Zbornik radova
Proceedings

8. Međunarodna konferencija
o obnovljivim izvorima električne energije
Beograd, 16. oktobar 2020

8th International Conference
on Renewable Electrical Power Sources
Belgrade, October 16, 2020

ZBORNIK RADOVA
Proceedings

pisanih za 8. Međunarodnu konferenciju o obnovljivim izvorima električne energije

8th International Conference on Renewable Electrical Power Sources

CIP - Каталогизација у публикацији - Народна библиотека Србије, Београд

502.171:620.9(082)(0.034.2)

MEĐUNARODNA konferencija o obnovljivim izvorima električne energije (8 ; 2020 ; Beograd)

Zbornik radova [Elektronski izvor] / 8. Međunarodna konferencija o obnovljivim izvorima električne energije, Beograd, 16. oktobar 2020 ; [urednik Zoran Stević] = Proceedings / 8th International Conference on Renewable Electrical Power Sources, Belgrade, October 16, 2020 ; [editor Zoran Stević]. - Beograd : Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije - SMEITS, 2020 (Beograd : Paragon). - 1 elektronski optički disk (CD-ROM) ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 150. - Abstrakti. - Bibliografija uz svaki rad.

ISBN 978-86-85535-06-2

a) Енергетски извори - Одрживи развој - Зборници

COBISS.SR-ID 25077513

2020

ZBORNIK RADOVA
pisanih za 8. Međunarodnu konferenciju o obnovljivim izvorima električne energije
Hotel „Zepter“, Beograd
16. oktobar 2020.

PROCEEDINGS
8th International Conference on Renewable Electrical Power Sources
Hotel „Zepter“, Belgrade
October 16, 2020

Izdavač
Savez mašinskih i elektrotehničk ihinženjera i tehničara Srbije (SMEITS)
Društvo za obnovljive izvore električne energije
Kneza Miloša 7a/II,
11000 Beograd

Publisher
Union of Mechanical and Electrotechnical Engineers and Technicians of Serbia (SMEITS)
Society for Renewable Electrical Power Sources
Kneza Miloša str. 7a/II,
11000 Beograd

Predsednik Društva za obnovljive izvore električne energije pri SMEITS-u
Dr Zoran Nikolić, dipl. inž.

President to the Society for Renewable Electrical Power Sources within the SMEITS
Zoran Nikolić, Ph. D.

Urednik
Prof. dr Zoran Stević

Editor
Prof Zoran Stević, Ph. D.

Za izdavača
Vladan Galebović

For Publisher
Vladan Galebović

Tiraž
150 primeraka

CD umnožava
Paragon, Beograd

ISBN
978-86-85535-06-2

Organizator
Organizer

Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije (SMEITS),
Društvo za obnovljive izvore električne energije

Union of Mechanical and Electrotechnical Engineers and Technicians of Serbia (SMEITS),
Society for Renewable Electrical Power Sources

Kneza Miloša 7a/II, 11000 Beograd
Tel. +381 (0) 11 3230-041, +381 (0) 11 3031-696, tel./faks +381 (0) 11 3231-372
office@smeits.rs • www.smeits.rs

Održavanje 8. MKOIEE finansijski je pomoglo
Ministarstvo prosvete, nauke i tehnološkog
razvoja Republike Srbije

Međunarodni programski odbor
International Programme Committee

Prof. dr Slađana Alagić	Srbija
Prof. Viorel Badescu	Rumunija
Prof. dr Pellumb Berberi	Albanija
Prof. dr Miroslav Bjekić	Srbija
Prof. dr Oleksandr Bondarenko	Ukrajina
Prof. dr Alla Denysova	Bugarska
Dr Stevan Dimitrijević	Srbija
Akademik prof. dr Zoran Đurić	Srbija
Dr Aleksandar Ivančić	Španija
Prof. dr Miroljub Jevtić	Srbija
Prof. dr Branko Kovačević	Srbija
Prof. Vladimir Krstić	Kanada
Prof. Nikolay Lopatkin	Rusija
Prof. Nikolay Mihailov	Bugarska
Prof. dr Milica Naumović	Srbija
Prof. dr Stefka Nedeltcheva	Bugarska
Dr Dušan Nikolić	Australija
Dr Zoran Nikolić	Srbija
Prof. dr Elena Ponomaryova	Ukrajina
Dr Mila Pucar	Srbija
Prof. dr Nikola Rajaković	Srbija
Prof. dr Birgit Scheppat	Nemačka
Prof. dr Valerij Sytnikov	Ukrajina
Prof. dr Velimir Stefanović	Srbija
Prof. dr Zoran Stević	Serbia (predsednik)
Prof. dr Zoran Stojiljković	Srbija
Prof. dr Volodymyr Sydorets	Ukrajina
Prof. dr Nada Štrbac	Srbija
Prof. dr Dragan Tasić	Srbija
Prof. dr Michael Todorov	Bugarska
Dr Nataša Tomić	Srbija
Dr Milica Vlahović	Srbija
Dr Zhongying Wang	Kina
Dr Wanxing Wang	Kina
Dr Xuejun Wang	Kina
Prof. dr Hengzhao Yang	SAD
Dr Ruiying Zhang	Kina

