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PROGRAM

ČETVRTAK • THURSDAY, October 17, 2019.		
09.00–10.00 h	Prijavljivanje učesnika	Registration
10.00–10.30 h	Otvaranje Konferencije	Opening ceremony
10.30–11.30 h	Plenarna predavanja	Plenary session
11.30–12.30 h	Izlaganje radova I tematske grupe	First session
12.30–13.00 h	Koktel	Coctail
13.00–15.00 h	Izlaganje radova II tematske grupe	Second session
15.00–15.15 h	Pauza	Break
15.15–18.00 h	Izlaganje radova III tematske grupe	Third session

PETAK • FRIDAY, October 18, 2019		
9.00–10.30 h	Izlaganje radova IV tematske grupe	Fourth session
11.00–11.30 h	„Električni bicikl“	Electric Bicycle
11.30–12.00 h	„Električna strela“	„Electric Arrow“
12.00–17.00 h	Tribina: Električna vozila – juče, danas i sutra	Panel: Eelctrical vehicles – yesterday, today and tomorrow

FOREWORD

According to the International Energy Agency, increased energy consumption caused the global rise in CO_2 emissions up to incredible 33.1 Gt. This is the fastest rate since 2013. Energetic facilities contribute with almost two thirds of this grow. Forecasts are that CO_2 emssions will not slow down enough by middle of the century and that 2 °Ctemperature rise will occur in next thirty years. It is also expected that by 2050 the Earth will be warmer by 2.4 °C than in pre-industric period. We must act immediately to prevent climate changes with stronger storms, flods, droughts, sea level rise and supply disruptions.

We need political actions: actions that promote renewable energy sources, new technologies and systems for decarbonization and better energy efficiency. We witness transition from fosil fuels to "green technolgies, but not fast enough to comply with Paris Agreement: to limit global warming significantly below 2 °C. By 2030 production of about 50 million electric vehicles is expected wich asks for 50 batteries production 50 times larger than today. The best solution for batteries charging and increased electrical energy consumption are all kinds of renewable electrical energy sources.

Main goal of the 7th International Conference on Renewable Electrical Power Sources is to analyse comparative advantages and disadvantages of contemporary solutions among reneweable sources in the world and in Serbia, and to provide fruitfull exchange of opinions and ideas on development and implementations of these ideas.

The 7th Conference is accredited by the Institute for Education Promotion of Republic of Serbia

This international conference i s for the seventh time organized by the Society for Renewable Electrical Power Sources within the Union of Mechanical and Electrotechnical Engineers and Technicisans of Serbia (SMEITS), since 2010.

Belgrade,
October 2019

PREDGOVOR

Sve veća potrošnja energije dovela je do globalnog porasta emisije ugljen-dioksida (CO_2) na rekordnih 33,1 Gt, prema podacima Međunarodne agencije za energetiku. Ovo je bio najbrži rast od 2013. godine. Emisija gasova iz postrojenja za proizvodnje električne energije čini gotovo dve trećine ovog rasta. Smatra se da se emisija CO_2 neće dovoljno usporiti do sredine veka tako da će se povećanje prosečne temperature za 2 °C dogoditi već sredinom ovog veka. Prognoze ukazuju da će krajem ovog veka zemljina kugla biti za 2,4 °C toplija nego u predindustrijskom periodu. Zbog toga je potrebno što pre da se deluje kako bi sprečili da klimatske promene donose sve jače oluje, sve češće poplave i suše, sve viši nivoe mora i poremećaje u snabdevanju hranom.

Potrebne su nam političke akcije: akcije koje unapređuju obnovljive izvore energije, nove tehnologije i sisteme dekarbonizacije, kao i postupci za povećanje energetske efikasnosti. Svedoci smo da se vrši prelaz sa fosilnih goriva na „zelene tehnologije" ali ne dovoljno brzo da bi se ispuni ciljeve Pariskog sporazuma kojim bi se postiglo da se globalno zagrevanje ograniči na vrednost „znatno ispod 2 °C“. Smatra se da će do 2030. godine biti pravljeno oko pedeset miliona električnih vozila godišnje a za to će biti potrebna 50 puta povećana proizvodnja akumulatorskih baterija. Smatra se i da je za dopunjavanje akumulatorskih baterija kao i za povećanu potrošnju električne energije najbolje rešenje razvoj svih vrsta obnovljivih izvora električne energije.

