# Zbornik radova
# Proceedings

7. Međunarodna konferencija o obnovljivim izvorima električne energije

Beograd, 17–18. oktobar 2019

7th International Conference on Renewable Electrical Power Sources

Belgrade, October 17–18, 2019

SMEITS

DOIEE

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

502.171:620.9(082)(0.034.2)

**MEĐUNARODNA konferencija o obnovljivim izvorima električne energije (7 ; 2019 ; Beograd)**
Zbornik radova [Elektronski izvor] / 7. Međunarodna konferencija o obnovljivim izvorima električne energije, Beograd, 17-18. oktobar 2019 ; [urednik Zoran Stević] = Proceedings / 7th International Conference on Renewable Electrical Power Sources, Belgrade, October 17-18, 2019 ; [editor Zoran Stević]. - Beograd : Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije - SMEITS, 2019 (Beograd : Graphic studio). - 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 978-86-81505-97-7

a) Енергетски извори -- Одрживи развој -- Зборници

COBISS.SR-ID 280174860

# ZBORNIK RADOVA
# Proceedings

**pisanih za 7. Međunarodnu konferenciju o obnovljivim izvorima električne energije**

**7th International Conference on Renewable Electrical Power Sources**

SMEITS

2019

**ZBORNIK RADOVA**
**pisanih za 7. Međunarodnu konferenciju o obnovljivim izvorima električne energije**
Dom inženjera i tehničara „Nikola Tesla“, Beograd
17. i 18. oktobar 2019.

**PROCEEDINGS**
**7th International Conference on Renewable Electrical Power Sources**
Dom inženjera i tehničara „Nikola Tesla“, Belgrade
17 and 18 October 2019

**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

**Štampa**
Graphic studio, Beograd

**Printing**
Graphic studio, Beograd

**Tiraž**
150 primeraka

**Circulation**
150 primeraka

**ISBN**
**978-86-81505-97-7**

**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 6. MKOIEE finansijski je pomoglo
Ministarstvo prosvete, nauke i tehnološkog
razvoja Republike Srbije

**Medijski partneri**
**Media partners**

ENERGETSKI PORTAL

ČASOPIS grenef. GRAĐEVINARSTVO & ENERGETSKA EFIKASNOST

## Međunarodni programski odbor
## International Programme Committee

| | |
|---|---|
| Prof. dr Slađana Alagić | Srbija |
| Prof. dr Viorel Badescu | Rumunija |
| Prof. dr Pellumb Berberi | Albanija |
| Prof. dr Miroslav Bjekić | Srbija |
| Prof. dr Oleksandr Bondarenko | Ukrajina |
| Prof. dr Alla Denysova | Bugarska |
| Dr Željko Despotović | Srbija |
| Dr Stevan Dimitrijević | Srbija |
| Akademik prof. dr Zoran Đurić | Srbija |
| Prof. dr Aleksandar Gajić | Srbija |
| Dr Aleksandar Ivančić | Španija |
| Prof. dr Miroljub Jevtić | Srbija |
| Prof. dr Branko Kovačević | Srbija |
| Rastislav Kragić | Srbija |
| Prof. dr Vladimir Krstić | Kanada |
| Prof. dr Nikolay Lopatkin | Rusija |
| Dr Stefan Mandić-Rajčević | Italija |
| Prof. dr Nikolay Mihailov | Bugarska |
| Prof. dr Nebojša Mitrović | Srbija |
| Prof. dr Milica Naumović | Srbija |
| Prof. dr Stefka Nedeltcheva | Bugarska |
| Mr 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 | Srbija (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**

# 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:<br>Električna vozila – juče, danas i sutra | Panel:<br>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

## 3. Energetska efikasnost

## 4. Aplikacije i usluge

# ELEKTRIČNE PERFORMANSE SISTEMA FOTONAPONSKIH MATERIJALA INTEGRISANIH U ZGRADE
# ELECTRICAL PERFORMANCES OF BUILDING-INTEGRATED PHOTOVOLTAIC SYSTEMS