Organizacioni odbor
Organizing Committee

Mila **Pucar**
Rastislav **Kragić**
Zoran **Nikolić** (*predsednik*)
Ilija **Radovanović**
Žarko **Ševaljević**
Jelena **Salević**
Vladan **Galebović**

3. Energija vetra

4. Solarna energija

MOGUĆNOSTI IMPLEMENTACIJE FOTONAPOSNKIH SOLARNIH PANELA U PODRUČJIMA NAMENJENIM VIŠEPORODIČNOM STANOVANJU

THE POSSIBILITIES FOR IMPLEMENTATION OF PHOTOVOLTAIC SOLAR PANELS IN MULTI-FAMILY HOUSING AREAS

Borjan BRANKOV[*1], Ana STANOJEVIĆ[2], Mila PUCAR[1], Marina NENKOVIĆ-RIZNIC[1]

[1] Institute of Architecture and Urban&Spatial Planning of Serbia, Belgrade, Serbia

[2] Faculty of Civil Engineering and Architecture, University of Niš, Serbia

https://doi.org/10.24094/mkoiee.020.8.1.167

Usled dinamičnije promene klime i porasta broja ljudi u gradovima obnovljivi izvori energije (OIE) sve više doprinose racionalnijem korišćenju energije. Imajući u vidu značaj koji upotreba OIE u stanovanju donosi u pogledu finansijske uštede i smanjenja emisije CO_2*, rad ispituje mogućnost upotrebe OIE u područjima višeporodičnog stanovanja sa aspekta sakupljanja i konverzije solarne energije odnosno implementacije fotovoltaičnih panela i generisanja električne energije. Kod višeporodičnog stanovanja, problem održivosti i primene OIE je složen zadatak, prvenstveno zbog postojećih načina korišćenja prostora i vlasništva koje je višeslojno, ali i postojanja potrebe za aktivnim uključenjem cele stambene zajednice u procesu donošenja odluka i pokretanja inicijativa. Istraživanje analizira prednosti i mane za postavljanje solarnih panela i to na krovovima i fasadama objekata, i u okviru zajedničkih otvorenih prostora u bloku, postavljanjem solarnih svetiljki, solarnog napajanja za električna vozila, solarnih punjača itd. Ispitivanje mogućnosti za korišćenje solarne energije sprovedeno je na primeru stambenog Bloka 29 na Novom Beogradu, urbanističkom analizom uz podršku odgovarajućih podataka o solarnoj radijaciji za analizirano područje i softvera Skelion i PVGIS-a za numeričku i grafičku ilustraciju količina energije koje je moguće dobiti postavljanjem fotonaponskih solarnih panela. Rad sagledava dva različita scenarija: kada se paneli instaliraju na krovovima stambenih objekata i kada se oni postavljaju na otvorenim prostorima, istovremeno analizirajući potencijale svakog od njih i preduslove za njihovu realizaciju u praksi. Dobijeni rezultati imaju za cilj da uporede kolicine elektricne energije dobijene proracunom za dva različita scenarija.*

Ključne reči: *solarna energija, fotovoltaični solarni paneli, električna energija, višeporodično stanovanje, stambeni blok, Novi Beograd*

Due to the increasingly dynamic climate change and the increase in the number of people in cities, renewable energy sources (RES) are contributing to a more rational use of energy. Given the importance that the use of RES in housing directly brings in terms of financial savings and reduction of CO2 emissions, the paper examines the possibility of using RES in multi-family housing from the aspect of solar energy collection and conversion respectively implementation of photovoltaic panels and electricity generation. In multi-family housing, the problem of sustainability and implementation of RES is a complex task, primarily due to the existing ways of using space and ownership, which is multi-layered, but also the need for the active involvement of the entire housing community in decision-making and initiatives. The research analyzes the advantages and disadvantages of installing solar panels on the rooftops and facades of buildings, and within the common open spaces in the block, by installing solar lamps, solar power for electric vehicles, solar chargers, etc. The examination of the possibilities for using solar energy was conducted on the example of the residential Block 29 in New Belgrade, using urban analysis supported by appropriate data on solar radiation for the analyzed area and Skelion software for a numerical and graphical illustration of the amount of energy that can be obtained by installing photovoltaic solar panels. The paper considers two different

[*] Corresponding author, email: sanja.borjan@iaus.ac.rs

scenarios: when panels are installed on the roofs of buildings and when they are installed in open spaces, analyzing the potential of each and the prerequisites for their implementation in practice. The results aim to compare the quantities of electricity obtained by calculation for two different scenarios.