Osnovni cilj 7. Međunarodne konferencije o obnovljivim izvorima električne energije jeste da se analiziraju uporedne prednosti i nedostaci savremenih rešenja u oblasti obnovljivih izvora električne energije u svetu i kod nas, i da se obezbedi plodotvorna razmena kompetentnih mišljenja i ideja vezanih za razvoj i primenu ovih izvora.

Tribinu „Električna vozila - juče, danas i sutra", koja se održava u okviru programa 7. Konferencije, akreditovao je Zavod za unapređivanje obrazovanja i vaspitanja Republike Srbije.

Ovaj međunarodni skup po sedmi put organizuje Društvo za obnovljive izvore električne energije Saveza mašinskih i elektrotehničkih inženjera i tehničara Srbije (SMEITS).

U Beogradu,
oktobra 2019.

SADRŽAJ

Plenarna predavanja

1. Životna sredina, održivost i politika

2. Energetski izvori i skladištenje energije

3. Energetska efikasnost

FOTONAPONSKI SISTEMI INTEGRISANI U OMOTAČ ZGRADE – STUDIJA SLUČAJA IMPLEMENTACIJE NA FAKULTETU INŽENJERSKIH NAUKA U GRADU KRAGUJEVCU

BUILDING INTEGRATED PHOTOVOLTAICS – CASE STUDY OF IMPLEMENTATION AT FACULTY OF ENGINEERING IN THE CITY OF KRAGUJEVAC

Natalija ALEKSIĆ[*], Danijela NIKOLIĆ, Vanja ŠUŠTERŠIČ, Jasmina SKERLIĆ, Mladen JOSIJEVIĆ
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Razvoj fotonaponskih sistema integrisanih u omotač zgrade (BIPV) i njihova implementacija kod novih ili postojećih konstrukcija omotača zgrade pružaju estetska, ekonomska i tehnička rešenja za integraciju solarnih ćelija za proizvodnju električne energije u energetski efikasnim omotačima zgrada. U modernim i razvijenim zamljama postoji tranzicija ka potpuno energetski održivoj arhitekturi kroz realizaciju niskoenergetskih zgrada. U isto vreme, BIPV predstavlja toplotni omotač zgrade i izvor koji generiše električnu energiju BIPV igra važnu ulogu u novoj eri distribucije električne energije. Ovaj rad daje pregled aktulenih tipova BIPV sistema kao i njihovu primenu, i ukazuje na mogućnosti i potrebe za integracijom BIPV sistema na već postojeće objekte. U okviru rada je takodje predstavljena studija slučaja moguće implementcije BIPV sistema na jednom od objekata Fakulteta inženjerskih nauka u gradu Kragujevcu, sa analizom mogućnosti uštede energije sa ugradnjom različitih vrsta BIPV sistema na zgradu fakulteta.

Ključne reči: *Fotonaponski sistemi integrisani u omotač zgrade; zgrada; implementacija; energija*

The development of building integrated photovoltaic (BIPV) technology and its implementation in new or existing construction of the building envelope provide aesthetical, economical and technical solutions to integrate solar cells for produce electricity within the energy-efficient envelopes of buildings. In modern and developed countries, there is transition to fully energetically sustainable architecture through the realization of low energy buildings. BIPV represents the thermal building envelope, and at the same time a source which is generating electricity. BIPV play an important role in the new era of distributed power generation. This paper gives an overview of the current classification of BIPV and their application, and w and points out the possibilities and needs for integrating the BIPV system into already existing buildings. A study of the possible implementation of the BIPV system at one of the buildings of the Faculty of Engineering in the city of Kragujevac was also presented in the paper, with an analysis of the possibilities of energy saving with the installation of various types of BIPV systems in the faculty building.

Key words: *Building integrated photovoltaics; building; implementation; energy*

1 Introduction

Global environmental concerns, rising demands for energy and continuous advancement in renewable energy technologies are creating new opportunities for the use of renewable energy sources. Solar energy is a clean, abundant and inexhaustible renewable source of energy. For this reason, photovoltaic technology is one of the best ways to harness this solar power. So, it seems wise for engineers and architects to help protect the environment by designing buildings that maximize the efficient use of natural energy sources, such as solar energy.

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Building Integrated Photovoltaics (BIPV) is the integration of photovoltaics (PV) into the building envelope. BIPV systems are involved into the construction of many new buildings as a new modern type of building envelopes and as a main or auxiliary source of energy. Also, BIPV systems can be easily added on the existing buildings. These integrated systems replace parts of conventional building materials and different elements in the climate envelope of buildings, such as roofs and facades. At the same time BIPV serve as an electricity generator. In the literature the various BIPV definitions have been adopted. Table 1 shows comprehensive product categorization for BIPV systems [2].

Table 1. Categorization of BIPV systems [2]

Area	SEAC	*BCC*	SUNRISE	ABIO	*SUPSI*
Pitched roofs	In-roof systems Small tiles shingles slates Large tiles shingles slates	Roofing	Standard in-roof systems Solar tiles and shingles Flexible laminates	Solar tiles Opaque flat/sloped/roof Transparent roof Multipurpose roof Roof element	In-roof mounting systems Full roof solutions Small tiles shingles slates Large tiles shingles slates Metal panels Solar glazing
Flat and curved roofs	Skylights and semi-transparent roof systems Flexible laminates	Glazing	Semi-transparent solution Flexible laminates	Opaque flexible roof Transparent flexible roof	Metal panels Solar membranes Solar glazing
Façades	Cladding systems Semi-transparent solution Louver systems	Glazing Sun-shading	Cladding systems	Façade elements Continuous façade systems Windows Shading systems Multipurpose façade	Accessories Warm façade Cold façade Solar glazing
Other application		Architectural fabrics		Urban furniture BIPV custom design	
Source	[3]	[4]	[5]	[6]	[2]

BIPV products or systems also can be categorized into the following groups: BIPV foil products, BIPV tile products, BIPV module products and solar cell glazing products. In BIPV applications, photovoltaic modules are available as flat or flexible surfaces and as opaque, transparent or semi-transparent. Besides harvesting energy, well-integrated PV-modules are suitable to contribute to the comfort of the building: they serve as weather protection, heat insulation, noise protection, shading modulation, thermal isolation and etc.

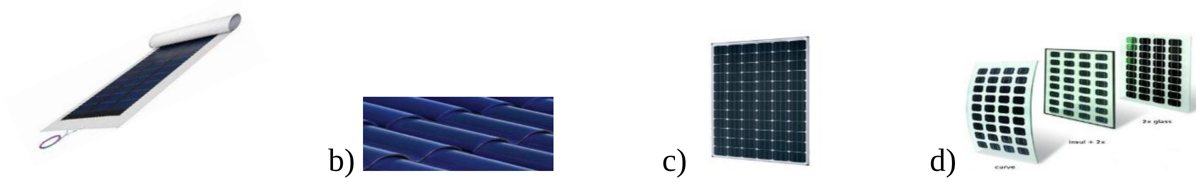
2 BIPV systems

BIPV systems can either be designed as stand-alone, off-grid system or they may be interfaced with the available utility grid. Main benefits of power production at the point of use include savings to the utility in the losses associated with transmission and distribution, and savings to the consumer through lower electric bills because of peak shaving. Also, buildings that produce power using renewable energy sources reduce the demands on traditional utility generators. This type of buildings usually reduces the overall emissions of climate-change gasses.

A complete BIPV system includes PV modules (thin-film or crystalline, transparent, semi-transparent, or opaque); a charge controller, to regulate the power of the battery storage bank (in stand-alone systems); a power storage system; power conversion equipment; backup power supplies such as diesel generators and appropriate support and mounting hardware, wiring, and safety disconnects.

