

Četvrta međunarodna konferencija
o obnovljivim izvorima
električne energije

The 4th International Conference
on Renewable Electrical
Power Sources



ZBORNİK RADOVA PROCEEDINGS



17. i 18. oktobar 2016.
Beograd, Sava centar



ZBORNİK RADOVA
pisanih za 4. Međunarodnu konferenciju
o obnovljivim izvorima
električne energije

Sava centar
17. i 18. oktobar 2016.

PROCEEDINGS
4th International Conference
on Renewable Electrical
Power Sources

Sava Center
17 and 18 October 2016

Izdavač

Savez mašinskih i
elektrotehničkih inženjera
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.

Za izdavača

Vladan Galebović

For Publisher

Vladan Galebović

Štampa

Graphic studio d.o.o.,
Beograd

Printing

Graphic studio d.o.o.,
Beograd

Tiraž

150 primeraka

Circulation

150 primeraka

ISBN

978-86-81505-80-9

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

GENERALNI POKROVITELJ
GENERAL PATRON
ЕЛЕКТРОПРИВРЕДА СРБИЈЕ

PROGRAMSKI POKROVITELJI
PROGRAMM SUPPORTERS



Republika Srbija,
Ministarstvo prosvete, nauke i tehnološkog razvoja

Ministarstvo rudarstva i energetike



Elektrotehnički fakultet, Beograd



Tehnološko-metalurški fakultet, Beograd



Institut za hemiju, tehnologiju i metalurgiju,
Beograd



Institut tehničkih nauka
Srpske akademije nauka, Beograd

POKROVITELJI
SPONSORS



BOSCH
Tehnologija za život

Robert Bosch, Beograd



Inženjerska komora Srbije, Beograd

VISSMANN

Viessmann, Beograd

–weishaupt–

Weishaupt, Beograd

ZODAX[®]

Zodax, Beograd

**MEĐUNARODNI
PROGRAMSKI ODBOR
INTERNATIONAL
PROGRAMME COMMITTEE**

| | |
|------------------------------------|--|
| Prof. Viorel Badescu | Romania |
| Prof. dr Pellumb Berberi | Albania |
| Prof. dr Alla Denysova | Bulgaria |
| Prof. dr Aleksandar Gajić | Serbia |
| Prof. dr Branko Kovačević | Serbia |
| Rastislav Kragić | Serbia |
| Dr Aleksandar Ivančić | Spain |
| Prof. dr Miroljub Jeftić | Serbia |
| Prof. Vladimir Krstić | Canada |
| Prof. Nikolay Mihailov | Bulgaria |
| Prof. dr Stefka Nedeltcheva | Bulgaria |
| Mr Dušan Nikolić | Australia |
| Dr Zoran Nikolić | Serbia |
| Elena Ponomareva | Ukraine |
| Dr Mila Pucar | Serbia |
| Prof. dr Nikola Rajaković | Serbia |
| Prof. dr Valerij Sitnikov | Ukraine |
| Prof. dr Velimir Stefanović | Serbia |
| Prof. dr Zoran Stević | Serbia (<i>the Committee Chairman</i>) |
| Prof. dr Zoran Stojiljković | Serbia |
| Prof. dr Michael Todorov | Bulgaria |
| Dr Zhongying Wang | China |
| Dr Wanxing Wang | China |
| Dr Xuejun Wang | China |
| Dr Ruiying Zhang | China |

**POČASNI ODBOR
HONORARY COMMITTEE**

| | |
|----------------------------------|--|
| Prof. Viorel Badescu | <i>Bosch</i> , Beograd |
| Prof. dr Pellumb Berberi | <i>Inženjerska komora Srbije</i> , Beograd |
| Prof. dr Alla Denysova | <i>Viessmann</i> , Beograd |
| Prof. dr Aleksandar Gajić | <i>Weishaupt</i> , Beograd |
| Zoran Jakšić | <i>Zodax</i> , Beograd |

**ORGANIZACIONI ODBOR
ORGANIZING COMMITTEE**

Rastislav **Kragić**
Zoran **Nikolić** (*predsednik Odbora*)
Ilija **Radovanović**
Zoran **Stević**
Žarko **Ševaljević**
Dragomir **Šamšalović**
Vladan **Galebović**

FOREWORD

The world population growth reaching over 7 billion people causes the increasing global energy demand, especially electricity demand. Non-renewable energy sources are depletable and environmentally unacceptable (environmentally unfriendly), since they cause various forms of pollution, as well as one of the biggest challenges in the human history – climate change and global warming. In order to mitigate this, the use of fossil fuels must be reduced, and as long as coal, oil and gas are primary energy sources, the world will not make that necessary step forward. Therefore, a significantly higher share of renewable energy sources is required, and these sources are not only renewable, but also much more environmentally acceptable (environmentally friendly).

As a result, it is believed that renewable energy sources will be increasingly used in Europe, which will lead to the reduction of greenhouse gas emissions and less dependence on oil. Searching for such solutions, the European Union set an ambitious goal – Directive 2009/28/EC, which prescribes the reduction of total energy by 20%, the increase of the share of renewable energy in the total energy by 20% and the reduction of greenhouse gas emission by 20%. The European Union has been making large investments in order to reduce carbon emission, achieve competitive prices and protect the environment.

The main goal of the 4th international conference on renewable electricity (electric power) sources is to analyse the comparative advantages and disadvantages of modern solutions in the field of renewable electricity sources used globally and in this country, and to provide the constructive exchange of competent opinions and ideas related to the development and use of these sources.

This international conference is for the fourth time organised by the Society for Renewable Electricity Sources within SMEITS (Serbian Union of Mechanical and Electrical Engineers and Technicians).

*Belgrade,
October 2016*

PREDGOVOR

Porast broja stanovnika u svetu na preko 7 milijardi uslovljava da svetske potrebe za energijom, posebno električnom, postaju sve veće. Neobnovljivi izvori energije su iscrpivi, nisu ekološki prihvatljivi, jer izazivaju razne oblike zagađenja, kao i jedan od najvećih izazova u ljudskoj istoriji - klimatske promene i globalno zagrevanje.

Da bi se to ublažilo korišćenje fosilnih goriva se mora smanjiti, jer dok god su ugalj, nafta i gas primarni energetske izvori, svet neće napraviti taj neophodan korak napred. Zbog toga se zahteva znatno veće učešće obnovljivih izvora energije koji su pored toga što su obnovljivi, i ekološki znatno prihvatljiviji.

Zbog toga se veruje da će se obnovljivi izvori energije u Evropi sve više koristiti, što vodi smanjenju emisije gasova sa efektom staklene bašte i manjoj zavisnosti od nafte. U traganju za takvim rešenjima, Evropska unija je postavila ambiciozan cilj – Direktivu 2009/28/EC koja propisuje da se do 2020. godine ukupna potrošnja energije smanji za 20%, da u ukupnoj potrošnji energije obnovljivi izvori učestvuju sa 20%, kao i da se emisija gasova sa efektom staklene bašte smanji za 20%. Evropska unija ulaže velika sredstva u ostvarenje ciljeva smanjenja emisije ugljenika, postizanja konkurentnih cena i zaštite životne sredine.

Osnovni cilj 4. 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.

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

*U Beogradu,
oktobra 2016*

ENC



ENC



SADRŽAJ

Contents

1. KORIŠĆENJE DRVNE BIOMASE U VODEĆIM ZEMLJAMA
EVROPSKE UNIJE, JUGOISTOČNOG BALKANA I SRBIJI
– PRIKAZ I POREĐENJA
UTILIZATION OF WOOD BIOMASS IN THE LEADING EU
COUNTRIES, SOUTH-EAST BALKAN REGION AND SERBIA –
OVERVIEW AND COMPARISON
Aleksandar DEDIĆ 17
2. ELEKTRIČNI I MAŠINSKI SKLOPOVI VETROGENERATORA
ELECTRICAL AND MECHANICAL ASSEMBLIES IN WIND
TURBINES
Dejan TANIKIĆ 27
3. IZBALANSIRANO DOSTIZANJE NACIONALNIH CILJEVA
ENERGETSKE POLITIKE KOD ODRŽIVIH ENERGETSKIH SISTEMA
BALANCED ACCOMPLISHMENT OF NATIONAL ENERGY POLICY
GOALS WITH SUSTAINABLE ENERGY SYSTEMS
Ilija BATAS BJELIĆ 35
4. UTICAJ GODIŠNJE RASPOREDELE SOALRNE ENERGIJE
NA ISPLATIVOST SOLARNIH KOLEKTORA U TIRANI
INFLUENCE OF YEARLY DISTRIBUTION OF SOLAR ENERGY
ON THE FEASIBILITY OF SOLAR COLLECTORS
IN THE CITY OF TIRANA
*Daniela HALILI, Pëllumb BERBERI, Driada MITRUSHI,
Valbona MUDA, Urim BUZRA, Irma BËRDUFU, Eduart SERDARI* 45
5. UPOTREBA SATELITSKIH PODATAKA ZA PROCENU EFIKASNOSTI
FOTONAPOSNKIH SISTEMA POSTAVLJENIH U RAZNIM
DELOVIMA ALBANIJE
REGIONAL VARIATION LCOE OF PHOTOVOLTAIC SYSTEMS IN
ALBANIA USING SATELLITE SOLAR DATA
*Driada MITRUSHI, Pëllumb BERBERI, Irma BËRDUFU,
Valbona MUDA, Daniela TOPÇIU, Urim BUZRA, Eduart SERDARI* 57
6. SIMULACIJA VETROGENERATORSKOG SISTEMA NA OSNOVU
TEHNO-EKONOMSKE ANALIZE
SIMULATION OF WIND POWER GENERATION SYSTEM
BASED ON TECHNO-ECONOMIC ANALYSIS
*Eduart SERDARI, Pëllumb BERBERI, Valbona MUDA,
Urim BUZRA, Driada MITRUSHI, Daniela HALILI, Irma BËRDUFU* 67
7. PROMENE POTENCIJALA SOLARNE ENERGIJE USLED DELOVANJA
ANTROPOGENIH AEROSOLA U ATMOSFERI TIRANE
MODIFICATION OF SOLAR ENERGY POTENTIAL DUE TO
ANTHROPOGENIC AEROSOLS IN ATMOSPHERE OF TIRANA
*Urim BUZRA, Pellumb BERBERI, Driada MITRUSHI,
Valbona MUDA, Daniela HALILI, Irma BERDUFU, Eduart SERDARI* 75

8. UPOREĐIVANJE PODATAKA O POVRŠINSKOM SUNČEVOM ZRAČENJU U TIRANI, ALBANIJA, DOBIJENIH SA ZEMLJE I SA SATELITA
MERGING OF GROUND-BASED AND SATELLITE-DERIVED DATA OF SURFACE SOLAR RADIATION IN CITY OF TIRANA, ALBANIA
Valbona MUDA, Pëllumb BERBERI, Irma BËRDUFI, Driada MITRUSHI, Daniela TOPÇIU, Urim BUZRA, Eduart SERDARI 85
9. EMPIRIJSKI MODEL RADA FOTONAPONSKOG SISTEMA POVEZANOG NA MREŽU
EMPIRICAL MODELS FOR ENERGY YIELD OF A PHOTOVOLTAIC SYSTEM CONNECTED TO THE GRID
Irma BËRDUFI, Pëllumb BERBERI, Driada MITRUSHI, Valbona MUDA, Daniela TOPÇIU, Urim BUZRA, Eduart SERDARI 93
10. PASIVNE KOMPONENTE OBNOVLJIVE ENERGIJE
PASSIVE COMPONENTS OF RENEWABLE ENERGY
V. KUDRYA, V. SYTNIKOV 103
11. RAČUNARSKO UPRAVLJANJE OPTIMIZACIJOM RADA SISTEMA SUNČEVIH ELEKTRANA I ELEKTRANA NA VETAR
COMPUTER COMPONENT CONTROL OF THE SYSTEM'S WORK
OPTIMIZATION OF SOLAR AND WIND ENERGY GENERATION
Hanna UKHINA, Valeriy SYTNIKOV 109
12. MODELOVANJE SUPERKONDENZATORA U SISTEMIMA ZA MIKROZAVARIVANJE
SUPERCAPACITOR MODELING FOR MICRO RESISTANCE WELDING APPLICATIONS
Oleksandr BONDARENKO, Volodymyr SYDORETS, Iuliia BONDARENKO, Zoran STEVIĆ 113
13. PREGLED SOLARNO TERMALNIH TEHNOLOGIJA I ISKUSTVA NA PODRUČJU JUŽNE ŠPANIJE
REVIEW OF SOLAR THERMAL TECHNOLOGIES AND EXPERIENCES IN THE AREA OF SOUTHERN SPAIN
Ilija RADOVANOVIĆ 119
14. IMPLEMENTACIJA INTERAKTIVNIH FASADNIH OMOTAČA U CILJU UNAPREĐENJA ENERGETSKIH PERFORMANSI SAVREMENIH ARHITEKTONSKIH OBJEKATA
IMPLEMENTATION OF INTERACTIVE FAÇADE SKINS IN ORDER TO IMPROVE ENERGY PERFORMANCE OF CONTEMPORARY ARCHITECTURAL BUILDINGS
Ana STANOJEVIĆ 129
15. EKONOMSKI ASPEKTI ODRŽIVOG RAZVOJA I UTICAJ NA ŽIVOTNU SREDINU
ECONOMIC ASPECTS OF SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL IMPACT
Dejan RIZNIĆ, Snežana UROŠEVIĆ, Milovan VUKOVIĆ, Zoran STEVIĆ . . . 139

16. ENERGETSKI EFIKASNA RECIKLAŽA PLEMENITIH METALA DOBIJENIH IZ RAČUNARSKOG OTPADA HIDROMETALURŠKOM OBRADOM
ENERGY EFFICIENT RECYCLING OF PRECIOUS METALS FROM COMPUTER WASTE BY HYDROMETALLURGICAL PROCESSING
Silvana B. DIMITRIJEVIĆ, Zoran M. STEVIĆ, Biserka T. TRUMIĆ, Aleksandra T. IVANOVIĆ, Stevan P. DIMITRIJEVIĆ 149
17. ODREĐIVANJE I ANALIZA OSETLJIVOSTI KONSTANTE BRZINE STVARANJA METANA (K) ZA PROCENU POTENCIJALA DEPONIJSKOG GASA KAO OBNOVLJIVOG IZVORA ENERGIJE U SRBIJI
DETERMINATION AND SENSITIVITY ANALYSIS OF METHANE GENERATION RATE (K) NEEDED FOR LANDFILL GAS – RENEWABLE ENERGY SOURCE EXTRACTION POTENTIAL
Dimitrije STEVANOVIĆ, Stefan MANDIĆ-RAJČEVIĆ, Ana DAJIĆ, Marina MIHAJLOVIĆ, Milica KARANAC, Jovan JOVANOVIĆ, Mića JOVANOVIĆ 155
18. ANALIZA EFEKTA SISTEMA REGIONALNIH DEPONIJA NA EMISIJE GASOVA SA EFEKTOM STAKLENE BASTE U REPUBLICI SRBIJI
ANALYSIS OF THE REGIONAL LANDFILL SYSTEM EFFECTS ON GREENHOUSE GAS EMISSIONS IN THE REPUBLIC OF SERBIA
Stefan MANDIĆ-RAJČEVIĆ, Dimitrije STEVANOVIĆ, Jovan JOVANOVIĆ, Milica KARANAC, Marina MIHAJLOVIĆ, Ana DAJIĆ, Mića JOVANOVIĆ . . . 163
19. PRIMENA OBNOVLJIVIH IZVORA ELEKTRIČNE ENERGIJE SA ASPEKTA EKONOMSKE, EKOLOŠKE I SOCIJALNE ODRŽIVOSTI
APPLICATION OF RENEWABLE SOURCES OF ELECTRICAL ENERGY FROM THE ASPECT OF ECONOMICAL, ECOLOGICAL AND SOCIAL SUSTAINABILITY
Mila PUCAR, Marina NENKOVIĆ-RIZNIĆ 169
20. UTICAJ SMANJENJA EMISIJE NO_x GASOVA U CILJU ZAŠTITE ŽIVOTNE SREDINE PROMENOM PROJEKTA (DIZAJNA) KATALIZATORA PT
THE EFFECT OF REDUCING THE EMISSION OF NO_x GASES FOR THE PURPOSE OF ENVIRONMENTAL PROTECTION CHANGING IN DESIGN OF PT CATALYSTS
Biserka TRUMIĆ, Aleksandra IVANOVIĆ, Silvana DIMITRIJEVIĆ, Stevan DIMITRIJEVIĆ 183
21. METODOLOGIJA MERENJA NISKOFREKVENTNOG MAGNETNOG POLJA I NJEGOVOG UTICAJA NA KORISNIKE PRENOSIVIH RAČUNARA
METHODOLOGY OF THE LOW-FREQUENCY MAGNETIC FIELD MEASUREMENT AND ITS INFLUENCE TO THE EXPOSURE OF THE PORTABLE COMPUTER USERS
Darko BRODIĆ, Milena JEVTIĆ, Jordan RADOSAVLJEVIĆ 195

22. MODELI ZAVISNOSTI ČVRSTOĆE MALTERA OD VREMENA
OČVRŠĆAVANJA I SADRŽAJA LETEĆEG PEPELA
MODELS OF DEPENDENCE OF MORTAR STRENGTH
ON HARDENING TIME AND FLY ASH CONTENT
*Ivana JOVANOVIĆ, Srđana MAGDALINOVIĆ, Sanja PETROVIĆ,
Miomir MIKIĆ, Milenko LJUBOJEV, Dragan MILANOVIĆ 201*
23. UTICAJ PRETHODNE METALURŠKE PRIPREME
TOPIONIČKE ŠLJAKE BAKRA NA MELJIVOST
EFFECT OF PREVIOUS METALLURGICAL PREPARATION
ON THE COPPER SMELTING SLAG GRINDABILITY
*Srđana MAGDALINOVIĆ, Ivana JOVANOVIĆ, Sanja PETROVIĆ,
Dragan MILANOVIