual emission of CO_2 [kg/a] [kg/m^{2}a]	6600	400

In order to satisfy the energy needs for this single residential house, a large amount of CO2 is released. It is clear that for environmental reasons, more attention needs to be paid to this problem. If the house was heated by electricity instead of natural gas, this annual production of 6,600 kg of CO2 would rise to 32,000 kg. And if solar energy was used instead, the CO2 production would be minimized.

4. SOLAR POTENTIAL AT THE TARGET LOCATION

Determining the solar potential at the target location is crucial for the development of a photovoltaic system project. The analysis of the calculation of the solar potential at the location of the building (N45.14, E20.13) was performed using the free online version of the PVGIS program, which uses satellite data for the calculation of the solar potential.
The reference building is not surrounded by tall buildings. Therefore, there is no shadow on its roof at any time during the year, which is why the shadow factor does not have to be considered. The roof of the building is duo pitch, the axis is oriented in the direction north-south, which is the worst possible orientation. The pitch angle of the roof is 45°.
PVGIS program evaluates the direct, diffusion, and reflected components of solar radiation by combining a clear-day model and real data measured at angles of 0°, 15°, 25°, and 40°. The program also includes a snapshot of the entire terrain on which the assessment is performed, so that when calculating the irradiation the effect of shadows due to the surrounding objects and the terrain is taken into account. The program provides information on the average irradiation for each month as well as for the whole year.
The input data for the roof were inserted into the PVGIS and the corresponding insolations were obtained, which is shown in the following table.

Table 2. Horizontal solar potential data

Month	H_h	H_{opt}	*H(45)*	*DNI*	I_{opt}	T_D	T_{24h}
Jan	1110	1660	1040	1220	61	1.8	0.3
Feb	1860	2620	1730	1990	55	2.5	1.0
Mar	3600	4540	3330	3530	45	8.6	6.7
Apr	4820	5340	4340	4500	30	14.6	12.5
May	5720	5740	5040	5110	17	19.6	17.6
Jun	6330	6040	5550	5660	11	22.9	21.2
Jul	6450	6310	5680	6290	15	25.1	23.3
Aug	5700	6150	5060	6050	27	25.0	23.0
Sep	3990	4880	3610	4170	41	19.8	17.6
Oct	2810	4020	2630	3430	54	14.9	12.6
Nov	1560	2510	1490	2120	63	9.2	7.3
Dec	894	1370	840	1010	62	3.0	1.5
Year	3750	4270	3370	3770	34	13.9	12.1

In this table, the labels have the following meanings:

Hh: Average horizontal insolation per unit area (*Wh/m²/day*)
Hopt: Average insolation for optimal tilt angle (*Wh/m²/day*)
H(45): Average insolation for tilt angle 45° (*Wh/m²/day*)
DNI: A direct component of solar insolation (*Wh/m²/day*)
I_{opt}: Optimal angles (degrees)
T_D: Average daily temperature in degrees Celsius (during the day)
T_{24h}: Average daily temperature during all 24 hours in degrees Celsius

Based on all the above data, the conclusions can be drawn about the horizontal solar potential:

1. Average annual irradiation: **156.25** ***W/m²***
2. Total annual insolation: **1368.75** ***kWh/m²***

Conclusions on the solar potential for a roof pitch of 45 °:

1. Average annual irradiation: **140.41** ***W/m²***
2. Total annual insolation.: **1230** ***kWh/m²***

Prediction of the solar potential for an arbitrary year is impossible with 100 percent accuracy. Depending on the year when the data on solar irradiation were collected and processed, different values for the solar potential are obtained. However, as the production of photovoltaic systems shows less stochasticity than e.g. wind power, experience shows that taking annual data yields an error of less than 5%. For an azimuth angle of 90°, the optimal slope is 0°. From here, it is obtained that due to this effect, there is a reduction of 10% in annual solar insolation. The calculation shows that the optimal azimuth angle at the target location is 0°, slope 34°, from which the annual insolation of 1558 kWh/m² is obtained. It is calculated that the solar potential on the analyzed object due to its poor orientation would have 21% less insolation than ideal.

5. PHOTOVOLTAIC SYSTEM AT THE ROOF

5.1 Type of photovoltaic system

Photovoltaic systems are still a relatively expensive technology with an efficiency of conversion of electromagnetic radiation into electricity below 20%. For that reason, it is necessary to pay special attention to the choice of photovoltaic systems.
A review of the catalogs of various manufacturers has estimated that the most economical solution is the Yingli Solar Panda YL275C-30b (275Wp) Monocrystal with Efficiency of 16.8% and wattage of 275 W.

5.2 Layout of photovoltaic panels on the roof of the building

The dimensions of the photovoltaic panels are 165cm x 99cm. Taking into account the dimensions of the roof, its geometry, as well as the dimensions of one panel, it is possible to install 45 photovoltaic panels on one side of the house, while it is possible to install 51 panels on the other side of the house. The anticipated panel layout is shown in Figure 3. The total installed power of the proposed photovoltaic system is 23.65 kWp.

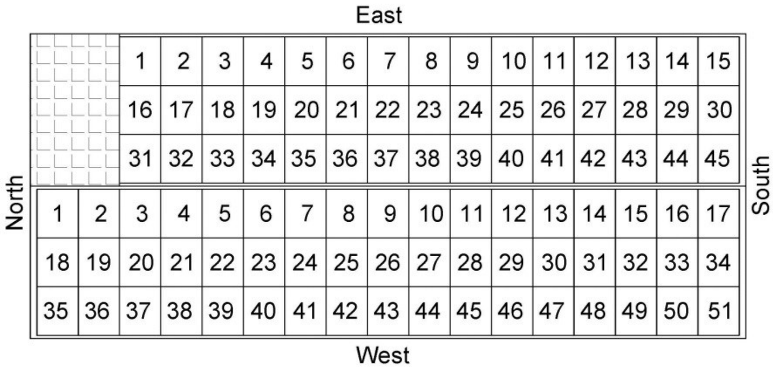

Figure 3. Layout of the photovoltaic panels at the roof

5.3 Estimation of electricity production from an adopted photovoltaic system

Production estimation was performed using the PVGIS software package. Details about PVGIS as well as the way it performs potential assessment are given in previous chapters. The layout of PVGIS software with input data is shown in Figure 4.

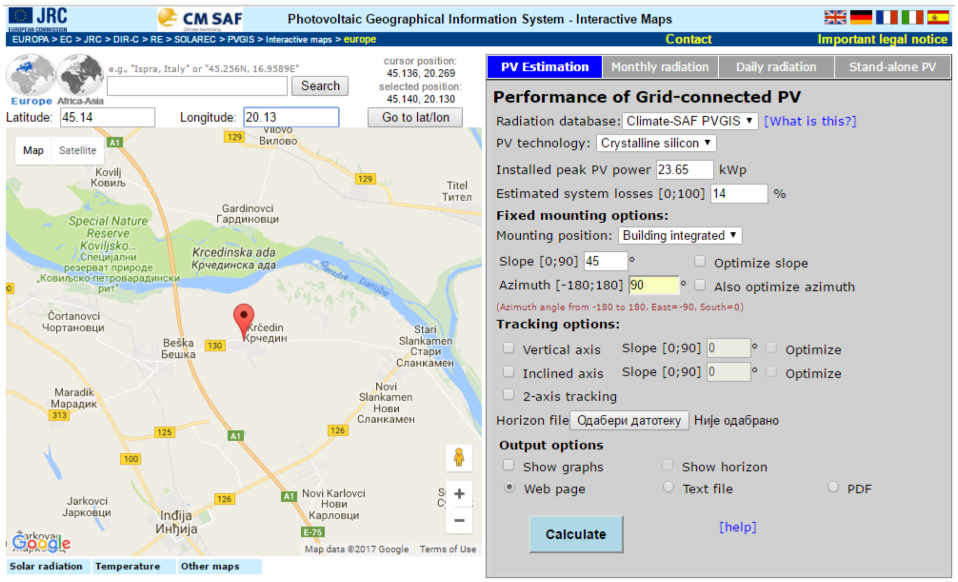

Figure 4. Data entered in PVGIS for the assessment of electricity production [4]

From software calculation, we get total production during one year: **20,400 kWh.**
The capacity utilization factor for the year is 9.85%, which is much lower than the optimal value for Serbia which is 14%. The reason for this is the unfavorable orientation of the roof of the house. The graph in Figure 5. shows the relationship between the production of the photovoltaic system and the building electricity consumption. Presented results imply that the production of the system significantly exceeds the need for electricity of the reference building.

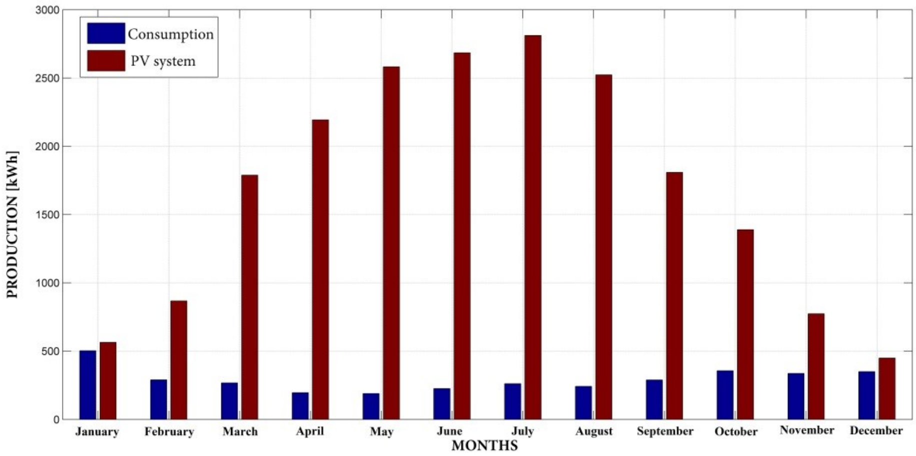

Figure 5. The comparison of the production of the photovoltaic system and the electricity consumption of the reference building

5.4 Photovoltaic system investment profitability

Investment in a photovoltaic system includes project development, permits collecting, purchase of necessary technology, transport, installation, and connection to the network. It is common for the investment price of energy systems to be considered per kW of power of the installed system. According to the current state of the market, the research revealed that for 1 kW of photovoltaic system power, an investment of around 1,100 euros is required, which includes all the previously listed costs. The biggest costs are panels whose price at the moment is about 700 euros per kW of power and inverters with the price of about 180 euros per kW of power. In accordance with the previous discussion for PV systems with an installed power of 23.65 kWp, which is proposed by this analysis, an investment of about 26,000 euros is required.

For further consideration, it is necessary to get acquainted with the concept of feed-in tariff which provides incentive purchase prices of electricity produced from renewable sources, and which are harmonized with the applied technology and prescribed by the Government of the Republic of Serbia for a certain period of time to encourage investors and reduce investment risk. What is important to note is that the incentives do not refer only to the excess electricity for a given building, but to the total amount of electricity produced by the photovoltaic system. For photovoltaic systems, the current guaranteed purchase price of produced electricity is 20.66 euro cents per kWh for 12 years. Producers who are granted a feed-in tariff are also named privileged electricity producers.

If there were no privileged producer status, the electricity produced from RES would have a price dictated by the market, which at the moment is about 5 euro cents per kWh. The annual production of the planned system is 20,400 kWh, so the annual profit for such a system is about 1,000 euros. As previously stated, the investment cost of the system is 26,000 euros, so a simple payback period would be 26 years, which is more than the guaranteed lifespan of a panel of 25 years.

Besides, if we discount future revenues to the present value, as it is shown in Table 3, the net present value is negative, which is a clear indicator of the unprofitability of the investment. The calculation was made with a discount rate of 8%, which according to the research is the usual amount for energy investments.

Table 3. Discount to the present value of the investment without feed-in tariff

Year	Profit [€]	NPV* [€]	Year	Profit [€]	NPV* [€]
1	1000	925.93	15	1000	315.24
2	1000	857.34	16	1000	291.89
3	1000	793.83	17	1000	270.27
4	1000	735.03	18	1000	250.25
5	1000	680.58	19	1000	231.71
6	1000	630.17	20	1000	214.55
7	1000	583.49	21	1000	198.66
8	1000	540.27	22	1000	183.94
9	1000	500.25	23	1000	170.32
10	1000	463.19	24	1000	157.70
11	1000	428.88	25	1000	146.02
12	1000	397.11			
13	1000	367.70	Total for 25 years		10,674.78 €
14	1000	340.46	Net present value		-15,325.22 €

If there is a status of the privileged producer, electricity produced from RES will have a guaranteed price of 20.66 euro cents per kWh in the first 12 years, and then the price dictated by the market, which is currently around 5 euro cents. The annual production of the planned system is 20,400 kWh, so the annual profit for such a system is about 4,200 euros per year for the first 12 years, and then about 1,000 euros for the remaining period. As previously stated, the investment cost of the system is 26,000 euros so a simple payback period would be 6.2 years.

By discounting future income to present value using a discount rate of 8%, we get the net present value of the profit of the investment is € 8,790.23, which indicates the profitability of the project.

6. CONCLUSIONS

Based on the analysis, the following conclusions can be made:

- The roofs of the houses in AP Vojvodina are a good location for photovoltaic systems. Using Table 2 it was determined that the total horizontal (annual) solar radiation at reference roof at Krčedin is 1368.75 kWh/m^2.

- The total installed power on the roof of the reference house could be up to 23.65 kW. If Yingli panels with a power of 275 W are used, the production of electricity could be up to 20,400 kWh per year.
- The estimated investment in 23.65kW solar system would be around € 26,000 at the moment. Based on the economic analysis, it was determined that there is a financial justification for the investment in the case of obtaining a status of the privileged producer, while otherwise, the project is not cost-effective. In the case of a feed-in tariff, the simple payback period is 6.2 years, while the guaranteed lifespan of the panels is 25 years, although they can last longer.
- Savings due to the emission of CO_2 on an annual basis in the production of electric energy of 20,400 kWh is about 27t.

REFERENCES

[1] Stamenić, Lj.: *Korišćenje solarne fotonaponske energije u Srbiji*, Jefferson Institute, **2009.**
[2] Grupa autora: *Studija o proceni ukupnog solarnog potencijala - solarni atlas i mogućnosti "proizvodnje" i korišćenja solarne energije na teritoriji AP Vojvodine,* Novi Sad, **2011.**
[3] Milekić, N.: *Analiza primene aktivnih solarnih sistema na postojeći stambeni objekat u Krčedinu, ul. Cara Dušana 79, Inđija*, Specijalistički rad, Građevinski fakultet univerzitet u Beogradu, **2017.**
[4] http://re.jrc.ec.europa.eu/pvgis/
[5] International Energy Agency: *Photovoltaics in buildings - A Design Handbook for Architects and Engineers*, Paris, France, **2010.**
[6] Grupa autora: *Nacionalni akcioni plan za korišćenje obnovljivih izvora energije Republike Srbije*, Ministarstvo energetike, razvoja i zaštite životne sredine R. Srbije, Beograd, **2013.**

АНАЛИЗА ИСПЛАТИВОСТИ УЛАГАЊА У ФОТОНАПОНСКЕ СИСТЕМЕ НА ТЕРИТОРИЈИ АП ВОЈВОДИНЕ

Резиме: *Зелена енергија је постала кључни део анализе одрживог развоја. Штавише, обновљиви изводи енергије морају бити препознати као зона са највећим потенцијалом за редуковање укупног загађења ваздуха у Републици Србији. Циљ овог рада је да покаже бенефите улагања у употребу соларне енергије и да одреди да ли постоји економска оправданост за имплементацију фотонапонских система на крововима кућа у АП Војводини.*

Кључне речи: *енергетска ефикасност , активни соларни системи, фотонапонски системи, одрживост, загађење*