2.1 BIPV categorization

BIPV Foil Products - flexible and lightweight products which can be easily installed on the roof systems. The PV cells are often made from thin film cells to maintain the flexibility in the foil and the efficiency regarding high temperatures for use on non-ventilated roof solutions.



a) b) c) d)

Fig. 1 Examples of BIPV categorization; a) Example of BIPV foil; b) Example of BIPV tile; c) Example of BIPV module; d) Example of solar cell glazing products

BIPV tile products - may cover selected parts of the roof or the entire roof. They are arranged in modules with the appearance and properties of standard roof tiles and substitute a certain number of traditional roof tiles. The type of cell and shape varies.

BIPV Module Products – similar to conventional PV modules. Main difference is that these modules are made with weather skin solutions (Fig. 1).

Solar Cell Glazing Products - BIPV as solar cell glazing products provide a great variety of options for windows, tiled or glassed facades and roofs. Different transparencies and colors can make many different aesthetically solution possible.

2.2 Application of BIPV systems

There are three main application of BIPV systems: flat and curved roofs, pitched roofs and facades.

Flat or curved roof are also known as "continuous roofs" and it is characterized by an uninterrupted layer. This layer has a main function to be water resistant. Solar floors, flexible membranes and other solutions can be easily used for integrating PV into the building envelope. Categories within the roof system application area include: solar glazing, metal panels, PV membranes and solar glazing [1].

Pitched roofs are also known as a "discontinuous roofs" which provide the best energy harvesting. This method of roof construction is common all over the world and it is perfectly suitable for PV modules because of its size, inclination, orientation towards the sun and easiness of install. Over the last years, a lot of constructive solutions have been developed [7]. For BIPV roofing solutions the crystal silicone and thin film technologies are available. Categories include: in-roof mounting systems, full roof solutions, large tiles, small tiles, metal panels and solar glazing.

Facade is conventionally made up of walls, cladding, glazing and fenestrations. Facade also include other structures like shading devices, balconies and parapets. Increasing demands in terms of energy efficiency in buildings result in an increase in the use of PV in the facade segment. PV acts as a substitute for traditional materials in the most common facade systems (e.g., warm facade, cold facade and curtain walls - Fig. 2), both opaque or transparent.

3 BIPV systems - Case study of BIPV implementation at the Faculty of engineering in the city of Kragujevac

This paper presents a case study architectural solution of BIPV implementation at Faculty of engineering in the city of Kragujevac. During the building analysis, various applications of the BIPV system are considered.

The Faculty of Engineering in Kragujevac consists of 4 separate buildings - A, B, C and D. The subject of this paper is the main building D of the faculty, which was built in 1962. In block A there are a central hall, administration rooms and classrooms on the first and second floors. In block B there are classroom classes, laboratories, while in the basement there are warehouses, substations and garages. Block C contains cabinets for professors and faculty associates. The amphitheater is located central building D.