**Jasna RADULOVIC*, Danijela NIKOLIC, Jasmina SKERLIC, Mina VASKOVIC JOVANOVIC**
Faculty of Engineering, University of Kragujevac, 34000 Kragujevac, Serbia

*Jedna od najistaknutijih i najčistijih tehnologija obnovljivih izvora energije, gde se sunčeva svetlost pretvara u električnu energiju je solarna fotonaponska tehnologija (PV). Fotonaponski materijali integrisani u zgrade (BIPV) su fotonaponski materijali koji se koriste da zamene konvencionalne materijale u delovima omotača zgrade, kao što su krovovi, krovni prozori ili fasade. Ovi materijali se mogu lako integrisati u zgrade, dajući joj nove oblike, nove mogućnosti, nove forme fasade zgrade, instalacije krovnog sistema, efikasan rad i druge praktične aspekte. Na globalnom nivou, električna energija dobijena pomoću PV-a predstavlja jednu ključnu komponentu naše energetske budućnosti i pomaže očuvanju vrednih prirodnih resursa. Poslednjih godina BIPV se ubrzano razvija i postaje sve atraktivniji za buduća istraživanja i primenu, zahvaljujući napretku u tehnologiji, smanjenim troškovima fotonaponskih materijala, itd. Cilj ovog rada je da istakne napredak prethodnih istraživanja o električnim performansama sistema fotonaponskih materijala integrisanih u zgrade (BIPV), kao i da ukaže na energetske i ekološke prednosti ovih sistema.*

***Ključne reči:*** *Fotonaponska tehnologija; Fotonaponski materijali integrisani u zgrade*

*One of the most prominent renewable energy technologie, where the sunlight is converted into electricity is solar Photovoltaic technology (PV). Building integrated photovoltaics (BIPV) are photovoltaic materials that are used to replace conventional building materials in parts of the building envelopes, such as the roofs, skylights or façades. These materials can be easily integrated to the buildings giving new shapes, new possibilities, new forms of building façade, roof system installation, efficient operation and other practical aspects. At global level, the electrical energy from the PVs stands for one crucial component of our energy future and aids to preservation of valuable natural resources. In recent years, BIPV has been developing rapidly and it has become increasingly attractive for future research and application due to advances in technology, the reduced cost of PV materials, etc. The objective of this paper is to highlight the progress of previous research on the electrical performances on BIPV systems and also to point out energy and environmental benefits of BIPV systems.*

***Key words:*** *Photovoltaics; Building integrated photovoltaics*

## 1 Introduction

It is generally believed that our climate is changing, and there is a growing concern about the increase in energy use and its adverse effects on the environment. Today, the renewable energy systems have a significant impact on the environment, so the development of renewable energy resources and the use of renewable energy are essential. One of the most promising renewable energy technologies is photovoltaic (PV) energy conversion. PV energy conversion represents the direct conversion of sunlight into electricity. Commercial PV materials commonly used for PV systems include solar cells of sillicium (Si), cadmium-telluride (CdTe), copper-indium-dieseline (CIS) and solar cells made of other thin layer materials. PV systems are still an expensive option for producing electricity compared to other energy sources, but many countries support this technology.

Starting from 1990 industry of photovoltaic conversion of solar irradiation shows constant annual economical growth of over 20 %, and from 1997 over 33 % annually. In 2000 total installed

* Corresponding author: jasna@kg.ac.rs

capacities worldwide have surpassed 1000 MW, and in developing countries have overreached more than million house-holds which are using electrical energy generated by means of the photovoltaic systems. It is predicted that PV will deliver about 345 GW by 2020 and 1081 GW by 2030. [1]. Silicon is a leading technology in making solar cell, due to its high efficiency. But many researchers, due to its high cost, are trying to find new technology to reduce the material cost for production of solar cells and thin film technology can be seen as a suitable substitution. However, the efficiency of solar cells based on this technology is still low, and researchers are intensively making an effort to enhance the efficiency. [2].