Key words: *solar energy, photovoltaic solar panels, electrical energy, multifamily housing, housing block, New Belgrade*

1 Introduction

Renewable energy sources (RES) are an indispensable part of sustainable postulates of urban development and modern life, which, in addition to a high standard, also require the protection of the environment and the active struggle of humanity against climate changes. Globally, many cities are leaders in the use of new RES within the dense urban matrix. Solar technology based on the use of ecologically clean solar energy in the form of light and heat, which is used by conversion to obtain heat or electricity, is the most common form of using RES. Namely, solar radiation is available all over the planet, while nowadays technological progress enables simple and financially cost-effective energy independence of users from connections to the electricity distribution network and the provision of hot water from an energy source that does not emit harmful gases. Sustainable solutions that rely on solar design are increasingly present in single-family housing, applying passive principles of energy transmission and accumulation, as well as installing solar panels on the rooftops of buildings. Given that passive solar systems require adequate considerations in the earliest stages of urban planning and design, implementing bioclimatic principles [1], improving the energy performances of already built facilities, and reducing energy consumption in residential and working spaces is often achieved using active solar systems [2].

Active solar systems mean the use of solar thermal or photovoltaic receivers for the conversion of solar energy into heat or electricity [3]. Solar collectors and panels are most often installed on the rooftops of buildings, on their facades, or the ground. Drawing energy from the Sun to heat water and air, through different types of collectors, is one of the oldest forms of using solar energy. Nowadays, solar water heating systems are used in single-family housing, educational institutions, restaurants, hospitals, agricultural buildings and for the needs of various technological processes in industrial production where large amounts of hot water are used [4]. The absorbed solar energy is successfully transformed into energy that heats the air inside the building, using advanced SolarWall technologies [5]. Nevertheless, the researches show that photovoltaic power is the strongest growth of all RES technologies, with recent annual growth rates of around 40% [6]. In Europe, the average amount of electricity generated per year from solar radiation on one square meter of horizontal ground surface is 1.000kWh [7]. Photovoltaic (PV) solar panels composed of photovoltaic cells in which there is a difference in the electric potential after the sun shines on their surface, and direct conversion into electricity, are most often placed on the rooftops. Merging the cells in several rows leads to the desired energy characteristics of solar panels, which also depend on the type of photovoltaic cell or its chemical composition [8]. For buildings that are located away from the distribution network, it is possible to form a self-contained, independent photovoltaic system (for example single-family buildings). Photovoltaic systems connected to the distribution network, i.e. solar power plants, are used in buildings with a larger roof area or are built as independent plants.

The number of hours of solar radiation on the territory of Serbia is between 1500 and 2200 hours per year, with an average intensity of solar radiation 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 the month of July [9,10]. Based on the currently available electricity capacities in Serbia, for the provision of tertiary reserves, the maximum usable capacity of solar power plants is 450 MW i.e. their technically usable potential is 540 GWh/per year (0.046 million toe/per year) [10,11]. By Decrees on incentive measures for the production of electricity from renewable sources from 2009, 2013, and 2016, the RS Government provided the opportunity to build solar power plants on the territory of the country using subsidies, whereby such plants become economically viable with a return on an investment after a period of six years. From 2009, when the National Action Plan for the Utilization of Renewable

Energy of RS was adopted in the legislative sense, which encourages investment in renewable energy sources, until October 2016, 104 solar power plants with a capacity of 8.8 MW were built [12].

Given the fact that practice shows that solar panels are most often used in single-family housing, as well as in larger public and industrial buildings, the paper explores the possibilities of using solar energy in the field of multi-family housing. Searching for realistic options for the implementation of photovoltaic panels in housing blocks, the paper aims to test the capacity of contemporary multi-family housing in Serbia and their associated open spaces for the use of solar power energy based on PV systems. Testing the possibility of generating electricity using a renewable source of solar radiation was conducted on the example of Block 29 in New Belgrade with the support of PVGIS and Skelion software [13]. The research compares two possible scenarios:

- Scenario 1: installation of PV panels on the rooftops of the buildings;
- Scenario 2: installation of PV panels within common open spaces.

The paper takes into account various parameters on which the final energy characteristics of solar power plants significantly depend: quality and length of solar radiation exposure in a given area, depending on the season and meteorological conditions, availability of solar panels on the national market, type of photovoltaic solar panel - in terms the type of solar cell being used.

2 Multi-family housing and RES in Serbia - the case study of Block 29 in New Belgrade

Housing has always been a dynamic space, while various intensified changes in cities, society, and family structure lead to more condensed housing in cities and changes in user patterns. In that sense, housing is often an ideal polygon for possible "upgrading" of how space is designed and used. Multi-family housing has always followed residents' needs and overall shifts in global changes and demands in the residential sphere. In the contemporary context, the change in the use of multi-family housing is mutually conditioned by social and other changes both in Europe and later at the global level. Possibilities and progress of the architectural design of multi-family assemblies are related to the current needs of solving social and spatial problems, both in different periods of the 20th century and today. Multi-family housing in the second half of the 20th century in former Yugoslavia is a good example of experimenting with new and improved functions and spatial dispositions as it was also focused a lot on the well-being of residents through different dwelling and common areas design [14,15].

The improvement of energy resources and the possibility of introducing PV panels as a common good of all tenants is one of the possible new common benefits. On the one hand, common functions generally tend to improve the comfort and possibilities of a multi-family housing complex by offering additional collective facilities to users and raising the quality of living space [16]. Emphasizing the better use of the building is an important aspect of multifamily housing, with residents expanding their sphere of privacy outside the dwelling [17]. The use of common energy resources of the building for tenants can mean a better understanding of the potentials of the building (spatial and energy potential). Therefore renewable energy sources in housing can show the importance and value of common space and the significance of the community to an individual resident. This paper also examines the possibility of how a residential complex can be upgraded in terms of energy efficiency during its lifetime and how much the collective sphere of space in multi-family housing can be an advantage over individual housing.

The focus of this paper analysis is the residential complex Block 29, which is located in the northwestern part of the central zone of New Belgrade (Fig. 1). The block is divided into two parts: the residential part of the block and the part for the regional center (which was never built and its place occupied a newer residential complex after the 2000s). The focus of the analysis in the paper will be only the original residential part of Block 29. DOCOMOMO Serbia has included this Block in its Atlas of housing as modern heritage in Serbia and emphasized its significance [18].

The competition for the design of Block 29 was announced in 1967, and the construction of Block took place in the period from 1969 to 1974. The designer of the urban solution of the Block is Milutin Glavički, while the authors of the building designs are the architects Dr. Mihailo Čanak and

Milosav Mitić. The contractor for Block 29 was the construction company "Rad" from Belgrade. The structure of the residential part of the block consists of 7 residential buildings, each with 7 above-ground floors, built in the IMS system, with a total of 1129 apartments and a projected population of 4358. Within the block, there is a local community building (today it is also a commercial space) and kindergarten, while the planned primary school was never built [15,19]. The residential buildings in the block are in the form of a two-lane road (Fig. 1,2). Open spaces include the central zone of the park, the zones around residential buildings, and along the perimeter of the block, as well as the basketball court. Road traffic is solved along the perimeter of the block, while the central part of the block is mostly reserved only for pedestrians.

Figure 1: View of the Block 29 residential complex
Source: https://mapio.net/pic/p-15908646 (left) https://www.designed.rs (right)

Within residential buildings, the architects used the parallel two-track so that in the communication zone (staircase and elevator) the space next to the apartments would not be a corridor but a common space for apartment owners (four apartments on the floor - common areas for two neighboring apartments) [15]. All residential buildings have the same number of floors and a sufficient distance between them, which why they are suitable for installing photovoltaic panels on their roofs (Fig. 2). The double tract in this case also corresponds to the fact that, in relation to the residential towers, it has more roof area, with a larger flat surface for the panels. However, on the other hand, the buildings are compact enough in the sense that the number of the residents and organization of one building for these types of energy improvements is feasible and the panels can be partially done from building to building. Compared to, for example, Blocks 21 and 28, buildings are mostly towers or long lamellas and it significantly increases the organization, and agreement between residents can be more complicated. This type of intervention overall enables better participation of users in the use of common space/resources and direct benefits within the living space, and the paper proposal includes two levels of common spaces (roofs and open spaces) [20].

3 Research Metodology

The methodology framework for this study was formulated in four main stages: (1) analyzing the solar radiation and urban morphology of the study area; (2) defining possible scenarios for implementing PV panels; (3) choosing the market available type of solar panels to be installed; (4) modeling solar gains using PVGIS and Skelion software.

3.1 Analyzing the solar radiation and urban morphology of Blok 29

The older multi-family housing part in Block 29 is situated in the zone of New Belgrade at N 44°49’latitude and E 24°25’ longitude. Regarding solar energy potential, as the main precondition for the construction of solar power plants, the territory of New Belgrade is suitable for the use of active solar systems in the form of PV panels. Namely, in Belgrade, the annual average daily solar radiation received on a surface ranges between 3,76kWh/m^2 and 3,86kWh/m^2 [21]. The highest amount of solar energy is available in the period between April and September. The mean solar power per unit area per year (global solar radiation on a horizontal surface) is approx. 1.300 to 1.400kWh/m^2 per year, while average daily solar radiation received on a horizontal surface ranges from 3,4 to 4,0kWh/m^2. There are 2019 sunny hours per year, with an average cloud coverage of 5-6%. Previous data indicate the convenience of using solar energy in the study area. The optimum angle for installing the PV panels in the area of New Belgrade is 44°. To maximize the electricity production, it is necessary to install PV panels at an angle of 35°, thus adapting the angle to the summer period and using this period of higher radiation to the maximum extent [21]. During the construction, solar panels should also be oriented towards the south.

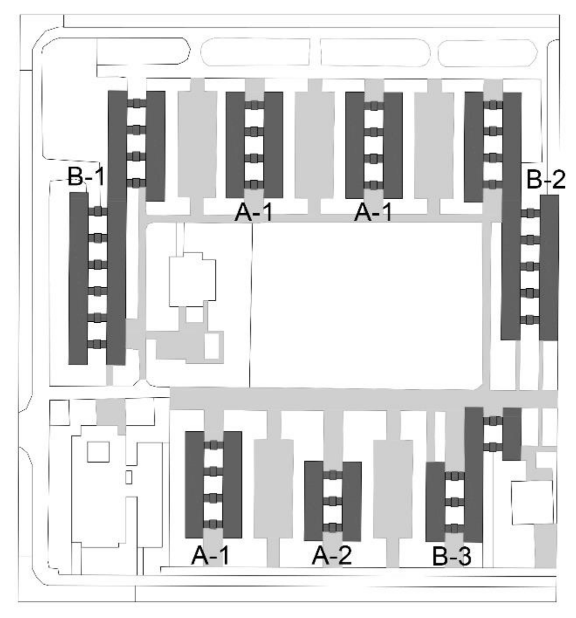

Figure 2: Urbanistic map with disposition of multi-family housing divided by type into A (compact) and B (longer and more complex) and its subtypes Source: Authors

Residential buildings organized in the form of parallel two-trackt, extend on their longer side in the direction northeast-southwest, with a deviation of 33° to the north, providing good insolation within the block and housing units. The distance between the residential buildings is optimally 33m, so there is no danger of creating a shadow between them, which would cover their roofs. The total area of the part of the Block that is the subject of analysis in the paper is 89.178m^2, where the area of the block under the buildings is 15.347m^2 while the open common areas occupy an area of 73.830m^2.

3.2 Defining possible scenarios for implementing PV panels

The urban analysis of the area of Block 29, which included the analysis of the orientation of the buildings, their position on the plot, distances and character of non-residential facilities and open common areas, has defined two possible scenarios for the implementation of solar power plant (PV panel installation). *Scenario 1* involves the installation of PV panels on all rooftops of multi-family housing buildings in the block, assuming that the generated electricity delivered to the distribution network is deducted from the electricity consumed in the housing units in the buildings, reducing the financial costs of users (Fig. 3). *Scenario 2* concerns the installation of solar panels on public areas, where we recognized the possibility of integrating panels within pedestrian paths and their installation in the part of the area intended for parking, assuming that parking zones will be covered with canopies (Fig. 3). The obtained electricity would either be deducted from the costs of electricity in housing units, or would be used in part or in full to illuminate the area. The conducted research did not consider the possibility of installing panels on public buildings in the complex (kindergarten, business-commercial building), nor the possibility of creating solar trees, and similar solar design solutions within the outdoor urban space for recreation.

3.3 Choosing the market available type of solar panels

For the paper purposes, the use of stationary PV panels is adopted. Due to the fact that the surfaces of all roofs of residential buildings are flat, Scenario 1 requires the use of free-standing PV panels, while the panels will be integrated into the path surfaces in Scenario 2. It is assumed that the parking lot will be covered with a construction that will have a flat roof, suitable for free-standing PV panels. The availability of solar panels on the national market is an indispensable factor in the process of creating a solar power plant project. The Serbian market offers a large number of PV panels that serve the smaller needs of users (for example weekend houses), but also offer the construction of power plants that can seriously contribute to energy independence. Individual PV panels are sold in different dimensions: 35x48.5cm; 67x46,5cm; 67x84,5cm; 67x148cm; 99x165cm etc., while based on their technology, they can be made of mono or poly-cristal structure, or rarely as thin-film panels. Their price depends on their dimensions and power, and it goes from 3.500 to 32.000 dinars. Some of the panels that are uslually used in Serbia are: MONO 310W EXE (mono-crystal, 1658x990mm, 310Wp, 18.35% effiency), EXE Solar EXP285 (poly-cristal, 1650x991, 285Wp, 17,50% eff.), LX270P Luxor (poly-cristal, 1640x992, 270Wp, 16,63% eff.), etc. For the simulation research purposes we chosed the solar panels Sanyo Electric HIP-270NJE1 (mono-cristal, 270Wp, 16,2% eff.) to be installed on the rooftops of the multi-family buildings and on the canopy of the parking space, with the dimension of single one 1600x100mm. For the pedestrian paths we have used Solar Roadways panels (270Wp) which is not available on our market yet, but are the most effective type of the panels that can be walked or even driven upon.

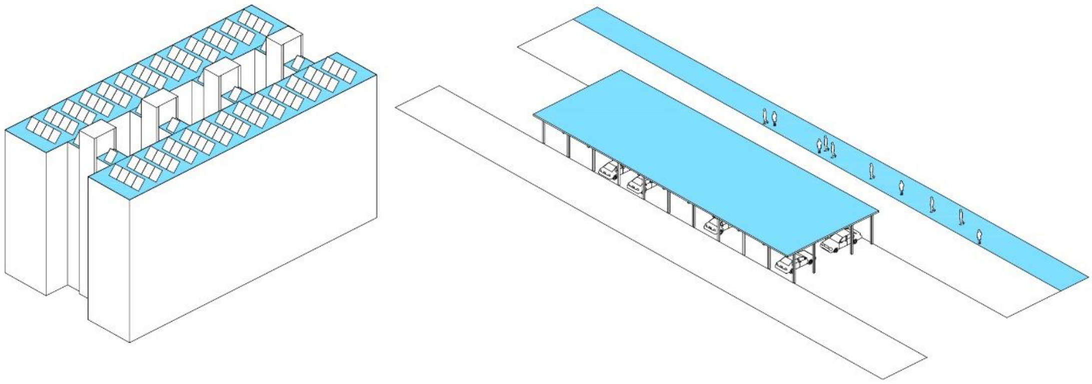

Figure 3: Scenario 1(left) - installation of PV panels on all rooftops of multi-family housing buildings in the block, Scenario 2(right) - installation of solar panels on public areas in the complex – parking canopies and pedestrian pathways Source: Authors

4 Results - Modelling energy gains provided by solar panels

The amount of electricity generated using the solar panels for set scenarios is calculated using the PVGIS (Photovoltaic Geographical Information System) and Skelion software, which is used as a plug-in for the Sketch up program. The calculation is conducted for the shadows at winter solstice noon 21.12.2020. (Fig. 4). In Tables 1, the analytic date gain from Skelion simulation for Scenario 1 are given, representing number of installed panels and they total power, and price per different types of buildings in block and in total. Table 2 represents the analytic date gain from PVGIS for Scenario 1 with average monthly electricity production (Em) and average monthly sum of global irradiation per square meter received by the modules of the given system (Hm), per months. In Tables 3 and 4 the same type of analytic date using Skelion anf PVGIS are presented for Scenario 2.

Figure 4: Modelling of PV panels on all rooftops of multi-family housing buildings and on public areas in the complex – parking canopies and pedestrian pathways Source: Authors

Table 1: The analytical data gain from Skelion simulation of creating solar power plant on the rooftops of the buildings (PV panel: Sanyo Electric HIP-270NJE1, nomilan power 270W)

Scenario 1	**Roof area [m²]**	**No.**	**No. of panels**	**Total power [kW]**	**Energy [kWh]**	**Yield [kWh/kWp]**
Rooftop A-1	1.240	3	356	96,12	113.159	1177,27
Rooftop A-2	930	1	264	71,28	83.887	1176,88
Rooftop B-1	3.085	1	865	233,55	276.606	1184,35
Rooftop B-2	2.780	1	799	215,73	253.916	1177,01
Rooftop B-3	1.500	1	442	119,34	140.424	1176,68
In total*	**12.015m²**		**3438**	**928,26**	**1.094,31**	**8.246,73**
*the total values consider all buildings in area including three buildings type A-1						

Table 2: The analytical data gain from PVGIS for Scenario 1
(Em- kWh/month; Hm- kWh/m²/month)

Scen. 1	**A-1**		**A-2**		**B-1**		**B-2**		**B-3**		**In total***
	Em	*Hm*	*Em*	*Hm*	*Em*	*Hm*	*Em*	*Hm*	*Em*	*Hm*	*Em*
January	3952	54.59	2928	54.58	9825	54.59	8866	54.59	4901	54.58	**38.376**
February	5251	72.40	3892	72.39	13057	72.40	11781	72.40	6514	72.38	**50.997**
March	9375	128.8	6949	128.7	23143	128.8	21036	128.8	11632	128.7	**90.885**
April	11756	161.5	8715	161.5	28768	161.5	26380	161.5	14589	161.5	**113.720**
May	12874	177.2	9545	177.1	31360	177.2	28891	177.2	15980	177.1	**124.398**
June	13350	183.9	9899	183.9	32419	183.9	29962	183.9	16573	183.9	**128.903**
July	14960	205.8	11093	205.7	36223	205.8	33574	205.8	18572	205.7	**144.342**
Avgust	14385	197.4	10665	197.4	34860	197.4	32282	197.4	17855	197.4	**138.817**
Septem.	10486	143.9	7772	143.9	25564	143.9	23528	143.9	13010	143.9	**101.332**
October	8037	110.3	5956	110.3	19755	110.3	18031	110.3	9969	110.3	**77.822**
Novem.	5391	74.21	3995	74.20	13345	74.21	12093	74.21	6686	74.19	**52.292**
Decem.	3337	46.15	2472	46.14	8282	46.15	7485	46.15	4138	46.14	**32.388**
*the total values consider all buildings in area including three buildings type A-1											

Table 3: The analytical data gain from Skelion simulation of creating solar power plant on the canopy of parking lots and at the pedestrian paths

Scenario 2	**Area [m²]**	**No. of panels**	**Total power [kW]**	**Energy [kWh]**	**Yield [kWh/kWp]**
Parking lot	9224	3165	704,16	829.357	1177.80
Paths	6413	2304	622,08	657.632	1055.32
In total	**15.637**	**5469**	**1.326,24**	**1.486,989**	**2.233,12**

Table 4: The analytical data gain from PVGIS for Scenario 1 (Em- kWh/month; Hm-kWh/m²/month)

Scen. 2	parking		paths		In total		parking		paths		In total
	Em	*Hm*	*Em*	*Hm*	*Em*		*Em*	*Hm*	*Em*	*Hm*	*Em*
January	28983	54.62	17265	39.32	**46.248**	July	109609	205.8	99820	211.2	**209.429**
Febr.	38504	72.44	25361	56.39	**63.865**	Avgust	105417	197.4	87491	186.6	**192.908**
March	68726	128.8	49779	108.3	**118.505**	Septe.	76867	144.0	57403	124.3	**134.270**
April	86163	161.6	70249	150.3	**156.412**	Oktob.	58930	110.4	37990	84.28	**96.920**
May	94333	177.2	84182	178.6	**178.515**	Nove.	39532	74.26	22539	51.47	**62.071**
June	97814	183.9	91197	192.8	**189.011**	Decem.	24473	46.18	14349	32.90	**38.822**

5 Conclusion

Multi-family housing is a polygon not only for creating new solutions for the organization of dwelling plans due to changes in family structure and living conditions, but is an excellent indicator of how much and in what way the common sphere of housing can contribute to an individual user in the complex. This type of housing differs from individual housing, and if common spaces and common interest are not used and stimulated, the value and the whole point of this type of housing is questioned. Thus, the paper emphasizes one aspect of the improvement of multi-family housing, which can contribute not only to the financial savings of residents, but also to achieving greater comfort and sustainability. These aspects are especially important in dense urban areas, which are increasingly attacked by enormous new construction, reduced greenery and lack of resources of all kinds, especially space. The potential of unused spaces of buildings (as roofs) that can be turned into an energy generator for the neighborhood is something refreshing and necessary.

Paper analysis has shown that in the case of Block 29 photovoltaic panels on the roofs of buildings generates less energy than parking lots and pedestrian paths in this Block. Bearing in mind that not all footpaths were used for this type of panel covering and also that spaces of non built types of spaces have not been taken into account, this area and consequently the energy gains can be higher. On the other hand, the capacity of electricity generated on the roofs of buildings is significant, which brings the autonomy of buildings in relation to the entire complex and can be managed independently of other buildings, while placing panels on public areas requires the involvement of the entire community of about 5,000 people. Another advantage of roofs is that it is the easiest space to place the PV panels compared to a parking lot that requires canopy, while paths are much more financially demanding.

Interesting aspect of making these kind of interventions in Serbia is that this is still a pilot solution, comparing to other countries. This can be also a type of "advertisement" of RES use in residential complexes and can drive more communities into this process.

There are some important aspects of such interventions which are beyond technical design. One is the problem of placing canopies above parking as an institutional and legislative problem, due to that design must fallow the legislative, also the question is who will have the jurisdiction, considering that parking spots are usually on public (city) owned land. The other possible problem is the issue of user participation in the endeavor. Organization of the community in these interventions is of high importance. This paper did not address this, but in further research it is necessary to look not only at the technical characteristics and benefits of RES systems in housing but also at potential problems that are not directly related to space or technology itself. Observing the condition of multi-family housing areas, non-maintenance, and even illegal construction within housing complexes, it is possible to expect that the aspect of user participation and initiative in this regard can prove to be one of the most difficult steps besides the financial aspect for this type of intervention.

6 References

[1] **Pucar, M., M. Pajević, M. Jovanović-Popović**, *Bioklimatsko planiranje i projektovanje - urbanistički parametri*, IP Zavet, Beograd, Srbija, 1994.

[2] **Milošević, M., D. Milošević, D. Stević, V. Dimić, A. Stanojević**, The analysis of energy efficiency indicators and renewable energy sources for existing buildings, Proceedings of 5th International Conference on Renewable Electrical Sources, SMEITS, Belgrade, Serbia, 2017, pp. 205-212.

[3] **Kosorić, V.**, EKOloška kuća, Građevinska knjiga, Beograd, Srbija, 2012.

[4] **Ogueke, N.V., E.E. Anyanwu, O.V.Ekechukwu**, A review of solar water heating systems, Journal of renewable and sustainable energy, 1 (2009), pp. 043109.

[5] **Saadatian, O., C.H. Lim, K. Sopian, E. Salleh**, A state of the art review of solar walls: Concepts and applications, *Journal of Building Physics, 30* (2013), issue 1, pp. 55-79.

[6] **Pavlović, T., D. Milosavljević, I. Radonjić, L. Pantić, A. Radivojević, M. Pavlović**, Possibility of electricity generation using PV solar plants in Serbia, *Renewable and Sustainable Energy Reviews, 20* (2013), pp. 201-218.

[7] **Radovanović, M., S. Popov, S. Dodić**, *Sustainable Energy Management*, Elsevier, Oxford, UK, 2013.

[8] **Rabaia, M.K.H., M.A.Abdelhareem, E.T. Sayed, K.J. Chae, T. Wilberforce, A.G. Olabi**, Environmental impacts of solar energy systems: A review, *Science of The Total Environment,* Available online 29 August 2020, 141989, In press

[9] **Pucar, M., M. Nenković-Riznić**, Application of renewable sources of electrical energy from the aspect of economical, ecological and social sustainability, Proceedings of the 4th International Conference on Renewable Electrical Sources, SMEITS, Belgrade, Serbia, 2016.

[10] Energy Sector Development Strategy of the Republic of Serbia for the period by 2015 with projections by 2030, The Republic of Serbia, Ministry of Mining and Energy, Belgrade, 2016.

[11] **Dimić, V., M. Milošević, D. Milošević, D. Stević**, Adjustable Model of Renewable Energy Projects for Sustainable Development: A Case Study of the Nišava District in Serbia, *Sustainability* (2018), issue 10, pp. 775.

[12] Progress Report on the Implementation of the National Renewable Energy Action Plan of the Republic of Serbia, The Republic of Serbia, Ministry of Mining and Energy, Belgrade, 2016.

[13] http://www.pvresources.com/en/software/software.php (5.9.2020)

[14] **Brankov, B.**, Zajednički prostori u razvoju višeporodičnog stambenog sklopa, *Arhitektura i urbanizam*, 49 (2019), pp. 32-39.

[15] **Marušić, D.** Prikaz konkursnih projekata 1965 – 1975, Arhitektura i urbanizam, 1975, str. 74-77.

[16] **Brankov, B.**, Common areas in multi-family housing in Serbia: case study of Cerak Vinogradi, Proceedings of the 3rd International doctoral-postdoctoral conference FACING POST-SOCIALIST URBAN HERITAGE, Faculty of Architecture, Budapest University of Technology and Economics, Budapest, Hungary, pp. 42-45.

[17] **Ilić, D.** Višespratne stambene zgrade – kolektivno porodično stanovanje u novim uslovima. U Stanovanje u višeporodičnim spratnim zgradama u novim tržišnim uslovima - Stanovanje 1. 1996, Prosveta, Niš, Srbija, 1996

[18] **Docomomo Serbia,** Atlas stanovanja: Blok 29 centralne zone Novog Beograda., [online]) Available at: http://www.docomomo-serbia.org/atlas/blok-29-centralne-zone-novog-beograda/, Available online 30 August 2020.

[19] **Bodlović, V**. Stambeni blok 29 u Novom Beogradu. Izgradnja. 1973. br. 12, str. 53- 58.

[20] **Brankov, B., A. Stanojević**, Diferenciranje upotrebljivosti otvorenih zajedničkih prostora u višeporodičnom stanovanju, Zbornik radova Međunarodnog naučno-stručnog skupa 16. Letnje škole urbanizma, Udruženje urbanista Srbije, Prolom Banja, Srbija, 2020., pp. 143-152.

[21] **Pucar, M., B. Brankov**, Possibility of using the solar energy by installing the PV panels on flat roofs of public buildings. Case Study: Market in Block 44 in New Belgrade-model-based approach, Proceedings of 5th International Conference on Renewable Electrical Sources, SMEITS, Belgrade, Serbia, 2017, pp. 163-168.