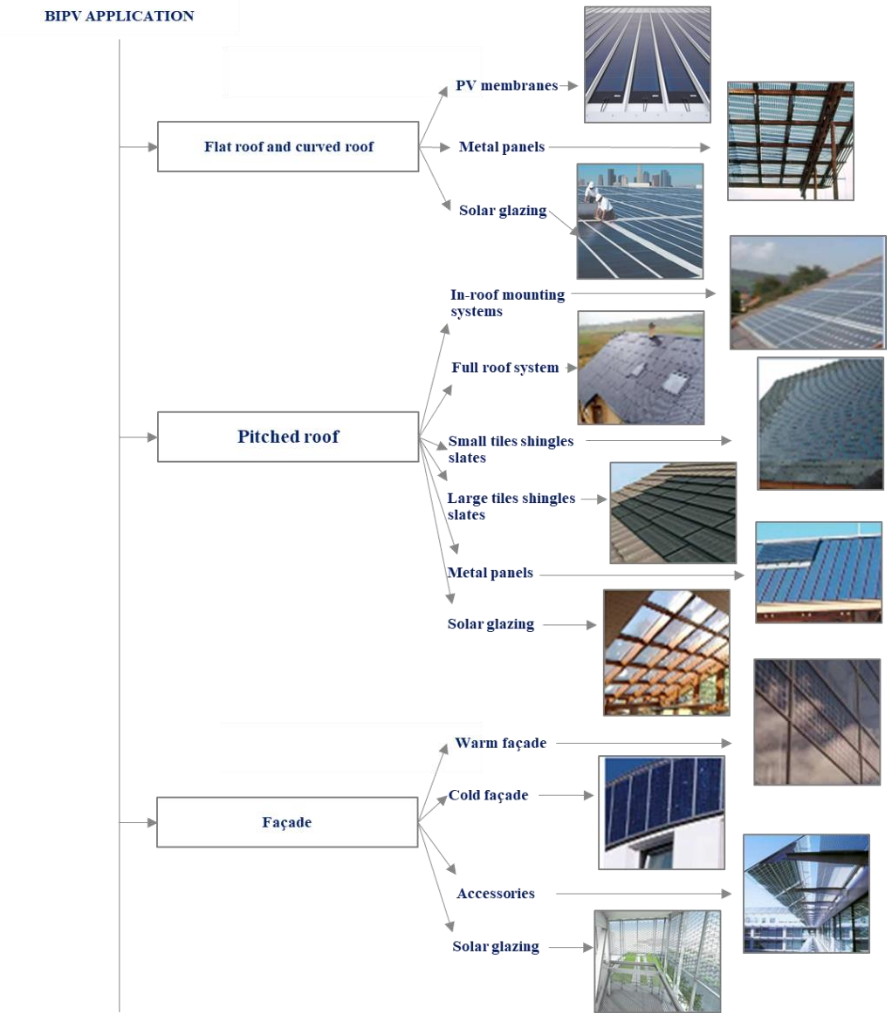


Fig. 2 The BIPV segmentation used in this paper [2]

This central building D is located in the northwestern part of the city alongside the city park. The building is very old and in the near future will require reconstruction. This paper represents one of the possibilities of renovating the building by implementing BIPV system. BIPV does not represent any standardized, hard-defined industrial product. It provides the whole range of potential applications of PV in construction, based on the integration of various multifunctional PV elements into the building envelope. The integration of these systems modernizes the appearance of the faculty itself. Important advantage is that the building is not in the shadow of other nearby objects, which makes the building suitable for integrating PV modules. As mentioned earlier, there are various possibilities of applying the BIPV system: roofs, facades, urban structures. This case study discusses each of the possible applications on the building of the Faculty of Engineering (Fig 3). The size of the object affects on the need for massive reduction of heat losses through the high insulation of the building envelope. This means that in such large buildings the roof space is not enough for integrating PV when aiming to the greatest reduction in energy consumption.

Blocks D and C have a flat roof which is ideal surfaces for applying the BIPV. In this case study, on a flat roof of block B it is placed the structures that slopes the BIPV panels towards the sun. These systems are mounted on top of the roof. They are mounted above and parallel to the roof surface with a standoff of several centimeters. The ideal case is to install these systems facing north-south orientation in order to increase the amount of solar energy received.

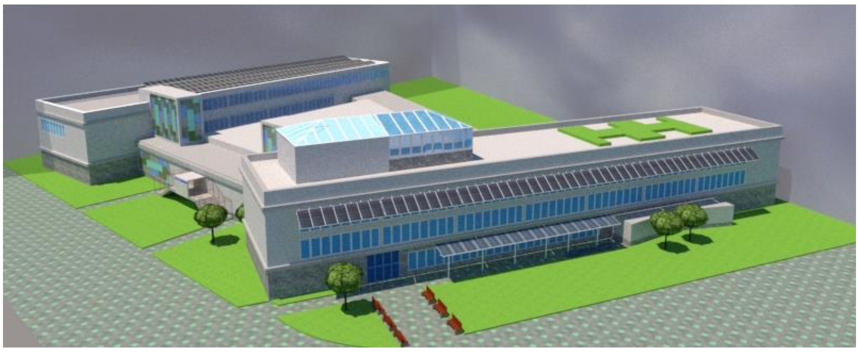


Fig. 3 – BIPV implemented at the building of Faculty of engineering

On a flat roof of block D, there are a glass classroom and green roof (Fig 4). The roof is partially covered with vegetation. Green roofs are suitable for reconstruction projects, and in addition they contribute to sustainability. The roof of this classroom is completely transparent. As roof-integrated transparent modules it is usually used glass-glass laminates without frame it is used. For Special roof types like curved roof plastic laminates are used. Crystalline cells are the most common solution - the transparency rate is defined by the distance between the solar cells [8]. On this way, a "roof window" was formed. This classroom should help students to understand the functioning of the BIPV system and the possibilities for their implementation.

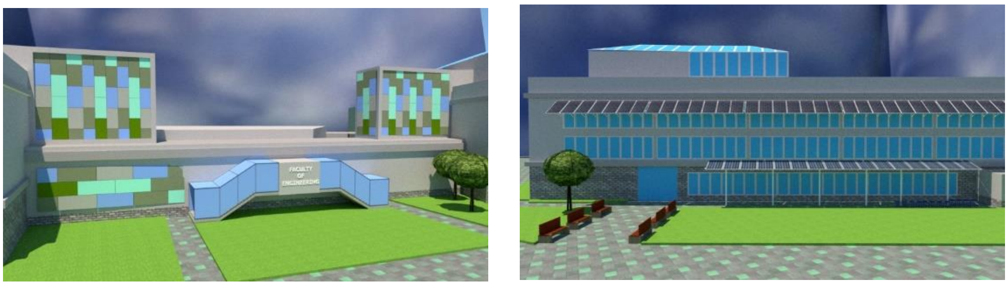


Fig. 4 – BIPV as shading devices at the building of Faculty of engineering

The facade mounting techniques can be performed in a variety of ways. Two typical types are mounting the BIPV in the plane of the façade in the curtain wall and the mounting of the BIPV in a way that provides window shading. If done properly, the window shading technique has the ability to provide passive solar heating and lighting in the winter and cooling in summer, in addition to generating electricity. BIPV systems are placed in the facade of the building blocks of the Faculty of Engineering. Since PV is fully integrated into the complex structure of envelope, when using highly-glazed curtain walls, the energy parameters related to solar gain control such as visual and thermal comfort are strictly related to the PV. Similarly, to skylights, the transparent functional layer (glass) is replaced with an active glazed pane including PV, while the bearing part is represented by a frame. These glazing areas provide a natural illumination and also, they are saving by reducing the need of using artificial lighting [9]. For this purpose, a semi-transparent thin film photovoltaic glass can be used on glazing systems refurbishment (Fig 4). The photovoltaic glazing filters up to 99% of the UV radiation. Various colors, thickness and transparency of the PV module are available.

The "solar accessories" also can be integrated into the building. These elements may include: balconies, outdoor parapets, shading systems and several other elements. Shading systems can be placed above the windows of the classrooms. They represent the most frequently used accessory. Control of the indoor microclimate, especially in classrooms with a large window surface, usually requires the use of the shading system. Shading devices may be of various type: applied on façades or even roofs, and they can be fixed or movable. Manual tracking-combined with shadowing system, or automatic tracking systems can be realized.

4 Simulation results

Using the EnergyPlus program, simulations of the application of the BIPV system were carried out at the D building of the Faculty of Engineering Sciences.

EnergyPlus software simulates the energy use in building and energy behavior of the building for defined period. EnergyPlus is made available by the Lawarence Berkley Laboratory in USA [10] and it has been tested using the IEA HVAC BESTEST E100-E200 series of tests [11]. For PV electricity generation, EnergyPlus uses the three different PV models and model of inverter [12]. Open Studio plug-in Google SketchUp software is a free 3D software tool that combines a tool-set with an intelligent drawing system [13]. The OpenStudio is free plug-in that adds the building energy simulation capabilities of EnergyPlus to the 3D SketchUp environment.

The Faculty of engineering is located at Kragujevac, in Serbia. Kragujevac lays in Balkan Peninsula. Its average height is 209 m above sea-level. The longitude of Kragujevac is 20.55℉, and the latitude is 44.1℉. The time zone is GMT+1.0 h. The summers are worm and humid with temperatures as high as 37℃. The winters are cold with snow and temperatures as low as -19℃. The EnergyPlus uses weather data from its own database file [14].