Leading technology in making solar cells is silicon, even though many researchers are trying to find new technology to reduce the material costs for production of solar cells, due to high cost of silicone. Thin film technology seems like suitable substitution, but the efficiency of this technology is still low, and researchers are making effort to enhance it. Commercial matherials commonly used for PV systems, besides silicon (Si), include solar cells of cadmium-telluride (CdTe), coper-indium-diselenide (CIS) and solar cells made of other thin layer materials [2]

Flexible modules used in new thin film PV technology give important perspective to PV systems, as these have possibility of simple integration in roofs and building facades. In applications where the weight is important flexible modules are very suitable and offer much faster payback than other conventional photovoltaics, which makes expectation that they will play an important role in the global PV market in the near future [3]

The system containing PV modules placed on building roof, as well as on building envelopes, is named building integrated PV (BIPV). Nowadays semi-transparent BIPV modules are often used to permit entrance of sunlight to interior of building, maintaining the function of electricity generation. BIPV integrated in building converts from purely electrical device to a construction product. As a construction product, it generates electricity, besides other features, thus replacing commonly used elements like roof, windows, blinds, fac, etc. [4]

As a technical solution for electricity self-sufficiency in buildings, electrical performances and electrical efficiency rates of BIPVs are very important parameters for design and implementation of photovoltaic modules [5]

This paper is organized in the following way. In Section 2 PV growth today and different PV technologies are considered. In Section 3 progress of previous research on the electrical performances on BIPV systems is presented. In Section 4 conclusions about energy and environmental benefits of BIPV systems are discussed and presented.

## 2 Building integrated photovoltaics

In Building integrated photovoltaics PV modules are integrated into new buildings as façades or roof construction materials or into existing buildings for retrofitting. When BIVP module is created using available PV structures in combination with rigid substructures, like metal plates or sheets of glass, it is called rigid BIVP, and it replace conventional covering matherials for roofs, facs and ades, Figure 1. Flexible BIPVs can be constructed with organic PV (OPV), dye-sensitized solar cells (DSC), perovskite solar cells (PSC). Also, all thin-film technologies can be used, such as amorphous silicon (a-Si), microcrystalline silicon (μ-Si), a combination of a-Si/μ-Si, copper indium gallium selenide (CIGS) and cadmium telluride (CdTe), Figure 2.

### *2.1 Building-integrated photovoltaic (BIPV) technology*

The Building integrated Photovoltaics (BIPV) market, which got increased political support during the last years is still one of the big hopes for TF technologies. In this context, these modules have many advantages compared to c-Si ones: strongly reduced weight for the application to the building stock, see through property, adjustable optical transmittance, excellent building appearance, potential capability for applying flexible substrates, and less sensitivity to the degradation of light intensity and increasing temperature of the module [6].

*Figure 1. Rigid building integrated photovoltaic modules on a laboratory building of Fraunhofer ISE. The BIPV modules were developed and produced in a pilot production facility at the institute. © Fraunhofer ISE [4]*

*Figure 2. Flexible BIPVs - Thin-film solar plant on the arched roof of a waste sorting station in Monte Crocetta, near Vicenza (40 kWp), constructed in collaboration with Rewatt, Vicenza [7]*

Flexible PV technologies in comparison with traditional Si-based photovoltaics offer a unique versatility that architects and engineers will harness to renew the facades of existing buildings, as well as in the construction of new buildings and in the development of power-generating products. Flexible solar cells provide building component manufacturers with thin and lightweight PV foils that allow integration with building materials of various architectural shapes. Combining PVs and architecture in this way is also cost-effective integration [8]. Flexible solar PV devices offer a convenient alternative energy source for indoor and outdoor applications. These flexible modules are suitable for applications where it is important that module weight is low, besides being flexible and easy integrated with elements of various shapes and sizes for the design of innovative energy-generating products. They offer a much faster payback than products based on conventional PVs [8].

New material tehnologies, like OPV and DSC are also applicable for building integration module [6]. Since OPV relies on carbon based semiconductors, low cost high volume manufacturing of flexible solar modules without any raw-material concern appears achievable. In combination with the feature that devices can be fabricated in a number of colors and levels of transparency, this makes DSC an attractive applicant for BIPV applications, making integration to building windows possible without loosing sunlight in the interior. Fortunately, cell efficiencies are stagnant at about 11% since more than 15 years and further optimization of any main component of DSC devices is not likely to yield significant efficiency improvements [9].

### *2.2 Building-integrated photovoltaic (BIPV) application*

PV systems can be integrated in buildings in many ways. As it is possible to use the BIPVs as construction products, with a wide range of forms, colours, patterns and flexible dimensions, many forms of roofing material, facs, ades, windows, shadings, etc. can be derived and integrated in existing buildings and new constructions. Taking into consideration the combination of roof and facades elements with additional layers, new functionalities and application of BIPV modules can be made, leading to more effective solutions in this field. The goal is a return of invested capital by electricity gained from BIPV modules. Further develpoment and impolementation will be in the urban contexts, such as bus shelters and roofs for parking lots [4].

Important part of BIPV integration is price. Cost of BIPVs is usualy calculated in €/Wp, or €/kWh. This is not convinient for architects and planners, so the price will be conveted to €/m$^2$ in the future, approaching the construction industry practice. It is expexted that the price for standard PV modules will decrease for 40-55% from today to 2030. Nowadays, additional costs for implementation of BIPVs in new constructions can be approximated by 100 €/m$^2$ [4].

## 3 Electrical performances on BIPV systems

There are various factors influencing the electrical performances of building-integrated PV systems. Based on module type, its fabrication and efficiency, electricity generation can be increased, or decreased. Mostly used PVs are founded on silicone technologies and their efficiency rates increased up to day, thus increasing the electricity generation rates, which makes overall system with employed modules more effective. According to the National Renewable Energy Laboratory [10] PVs with the highest efficiency growth and the highest efficiency are of single crystalline, multi-crystalline, thin-film crystalline, CdTe and CIGS photovoltaics.

Furthermore, different ways of installation of PV modules affects the electrical performance of BIPV system. Incidence angle and azimuth of PV module make difference in electrical performance [11] The best annual power performance of PV modules is for installation incidence angle of 30° facing south and azimuth of 0°. (Figure 3) Generation of electricity is more than 200% greater than electricity generation with PVs mounted on 90° (vertically).

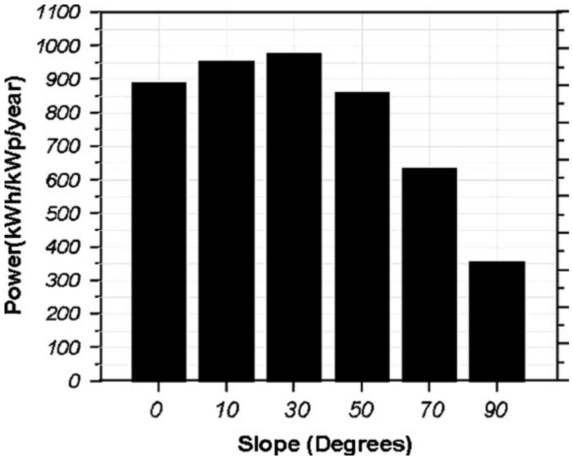


*Figure 3. Annual power production of PV module depending on the slope, and facing south (azimuth = 0°) [11]*

According to [12] improvement of 47% can be achieved by changing the azimuth angle in terms of facing to south and avoiding shading effect from building mass. Monitoring was made during 2 years with transparent a-Si thin film installed on 50° to the southwest, on the R&D Institute of Kolon, the first application in the practical building in Korea, as the window system (Figure 4).

Every PV module is affected by operating temperature. If the temperature is high, the electrical efficiency rate is decreased. If the photovoltaic module has been placed to building with an air gap between module and wall, from 12-16 cm, this type of BIPV could reduce the overheating problem [13]. Ritzen et al. [14] show that ventilated rooftop mounted BIPV gives 2.6% more electricity than non ventilated BIPV.

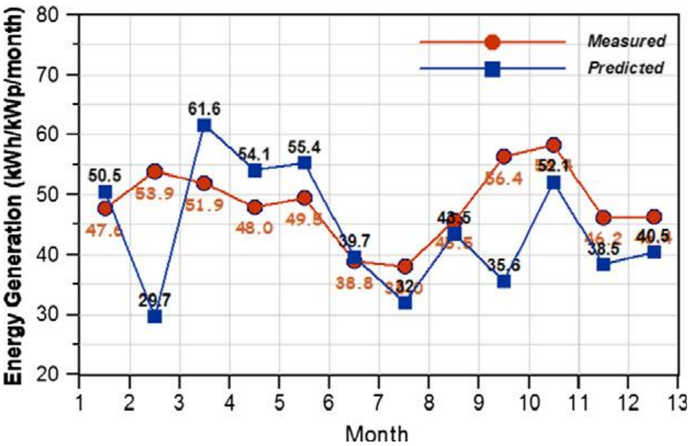


*Figure 4. Comparison of simulated and measured monthly power generation data for BIPV system in Kolon R&D Institute [12]*

*Table 1: The potential electricity generation capacity of building-integrated photovoltaics (BIPVs) for the selected countries of International Energy Agency (IEA) [15]*

| Country | Potential Area of Roofs *(km²)* | Potential Area of Façades *(km²)* | Potential of Roofs *(TWh/year)* | Potential of Façades *(TWh/year)* | Total Potential *(TWh/year)* | Actual Consumption *(TWh)* | Potential Demand Ratio *(%)* |
|---|---|---|---|---|---|---|---|
| Australia | 422.5 | 158.34 | 68.176 | 15.881 | 84.057 | 182.24 | 46.1 |
| Austria | 139.62 | 52.36 | 15.197 | 3.528 | 18.725 | 53.93 | 34.7 |
| Canada | 963.54 | 361.33 | 118.708 | 33.054 | 151.762 | 495.31 | 30.6 |
| Denmark | 87.98 | 32.99 | 8.710 | 2.155 | 10.865 | 34.43 | 31.6 |
| Finland | 127.31 | 32.99 | 11.763 | 3.063 | 14.827 | 76.51 | 19.4 |
| Germany | 1295.92 | 485.97 | 128.296 | 31.745 | 160.040 | 531.64 | 30.1 |
| Italy | 763.53 | 286.32 | 103.077 | 23.827 | 126.904 | 282.01 | 45.0 |
| Japan | 966.38 | 362.39 | 117.416 | 29.456 | 146.872 | 1012.94 | 14.5 |
| Netherlands | 259.36 | 97.26 | 25.677 | 6.210 | 31.887 | 99.06 | 32.2 |
| Spain | 448.82 | 168.31 | 70.689 | 15.784 | 86.473 | 180.17 | 48.0 |
| Sweden | 218.77 | 82.04 | 21.177 | 5.515 | 26.692 | 137.12 | 19.5 |
| Switzerland | 138.22 | 51.83 | 15.044 | 3.367 | 18.410 | 53.17 | 34.6 |
| United Kingdom | 914.67 | 343.00 | 83.235 | 22.160 | 105.395 | 343.58 | 30.7 |
| United States | 10,096.26 | 3876.10 | 1662.349 | 418.312 | 2080.661 | 3602.63 | 57.8 |

Table 1 shows the differences in solar electricity potential between selected countries with various accessible areas for BIPV implementation through the evaluation of the available roof and façade areas of residential, agriculture, industrial and commercial areas, carried out by the International Energy Agency [15]. The greatest energy potential has United States, with 57.8% of total energy requirement if the all available areas were used for installation of BIPV.

## 4 Conclusions

Energy potential of BIPV is increasing rapidly with technology development. Parameters that influence the electrical efficiency of modules, like fabrication procedure, implementation, or operating temperature, are improving, making overall efficiency of BIPV systems enhanced. Thus the usage of these systems is in expansion, fulfilling most of energy requirements of buildings with BIPV.


### *Acknowledgment*

This paper is a result of project TR33015, Investigation and development of Serbian zero-net energy house, supported by the Ministry of Science and Technological Development of Republic of Serbia.


## 5 References


[1] **Tyagi, V.V., Nurul, A.A. Rahim., Rahim, N.A., Jeyraj, A./L. Selvaraj**. Progress in solar PV technology: Research and achievement, *Renewable and Sustainable Energy Reviews*, 20 (2013), pp. 443–461.

[2] **Razykov, T.M., Ferekides C.S., Morel D., Stefanakos E., Ullal H.S.**, Solar photovoltaic electricity: Current status and future prospects, *Solar Energy 85,* (2011), pp. 1580–1608.

[3] **Kessler, F., Rudmann, D.,** Technological aspects of flexible CIGS solar cells and modules, *Solar Energy 77*, (2004), pp. 685–695.
[4] **Ferrara, C., Wilson, H.R., Sprenger, W.** Building-integrated photovoltaics (BIPV). *The Performance of Photovoltaic (PV) Systems*, (2017), pp. 235-250.
[5] **Zhang T., Wang, M., Yang, H.,** A Review of the Energy Performance and Life-Cycle Assessment of Building-Integrated Photovoltaic (BIPV) Systems, *Energies*, (2018)
[6] **Radulovic J., Bojic M., Nikolic D., Skerlic J.** Thin film photovoltaic technologies: status and perspectives, *45. International Congress and Exhibition on Heating, Refrigerating and Air-Conditioning*, Belgrade, Serbia, 2014.
[7] Centrosolar Group, 2015., *Available online: http://www.centrosolar-group.com/*
[8] **Pagliaro, M., Ciriminna, R., Palmisano, G.,** Flexible Solar Cells, *Chemistry and sustainability, energy and materials*, (2008), pp. 880 – 891.
[9] **Bojić, M., Radulović, J., Nikolić, D., Miletić, I.,** Flexible Thin-Film Photovoltaic Technologies: In Building Integration, *Proceedings of COST TU1205 Symposium Combined with EURO ELECS 2015 Conference*, Guimaraes, Portugal, 2015.
[10] **National Renewable Energy Laboratory (NREL),** *Best Research-Cell Efficiencies. Available online: https://www.nrel.gov/pv/assets/images/efficiency-chart.png*
[11] **Song, J.-H., An, Y.-S., Kim, S.-G., Lee, S.-J., Yoon, J.-H., Choung, Y.-K.,** Power output analysis of transparent thin-film module in building integrated photovoltaic system (BIPV), *Energy Build.*, 40, (2008), pp. 2067–2075.
[12] **Yoon, J.-H., Song, J., Lee, S.-J.,** Practical application of building integrated photovoltaic (BIPV) system using transparent amorphous silicon thin-film PV module, *Sol. Energy*, 85, (2011), pp. 723–733.
[13] **Gan, G.**, Numerical determination of adequate air gaps for building-integrated photovoltaics. *Sol. Energy***,** 83, (2009), pp. 1273–1353.
[14] **Ritzen, M.J., Vroon, Z.A.E.P., Rovers, R., Lupíšek, A., Geurts, C.P.W**., Environmental impact comparison of a ventilated and a non-ventilated building-integrated photovoltaic rooftop design in the Netherlands: Electricity output, energy payback time, and land claim, *Sol. Energy* 155, (2017), pp. 304–313.
[15] **International Energy Agency**, *Potential for Building Integrated Photovoltaics, Available online: www.iea-pvps.org/index.php?id=9&eID=dam_frontend_push&docID=394*

## Organizer

Serbian Union of Mechanical and Electrical Engineers and Technicians (SMEITS)

**Society for Renewable Electricity Power Sources (DOIEE)**

Kneza Miloša 7a/II, 11000 Belgrade
Tel. 011/ 3230-041, 3031-696, tel./fax 3231 372
office@smeits.rs • www.smeits.rs