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FACULTY OF MECHANICAL ENGINEERING

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COMETa 2020

„Conference on Mechanical Engineering Technologies and Applications“

PROCEEDINGS

26th-28th November

East Sarajevo, RS, B&H

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PREFACE

Faculty of Mechanical Engineering of the University of East Sarajevo is organizing the 5th International Scientific Conference COMETa 2020 – "Conference on Mechanical Engineering Technologies and Applications“ in specific circumstances. Namely, faced with numerous challenges due to the pandemic caused by the spread of COVID-19 virus on a global level, the Organizing Committee decided to hold the Conference COMETa 2020 virtually, in order to ensure the safety of participants and the entire community. Also, the continuity of the event was a significant reason for the establishment of the online model, especially considering the fact that the conference COMETa has been categorized by the relevant Ministry as an international scientific conference of the first category.

The main goal of the conference is to contribute to increasing the competitiveness of national business entities through the presentation and implementation of new scientific achievements in the field of mechanical engineering. In addition, the conference will provide additional support to researchers in the presentation of their results, as well as establishing a higher level of cooperation with leading national and international scientific institutions, universities, public companies and partners from industry.

The program of the conference COMETa 2020 consists of the following thematic areas:

- Manufacturing technologies and advanced materials,
- Applied mechanics and mechatronics,
- Machine design, simulation and modeling,
- Product development and mechanical systems,
- Energy and thermotechnic,
- Renewable energy and environmental,
- Maintenance and technical diagnostics,
- Quality, management and organization.

A total of 193 authors and co-authors from 12 countries are participating in the 5th International Scientific Conference COMETa 2020 where 70 papers have been accepted, including 5 plenary lectures. Round table on the very actual topic “Challenges in the education during COVID-19 pandemic – Online as a solution ...“ is planned to be held.

The participation of a significant number of domestic and foreign scientists and researchers strengthens our conviction that the online format of the conference will not diminish its importance. On the contrary, we are sure that together we will gain new experiences, which will further enable us better and more meaningful cooperation in the near future by generating new ideas and establishing modern approaches to solving complex issues in mechanical engineering in the context of challenges that are present in the technical and technological development of an advanced society in the 21st century. In that sense, we want to emphasize that each of your proposals is welcome and will be carefully considered from the aspect of organizing the next conferences.

On behalf of the Organizing and Scientific Committee of the conference COMETa 2020, we would like to express our gratitude to all authors, reviewers, universities, business entities, and national and international institutions and organizations that supported the organization of the conference. We would like to express special gratitude to the Ministry of Scientific and Technological Development, Higher Education and Information Society of the Republic of Srpska, the City of East Sarajevo and local communities.

In the hope that our joint efforts will meet the expectations of the scientific and professional public, the organizer of the Conference, Faculty of Mechanical Engineering, University of East Sarajevo, wishes all participants successful work. Welcome to the online conference COMETa 2020.

East Sarajevo, November 23rd, 2020.

President of the Scientific Committee
PhD Nebojša Radić, Full Professor

President of the Organizing Committee
PhD Milija Kraišnik, Associate Professor

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ENERGY ANALYSIS FOR BAPV AND BIPV IMPLEMENTATION IN A RESIDENTIAL HOUSE IN KRAGUJEVAC

Davor Jovanović[1], Danijela Nikolić[2], Novak Nikolić[3]

Abstract: The cost-effectiveness of installing photovoltaic panels in a residential house in the territory of Kragujevac (R. Serbia) is analyzed. By using solar to electric energy conversion (BAPV and BIPV systems) substantial electricity savings can be achieved. 3D model of the residential house is created using "SketchUp" software and "OpenStudio" plug-in is used to export the 3D model to the energy simulation software "EnergyPlus". For BAPV installation "EXM 300/156-60" module type is used with the module conversion efficiency of 18,35%, while for BIPV installation "UL-150M-36" module is used with a conversion efficiency of 14,8%. Also, a predetermined area of the rooftop must be covered equally by both BAPV and BIPV. For the payback period, 0,2066 €/kWh (feed-in tariff) is accounted for electricity sold to the electric distribution grid and 0,052 €/kWh is used for generated electricity (green zone tariff) which is used by the electric devices or lighting in the analyzed household. Only generated electricity which is not used in the household (higher production than demand) is sold to the electric distribution grid. Generated results show that BAPV systems are generating 2610,5 kWh/a, while BIPV systems generate 1598,38 kWh/a (38,77% less than BAPV). Also, the payback period for BAPV systems is 12,33 years and the BIPV system repay their initial investment after 16,17 years (31,14% longer payback period) in the observed case for Kragujevac territory.

Key words: PV panels, building integrated, building applied, payback period, simulation

1 INTRODUCTION

Solar PV panels exploitation has increased exponentially over the past years and currently has the highest growth on the global market with at least 500GW installed capacity (approximately 100GW of power added in 2018, which is twice as much capacity as wind) and around 30% of PV is installed on rooftops of residential

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houses/buildings and public facilities [1-4].

Solar irradiation in R. Serbia is estimated at 1400 kWh/m^2, which is higher than the European average (1096 kWh/m^2), thus, having higher potential in generating electricity and hot water from solar energy. The fact that in Kragujevac solar irradiation is even higher and its value is approximately 1448 kWh/m^2 creates an even higher potential for residential use of solar energy [5-7].

In [8] current state of the art for BIPV (building integrated photovoltaic system) and BAPV (building applied photovoltaic system) is explained, whereas the efficiency for different PV materials is overviewed. Also, in [9] comparison of BIPV and BAPV mono and polycrystalline PV panels is conducted numerically and it was concluded that monthly energy production is 40 to 45% in favor of BIPV systems (depending on the available rooftop area). In [10] practical evaluation of the measurement data and simulation on the BIPV windows is performed. In Cartagena [11] comparison between BIPV and BAPV is conducted from architectural and energy production perspective, thus, creating a balance between those aspects. In [12] performance compromises between BIPV and BAPV systems in Brazilian airports are performed and it is estimated that the final annual energy yield is 7% in favor of BAPV systems.

2 MATERIALS AND METHODS

Basic terms for BIPV and BAPV comparison are as follows:

- The same area of rooftop (30,58 m^2) that is determined to be covered with PV needs to be completely covered in both BIPV and BAPV case,
- Initial investment should not exceed 9000€,
- If the price of BIPV or BAPV is less than 9000€, then the difference between these prices should not be greater than 10%.

A residential house is 3D modeled in “SketchUp” software (see Fig. 1), which uses the “OpenStudio” plug-in for exporting to “EnergyPlus” software, which is ultimately used to conduct energy simulations for both cases [13-16].

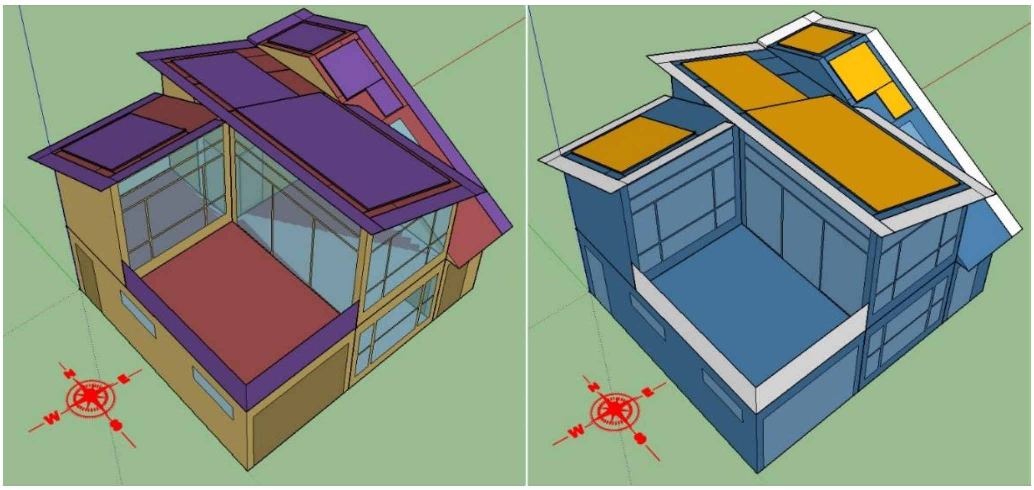

Figure 1. *3D model of house (left) and marked positions of photovoltaic modules (right)*

For electrical power produced by a PV surface [W] simple mathematical model (used in software "EnergyPlus") will be implemented, according to the following equation:

$$P = A_{surf} \cdot f_{activ} \cdot G_T \cdot \eta_{cell} \cdot \eta_{invert} \qquad (1)$$

Where A_{surf} [m^2] stands for the net area of a surface covered by PV, f_{activ} [-] is a fraction of surface area with active solar cells, G_T [W/m^2] is the total solar radiation incident on PV array, η_{cell} [-] is module solar to electrical conversion efficiency and η_{invert} [-] stands for DC/AC conversion efficiency [15].

For BAPV installation "EXM 300/156-60" module type is used with a module conversion efficiency of 18,35%, while for BIPV installation "UL-150M-36" module is used with a conversion efficiency of 14,8% [17,18].

By using "EnergyPlus" software, simulations and electricity consumption for electrical devices and lighting is performed and data is presented for each month for one year in figure 2.

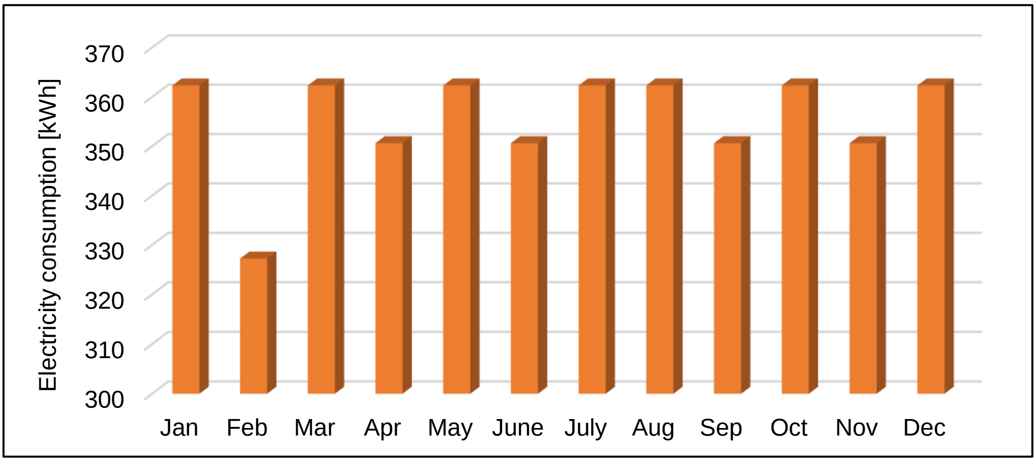

Figure 2. *Electrical devices and lighting monthly electricity consumption for one year*

By analyzing figure 2, it can be noticed that yearly electricity consumption for an observed household is 4266,06 kWh. During further economic analysis of BAPV and BIPV systems, generated electricity should be supplied to electric devices and lighting first, before selling produced electricity to the electric distribution grid.

For purposes of economic analysis, sold electricity to the grid will be accounted as 0,2066 €/kWh (feed-in tariff), while used electricity will be calculated as 0,052 €/kWh (according to the consumption shown in fig. 2, that price would be paid to electric power industry with taxes included) [19,20].

The initial investment for both BAPV and BIPV systems is shown in tables 1 and 2, respectively.

Table 1. *The initial investment for analyzed BAPV system [21,22]*

Model	*No. of pieces*	*Price per piece*	*In total*
EXE Solar EXM300 300W Full Black	19	192,63€	3625€
Solar MPPT regulator JYC GSC-F1224-60A	4	202,83€	811,32€
Solar Inverter X1-5.0 Boost Solax	1	1010,74€	1010,74€
Solar battery Long KPH100-12AN 12V 100Ah	5	181,42€	907,1€
Cables and fuses	160€		
• Fronius Smart Meter 63A/3F • DC/DC convertor 12/24V • Aluminum brackets for panel mounting • Solar MC4 connector • Solar cables 6mm^2 (30m)	1000€		
Installation and licenses	760€		

According to table 1, total costs for the analyzed BAPV system is 8274€, or 1,465 €/Wp (peak power of the analyzed system is 5645,54 Wp).

Table 2. *The initial investment for analyzed BIPV system [21,22]*

Model	*No. of pieces*	*Price per piece*	*In total*
UL-150M-36	30	119,55€	3586,5€
Solar MPPT regulator JYC GSC-F1224-60A	5	202,83€	1014,15€
Solar Inverter X1-5.0 Boost Solax	1	1010,74€	1010,74€
Solar battery Long KPH100-12AN 12V 100Ah	5	181,42€	907,1€
Cables and fuses	160€		
Fronius Smart Meter 63A/3F	335€		
Installation and licenses	700€		

By analyzing table 2, total costs for the analyzed BIPV system is 7713,5€, or 1,702 €/Wp (peak power of the analyzed system is 4532,6 Wp).

According to tables 1 and 2, the difference between prices of BAPV and BIPV is approximately 7,3%, which satisfies the condition that difference should be less than 10%.

3 RESULTS AND DISCUSSION

After conducted simulations in "EnergyPlus" software, results both for BAPV and BIPV systems are shown in figure 3.

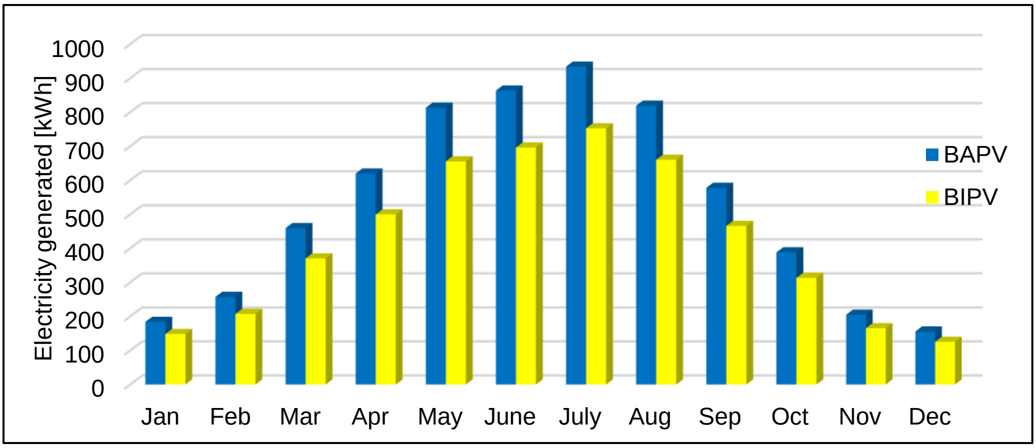

Figure 3. *Monthly generated electricity from BAPV and BIPV systems*

Figure 3 shows that the BAPV system generates the highest amount of electricity during July (933,6 kWh), while the least electricity is produced during December (155,6 kWh). For BIPV, electricity produced is slightly less than BAPV with highest in July (752,5 kWh) and lowest in December (125,4 kWh). In figure 4, the difference between generated electricity and its demand is shown.

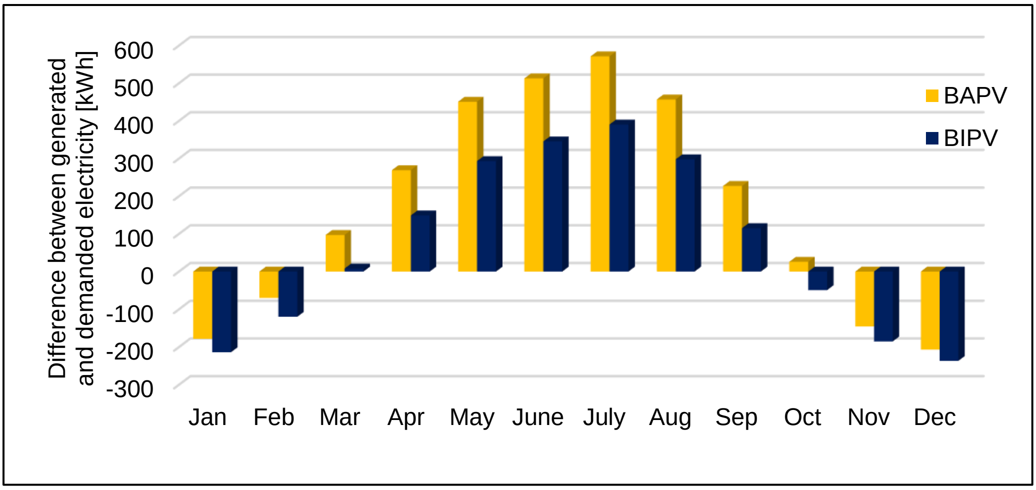

Figure 4. *Difference between generated and demanded electricity from BAPV and BIPV systems annually*

From figure 4 can be seen that BAPV systems have excess electricity production (compared to electrical devices and lighting electricity demand) starting from March until October. On the other hand, BIPV have excess electricity production until September. By examining the results, BAPV systems are generating 2610,5 kWh/a, while BIPV systems generate 1598,38 kWh/a, which is 38,77% less than BAPV. Figure 5 shows the payback period for both analyzed systems.

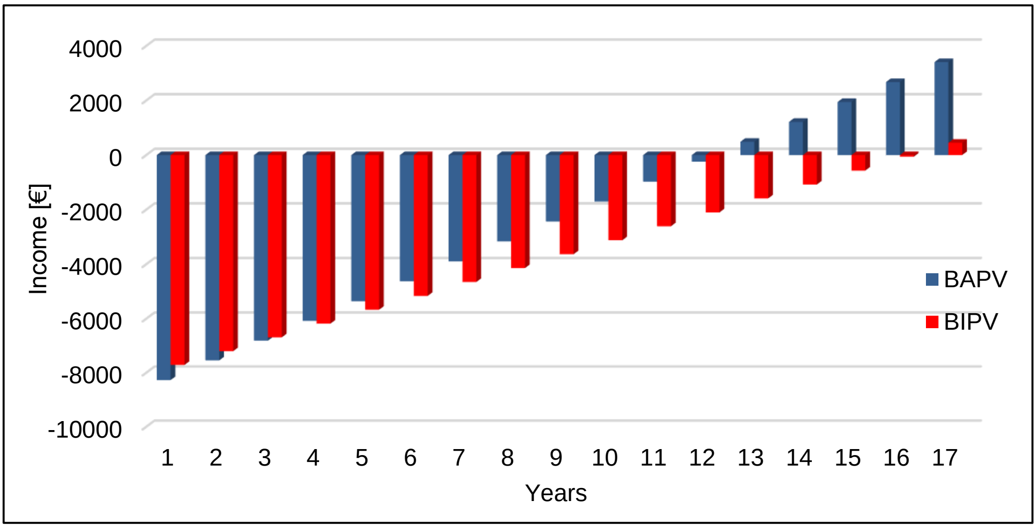

Figure 5. *Payback period from BAPV and BIPV systems*

The payback period for BAPV systems is 12,33 years (see fig. 5), while the BIPV system repays their initial investment after 16,17 years, which is 31,14% longer payback period compared to BIPV. Also, after 17 years the BIPV system creates a profit of approximately 449€, while at the same time the BAPV system created a profit of around 3405€ (approximately 7,58 times higher than BIPV).

One of the reasons that can cause longer payback periods for BIPV systems can be their higher initial price because there are no manufacturers of BIPV in R. Serbia and, therefore, any BIPV product must be imported, which raises its price (import tax, transportation, and VAT) and because of that lower efficiencies BIPV cost almost the same as higher efficiencies BAPV (see tables 1 and 2). On the other hand, BAPV have existed on the market for quite some time and a lot of companies have their representatives in R. Serbia, which drastically reduces the costs of PV. It is shown via energy simulations that in Kragujevac territory it is more profitable to invest in BAPV.

4 CONCLUSIONS

By using the “SketchUp” software 3D model of residential house is created and with simulation software “EnergyPlus” electricity generation from BAPV and BIPV systems is determined, by importing weather files for Kragujevac territory (R. Serbia), respectively. Data generated via simulation software is used to determine how much electricity demand from electric devices and lighting of the analyzed household can be supplied, as well as which system has a shorter payback period. The initial investment cannot exceed 9000€ and the difference between BAPV and BIPV initial investments can’t be greater than 10%. For the payback period, 0,2066 €/kWh (feed-in tariff) is calculated for electricity sold to the electric distribution grid and 0,052 €/kWh is calculated for generated electricity which is used by the analyzed household. The only excess generated electricity, which is not used by the household electric devices or lighting, is sold to the electric distribution grid. According to the generated results, BAPV (5645,54 Wp) systems are generating 2610,5 kWh/a, while BIPV (4532,6 Wp) systems generate 1598,38 kWh/a (38,77% less than BAPV). Also, the payback period for BAPV systems is 12,33 years, while the BIPV system repays its initial investment after 16,17 years (31,14% longer payback period).

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