This study analyzed the possibilities of generation electricity of the embedded BIPV panels on Faculty of Engineering. This simulation analyzes embedded BIPV systems on windows and shading systems. On the window of object D, active glazed panes that include PV are oriented towards the west, with a total area of 2 x 34 m^2. BIPV shading systems are placed above the window and the main entrance in the building of the D object, and they are oriented to the south (area 45 m^2). The efficiency of the embedded BIPV panels is 10% [15]. The results obtained by the simulation are presented in the table 2.

Table 2. Simulation results

	BIPV, Area [m2]	Generated electricity [GJ/year]	Generated electricity, [kWh/year]	Savings, [RSD/year], [16]
Windows	68	22.4	6222.2	95386.326
Sunshade systems	45	24.7	6861.1	105180.663
Total	113	41.1	13083.3	200566.989

By implementing these BIPV systems on windows of object D, Faculty of engineering, it is possible to generate 6222.2 kWh per year of electricity. By implementing sunshade systems above windows, it is possible to generate 6861.1 kWh per year of electricity. These BIPV systems can, in total, generate 13083.1 kWh per year of energy. That means that these systems can bring financial savings from 200 567 RSD/year.

The BIPV system cost depend on the size and type of system, on current PV technology, and on whether a standardized manufactured product or a custom product is used.

The cost includes items, such as the cost of the structural system (e.g. structural installation, racks, site preparation and other attachments), the electrical system costs (e.g. the inverter, transformer, wiring and other electrical installation costs) and the battery or other storage system cost in the case of off-grid applications.

Conventional façade technologies include fibrocement, brick-ceramic, metal, stone, wood, window, solar shading systems and curtain walls. Prices range all the way from 350 – 1000 €/m^2 for windows system. The price of the systems varies to 750 €/m^2 for a high-end PV solar shading system [15]. So, the cost of the implementation of these systems are:

$$\text{Windows} = 68\ m^2 * 500\ €/m^2 = 34000\ €$$

$$\text{Sunshade systems} = 45\ m^2 * 750\ €/m^2 = 33750\ €$$

The size and numbers of inverters required depend on Installed Cost balance of system the installed PV capacity and system design options. Inverters are the primary power electronics components of a PV system and typically account for 5% of total installed system costs [17]. Inverter =

0.512 €/Wp represents the average price for the inverter per the unit of the rated power [18]. For the total generated electricity, 13083.3 kWh, which is 1493.5 W, the price of inverter is:

Inverter = 1493.5 W * 0.512 €/Wp = 765 €

The total price of investment is:

Total price: 34000 € + 33750 € + 765 € = 68515 €.

The payback period for an energy system is calculated as the total investment cost divided by the revenues from energy saved, displaced, or produced.

Payback time for saving of 200566.989 RSD/year, which is 1699.72 €/year if 1 € is 118 RSD, is:

Payback = 68515 / 1699.72 = 40.30 year

This analysis has shown that the payback time for implementation of these BIPV systems at the building of the Facultie of engineering is 40 years. Due to the high price of PV technology, especially the BIPV system, which represent new products on the market, the value of investment is high and, also it is large payback period.

But, when generating electricity, BIPV systems produce no harmful environmental emissions.

5 Conclusion

Interest in the building integration of photovoltaics, where the PV elements actually become an integral part of the building, often serving as the building envelope, is growing worldwide. This paper shows the classification of BIPV systems through the case study of implementation of building integration photovoltaics at the one of buildings of Faculty of engineering in the city of Kragujevac. Building-integrated photovoltaics combine function with form, featuring solar panels that generate electricity and blend in with their surroundings. That's not an easy combo, since a solar panel's efficiency and aesthetics are often inversely proportional. Variation in products and integration possibilities could result in aesthetic appealing buildings.

Due to the increase in the demand of energy, the major area of concern is to utilize the renewable energy resources. Integration of PV system on buildings will make them able to generate at least part of power for their requirement and it will reduce the overall load on utility grid and transmission lines. From the simulation result, it has been found that integrated BIPV systems at Faculty of engineering can save 200567 RSD/year. Although, due to high price of these technologies the payback time is 40 years, it is expected that the price of the BIPV system will decrease in the near future, which will enable bigger implementation of these systems into buildings, which will also mean that the payback time will be faster. BIPV system can play significant role for designing of energy efficient of existing building.

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