ZBORNIK RADOVA
Proceedings

pisanih za 5. Međunarodnu konferenciju o obnovljivim izvorima električne energije

5th International Conference on Renewable Electrical Power Sources

SMEITS

2017

ZBORNIK RADOVA
pisanih za 5. Međunarodnu konferenciju o obnovljivim izvorima električne energije
Sava centar
12. i 13. oktobar 2017.

PROCEEDINGS
5th International Conference on Renewable Electrical Power Sources
Sava Center
12 and 13 October 2017

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

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

Glavni i odgovorni urednik
Prof. dr Zoran Stević

Editor-in-Chief
Prof. Zoran Stević, Ph. D.

Za izdavača
Vladan Galebović

For Publisher
Vladan Galebović

Štampa
BSIDE d.o.o.,
Beograd

Printing
BSIDE d.o.o.,
Beograd

Tiraž
450 primeraka

Circulation
450 copies

ISBN 978-86-81505-84-7

CIP - Каталогизација у публикацији - Народна библиотека Србије, Београд

502.171:620.9(082)(0.034.2)

МЕЂУНАРОДНА конференција о обновљивим изворима електричне енергије (5 ; 2017 ; Београд) Zbornik radova pisanih za 5. Međunarodnu konferenciju o obnovljivim izvorima električne energije, [Beograd] Sava centar 12. i 13. oktobar 2017. [Elektronski izvor] = Proceedings / 5th International Conference on Renewable Electrical Power Sources ; [organizator Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije (SMEITS), Društvo za obnovljive izvore električne energije]. - Beograd : Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije - SMEITS, 2017 (Beograd : BSIDE). - 1 elektronski optički disk (CD-ROM) ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 450. - Abstrakti. - Bibliografija uz svaki rad.

ISBN 978-86-81505-84-7

1. Савез машинских и електротехничких инжењера и техничара Србије (Београд).
Друштво за обновљиве изворе електричне енергије

а) Енергетски извори - Одрживи развој - Зборници

COBISS.SR-ID 247351308

3. Aplikacije i usluge • Applications and services

MOGUĆNOSTI KORIŠENJA SOLARNE ENERGIJE POSTAVLJANJEM PV PANELA NA RAVNIM KROVOVIMA JAVNIH OBJEKATA. STUDIJA SLUČAJA: PIJACA U BLOKU 44 NA NOVOM BEOGRADU - MODELSKI PRISTUP -

POSSIBILITY OF USING THE SOLAR ENERY BY INSATLLING THE PV PANELS ON FLAT ROOFS OF PUBLIC BUILDINGS. CASE STUDY: MARKET IN BLOCK 44 IN NEW BELGRADE - MODEL-BASED APPROACH -

Mila PUCAR[1], Borjan BRANKOV
Institute of Architecture and Spatial & Urban Planning of Serbia, Belgrade

Zbog velike potrošnje energije u zgradama, zagađivanja životne sredine, ali i velikog potencijala za uštedu energije, energetska efikasnost i OIE postaju nezaobilazni faktori u rešavanju ovih problema. Posebno važno pitanje je raspoloživost resursa obnovljive energije, a posebno sunčeve energije u gradskoj sredini. Projekti koji obuhvataju korišćenje OIE u zgradama dobijaju sve više na značaju, a njihovi rezultati bi trebalo da dovedu do značajnog smanjenja emisija gasova staklene bašte (GSB) u sledećim decenijama. U Institutu za arhitekturu i urbanizam Srbije izrađena je Studija mogućnosti postavljanja solarnih fotonaponskih panela na ravnom krovu pijace u Bloku 44 na Novom Beogradu, za investitora JKP Gradske pijace, Beograd. U ovom radu biće prikazani delovi ove Studije, ciljevi, varijantna rešenja i njihova ekonomska isplativost, kao i uticaj na životnu sredinu. Osnovni cilj ove Studije predstavlja korišćenje solarne energije za supstituciju potrošnje električne energije u gradskim sredinama. Kroz realizaciju ovog osnovnog cilja, ostvarili bi se i dodatni rezultati u projektovanju, eksploataciji, praćenju rada i promovisanju korišćenja obnovljivih i ekoloških izvora električne energije; afirmacija novih tehnologija koje se koriste za eksploataciju obnovljivih izvora energije, širom primenom ovih tehnologija uticaće na razvoj tržišta i veću zainteresovanost domaće industrije da se uključi u ovu vrstu poslova, što bi dovelo do otvaranja novih radnih mesta; demonstracija projekta iz oblasti obnovljivih izvora kroz uključivanje različitih aktera i ciljnih grupa; provera ekonomske održivosti opravdanosti ulaganja u ovakve projekte (poređenje sa referentnim slučajem koji podrazumeva investiranje u povezivanje potrošača na distributivnu mrežu); pozitivnom uticaju na životnu sredinu, kroz smanjenje korišćenja klasičnih izvora energije i smanjenje emisija CO_2 i drugih štetnih gasova.

Ključne reči: *javni objekti, PV paneli, klimatske promene, održivi razvoj, ekološki i ekonomski parametri*

Due to the high energy consumption in buildings, environmental pollution, but also great potential for energy savings, the energy efficiency and renewable energy are becoming the unavoidable factors in solving these problems. The availability of renewable energy sources is an especially important issue, and particularly the availability of solar energy in cities. Projects involving the use of RES in buildings are increasingly gaining importance, and their results should lead to a significant reduction in greenhouse gas emissions (GGE) in the coming decades. The Study of Possibilities of Installing the Solar Photovoltaic Panels on the Flat Roof of the Market in the Block 44 in New Belgrade has been carried out in the Institute of Architecture and Urban & Spatial Planning of Serbia for the investor "Belgrade City Markets". This paper will show some parts of this Study, objectives, variant solutions and their economic profitability, as well as environmental impacts. The main objective of this Study is the use solar energy for the substitution of electricity consumption in urban environments. Through the realization of this main objective, the additional results would also be achieved in designing, exploiting, monitoring and promoting the use of renewable and environmentally friendly energy sources for electricity generation; the affirmation of new technologies used for the exploitation of renewable energy sources which would, through wider implementation of these technologies, contribute to the market development and greater interest of domestic industry in including itself in this kind

[1] Corresponding author, e-mail: pucarmila@gmail.com

of business, which would result in creating new jobs; demonstration of projects in the field of renewable energy sources through the inclusion of different partners and target groups; checking the economic profitability of investing in such projects (the comparison with the reference case which implies investing in linking the consumers and distribution network); positive environmental effects through reducing the use of traditional energy sources and through reducing the emissions of CO_2 and other harmful gases.

Key words: *public buildings, PV panels, climate change, sustainable development, environmental and economic parameters*

1. Introduction

The energy sector in Serbia has an important role in the country's economy. The situation in the energy sector affects its future integration on the international market, as well as the fulfilment of conditions related to the environment during the European integration process. When it comes to the energy industry as a whole, Serbia is facing great problems. The energy consumption is increasingly greater year after year, as well as the pressure to increase the price of energy. In Serbia, all natural resources and all forms of energy are extremely irrationally used. Serbia must approach an increase in energy efficiency and the use of renewable energy sources (hereinafter referred to as the "RES") in a systematic, planned and strategic way, as well to protect all natural resources and the environment. It is necessary to work on reducing the dependence on imported energy, i.e. to stimulate substitution of imported fuels for domestic fuels and for renewable energy sources.

The research projects have been carried out in the Institute of Architecture and Spatial & Urban Planning of Serbia concerning the possibilities of installing the PV panels and solar thermal collectors on roofs and facades of public buildings. This paper shows some results dealt with in the "Study of Possibilities of Installing the Solar Photovoltaic Panels on the Flat Roof of the Market in the Block 44 in New Belgrade" for the investor "Belgrade City Markets". This work will show some parts of this Study, objectives, variant solutions and their economic profitability, as well as environmental impacts. The main objective of this Study is the use of solar energy for the substitution of electricity consumption in urban environments. Through the realization of this main objective, the additional results would also be achieved in designing, exploiting, monitoring and promoting the use of renewable and environmentally friendly energy sources for electricity generation, as well as the affirmation of new technologies used for the exploitation of renewable energy sources. One of the objectives of this paper is to also prove the link between the energy sector and the competitiveness of Serbian economy. Energy efficiency and the introduction of the renewable energy sources into energy production, distribution and consumption are the most important mechanisms in the fight against climate change in the energy sector itself.

2. Main data on the project

The optimum angle for installing the solar panels in the area of New Belgrade is 44° (which corresponds to its geographic latitude) in order to achieve an optimum production all year round. But, to maximize the production in terms of greater generation of electricity and heat energy, it is necessary to install solar panels and solar thermal collectors at an angle of 35°, thus adapting the angle to the summer period and using this period of higher radiation to the maximum extent. This angle is in accordance with the software *Solarec* developed by the European Union (Preliminary Design of the PV Power Plant, Vračar, 2008).

On the other hand, the orientation of the panels is also essential. In any case and in any season, it is best to orient the active solar systems (hereinafter referred to as the "ASS") towards the south, if possible. In case of the market in the Block 44, the ASS are oriented towards southeast with a deviation of 17^{o} to the south, which is taken in further calculation. The analysis of Serbian market has been carried out for the needs of this Study, but it shall not be shown in this paper due to the limited space.

3. Location Analysis

3.1. Description of micro-location, disposition of buildings and dimensions of roof surfaces

The building of the market in the Block 44 is situated in the zone of New Belgrade at N 44°48'2" latitude and E 20°22'58" longitude, at the corner of Jurija Gagarina and Nehruova streets. The building is in the urban environment with medium lot coverage. There are no tall buildings in the immediate vicinity which would cast shadow on the roof of the market building (Fig. 1).

The building consists of four parts: the masonry building shaped like Cyrillic "П" thus closing the market on three sides (eastern, southern and western sides). This part is covered by a flat panel, and the roof structure is stable. The dimensions of the roof covering the eastern part are 55.72 x 16.49 m. The dimensions of the roof covering the southern part are 98.50 x 10.49m. The dimensions of the roof covering the western part of the building are 47.72 x 16.49 m. The area of all roof planes on which the solar systems are to be installed are at the angle of 17° to the south (Fig.2).

Figure 1. Position of the building in relation to the closer location (source: Google Earth)

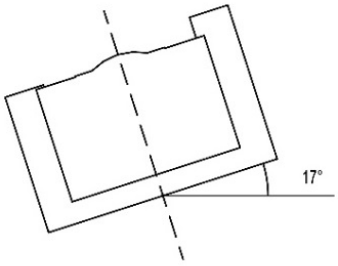

Figure 2. Position of the building in relation to the south

Figure 3. Roof of the Market in Block 44 in New Belgrade

The internal dimensions of the market are 65.52 x 47,72m. The inside roof is covered with Lexan panels installed on the central metal grid structure with dimensions 72.42 x 48.29m (Fig. 3). It is envisaged to install ASS on the flat roof of the building shaped like Cyrillic „П".

3.2. Analysis of climatic parameters of location

Solar energy: Knowledge about available potentials of solar energy is a main precondition for its successful use. The territory of New Belgrade belongs to the area rich in solar resources. The available potential of solar energy is high and suitable for the use of both active and passive solar systems. The annual average daily solar radiation received on a surface ranges between 3.76 and 3.86kWh/m^2.

The sunshine duration in average hours per year ("sunny hours") is much longer in Belgrade than in many European countries (2019 hours per year, one year has 8760), with an average cloud coverage of 5-6%, which are favourable conditions for the use of solar energy. These data indicate that the installation of solar collectors and photovoltaic systems is possible and profitable. The highest amount of solar energy is available in the period between April and September. It can be concluded that this area belongs to the zones suitable for the use of solar energy by applying the passive and active solar systems, primarily for generating the electricity and heat, as well as for applying the principle of passive solar architecture. In this location, the availability of solar radiation is estimated as follows:

- Mean power per unit area per year (global solar radiation on a horizontal surface) is approx. 1,300 to 1,400 kWh/m^2 per year;
- Average daily solar radiation received on a horizontal surface ranges from 3.4 to 4.0 kWh/m^2.

Wind: The ppotential wind capacity maps were created based on the standard meteorological measurements. The available amount of wind energy in the wider territory of Belgrade is considerable. It is possible to use wind energy both for the passive cooling of building and for cooling the ASS in case of the market building in the Block 44.

3.3. Analysis of shadow length in installing the solar panels

The lowest angle of sun position on December 21 is a problem for an urban organization of groups of buildings or settlements. The applicable angles are those from the southeast direction (9 am) and southwest direction (3 pm), which are at our latitudes about 12°, while from the south direction (12 pm -noon) about 22°. The solar energy can be used only to a small extent in the periods before 9 am and after 3 pm. The shadow analysis for installing the photovoltaic panels and solar thermal collectors for the Variant I for different periods of the year was carried out within this Study. In the critical period of the year, December 21 when the sun is lowest in the sky, small number of solar devices are in shadow between 10 am and 2 pm, because the care was taken of the optimum distances between them. On March 21 and on September 21, the solar devices are not in shade during the whole day. The most optimum situation is on June 21 when the sun is highest in the sky.

4. Variant solutions, cost and economic profitability of solar system

General technical data: The main market in the Block 44 has dimensions 96 x 66 m over all. The entire building, i.e. the roof surfaces on which the solar systems are to be installed, are oriented at an angle of 17° towards the southeast. A positive fact is that there are no high-rise buildings on the southern side of the building that could cast shadow on the market roof. Considering from the aspect of technical justifiability of installing the solar system, it can be concluded that the southern side of the building is illuminated by the sun during the daytime, as well as the entire canopy (the covered part of the market). The eastern side of the building is illuminated by the sun until noon, while its western side from noon onwards, with smaller shading of one part of the system, which can be seen in the graphics to the shadow analysis. The calculations started from the standard photovoltaic panels of the following dimensions: 148x67cm, area of $1m^2$, capacity of 160W. The presumption is that the panels are to be installed at the optimum angle of 35^0 for the purpose of generating maximum electricity each year. The panels are installed: at N 44°48'2" latitude and E 20°22'58" longitude; elevation 77 m above sea level (New Belgrade). The starting assumption was that total loss is 24.9%, because of the losses in power inventers, cables, too high temperature during the summer months, reflection, etc. When the panels are oriented at an angle of 17° towards the southeast in relation to the strict southern orientation, the overall annual electricity consumption should be reduced by 3 % relative to the maximum (southern) one.

Only the photovoltaic panels were installed in the Variant 1. The roof surfaces of the old building were used for installing the panels. The old roof of the building is shaped like Cyrillic "П" and consists of separated rectangular surfaces. The two side surfaces oriented towards the east and west have dimensions 55.72 x 16.49m and 47.72 x 16.49m. The southern part has dimensions 47.72 x 16.49m. The panels in the eastern and western part are arranged in rows of 16 panels in each row (dimension of panels: 148x67cm). The panels in the southern part are arranged in three rows, where a double row of panels is formed in the last, third row.

Overview of number of panels in Variant 1 – only photovoltaic panels			
Southern part (with double panels in the last row)	Side parts		Total photovoltaic panels (dimension of panels: 148x67cm)
	Western part	Eastern part	
518	233	267	1018

Southern part (with double panels in the last row): 518 **- total capacity of 82,880 W**

Side parts: 500 **- total capacity of 80,000 W**

Total: 1018 **- total capacity of 162,800 W**

For the purpose of connecting them to the electricity distribution network, it is necessary to install 2 power inverters 100 kW each. They are connected in a measuring distribution cabinet for electricity measurement.

Price of solar system in the Variant 1:

	Description of items for PV panels	Price (€)
01	Procurement of photovoltaic panels, mounts and installation on the roof 1 €/W x 162.800	162,800
02	Procurement of 2 power inverters 100 kW each	30,000
03	Main distribution cabinet	10,000
04	Design and setting into operation	25,000
05	VAT	40,000
	TOTAL	**267,800**

Characteristics of PV panels and return on investment:

It is believed that in this region the photovoltaic panels can generate electricity 6.1 hours per day during the summer months and only 1.1 hour during the winter months. The photovoltaic panels when operating at the nameplate capacity can generate electricity for about 1.245 hours. The orientation of the photovoltaic panels of 17^{o} towards the southeast can reduce the total electrical energy generated by the plant by 3%. This means that this solar power plant can generate 196,605.42 kWh, i.e. 196.6 MWh (708 GJ) of electricity. In case of acquiring the status of privileged electricity producer, with the price of 14.66 c€/kWh (Decree, 2017), 28.704 € could be earned annually from the EPS (Public Enterprise Electric Power Industry of Serbia). Excluding the earnings from electricity generation, the return on investment would be realized within 9.32 years in case the status of privileged electricity producer is acquired. The lifetime of the system is over 25 years.

The analyses for variants 2 and 3 were carried out under the same principle. In addition to the photovoltaic panels, the Variant 2 also contains the solar thermal collectors. The difference in relation to the Variant 1 is that solar thermal collectors are to be installed on the eastern and western parts of the roof in two rows on each with 12 panels in each row instead of the 2 last rows of photovoltaic panels. In addition to using the solar energy for generating the electricity, there is also the possibility of heating the water for the needs of the market building in the Block 44 in New Belgrade. The Variant 3 is an addition relative to the Variant 2. This variant has all elements, photovoltaic panels and solar thermal collectors as the Variant 2, but besides that, it also envisages the installation of the photovoltaic panels on the part of the new roof (canopy). The part for installing the photovoltaic panels is elevated in the central part of the new roof with dimensions 8x24m, on which it is planned to install photovoltaic panels in 7 rows with 11 panels in each row. Thus, this variant contains more photovoltaic panels relative to the Variant 2.

5. Conclusions

The Study in which the possibility of generating the electricity and thermal energy from the ASS (depending of the *variant solution*) proves that there are *technical possibilities and potential for that, and it also provides parameters of profitability of the system* for generating the energy from the (renewable) solar energy.

Depending on the offered variant, it is proposed to install between 954 – 1031m^2 of solar panels on the roof of the market in the Block 44 which could generate energy in the VARIANT 1: 196,605.42 kWh, i.e. 196.6 MWh (708 GJ), in the VARIANT 2: 184,335.696 kWh, i.e. 184 MWh (662 GJ), and in the VARIANT 3: 199,214 kWh, i.e. about 200 MWh = 720 GJ. In case the status of privileged produces is acquired, with the price of 14.66 c€/kWh (Decree, 2017), between 27,000 and 29,000 € could be earned from the EPS, depending on the variant solution. In addition, considering the data on bills issued in 2016 for electrical energy consumption of the market in the Block 44, for example, for months: April – 45,642 kWh, May – 45,723 kWh, June – 53,515 kWh, July – 57,297 kWh (average about 50,000 kWh per month), the annual production of electrical energy from the PV system could meet entire electricity needs for 3.5 to 4 months. With the status of privileged electricity producer, the return on investments would be realized in 9.32 to 9.5 years, excluding the earnings from the generated and sold electricity, or electricity generated for own needs, thus the costs paid to the EPS would be considerably reduced. The lifetime of the system is over 25 years.

This building is conceived as a pilot project within which the methodology would be established, as well as the criteria that would indicate all advantages and disadvantages of using this form of

renewable energy. Monitoring the system and measuring all relevant technical, economic and environmental parameters will help in creating a typology of a model for different types of buildings in different locations, not only in Belgrade, but also in the entire Serbia.

The main conclusions that can be derived from this research are: that the RES can be economically justifiable and often more economically profitable than the traditional energy sources; that the reduction in incentive measures directed towards the traditional energy sources can be redirected towards the RES; that electrical energy generated from the RES pollutes the environment considerably less than the fossil fuels; as well as that continuous availability of the RES depends on the combined use of different forms of renewable energy sources, as well as on the possibility of storing the energy in generating plans and distribution systems.

6. Acknowledgement

This paper was written as a result of the activities on the scientific research project "Spatial, Environmental, Energy and Social Aspects of Developing the Settlements and Climate Change - Mutual Impacts" (TR36035) funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

7. References

[1] *** *"Study of Possibilities of Installing the Solar Photovoltaic Panels on the Flat Roof of the Market in the Block 44 in New Belgrade"*, the Study led by: Pucar, M., Associate: Brankov, B., IAUS, Belgrade, 2017.

[2] *** Ecological atlas of Belgrade, 2002.

[3] *** Energy and Climate in Serbia, Challenges and Possibilities, (EUROPEAID /129767/C/SER/RS), Informative brochure, Sustainable development in the energy sector, Serbia, Project funded by the EU, 2012

[4] **Ferenčak, M.** *Pasivno korišćenje solarne arhitekture*, Sunčeva energija, mogućnosti and način korišćenja /The passive use of solar architecture, the Sun's energy, possibilities and the way of usage/, Sarajevo, 1982.

[5] *** *The preliminary design of the PV solar plant on the Vračar Municipality building was developed for the Assembly of the Vračar Municipality*, participants: Faculty of Electrical Engineering, University of Belgrade, the Institute of Architecture and Urban & Spatial Planning of Serbia, Belgrade, the Faculty of Civil Engineering, University of Belgrade, 2008.

[6] **Pucar, M**. *Održivo planiranje gradova and uticaj potrošnje energije u zgradama na promenu klime* /Sustainable planning for cities and effects of energy consumption in buildings on climate change/, Chapter in the IAUS Monongraph: Sustainable spatial development of towns and cities. 2005, pp.71-94.

[7] **Pucar, M.** *Energy aspects of developing settlements and climate change – strategies and legal regulations in Serbia*, / Monograph: Climate change and built environment – policy and practice in Scotland and Serbia, Special editions No. 70, Editors: Pucar, M., Dimitrijević, B., Marić,I., Institute of Architecture and Urban & Spatial Planning of Serbia, 2013, pp. 57-108,

[8] **Pucar, M., M. Devetakovic,** *Planung und Projekte im Hinblick auf den Klimawandel – Situation in Serbien, Klimawandel als Gesellschaftliche Herausforderung - Antworten aus der Perspektive von Jura und Architektur*, Goethe-Institut, Beograd, Sarajevo, 2011.

[9] **Pucar, M., M. Nenković-Riznić,** Uticaj obnovljivih izvora energije na prostorni razvoj naselja u Srbiji u svetlu klimatskih promena /Impacts of renewable energy sources on spatial development of settlements in Serbia in the light of climate change/, *Collection of papers of the Belgrade Town Planners Association " Future development of settlements in light of climate change" 2011*, Belgrade Town Planners Association, 2011b pp. 17-27.

[10] **Pucar, M., M. Nenković-Riznić,** Application of renewable sources of electrical energy from the aspect of the economical, ecological and social sustainability, *The 4th International Conference on Renewable Electrical Power Sources ICREPS 16*, Ed. Zoran Stevic, SMEITS, Belgrade, Serbia, 2016, pp. 169-183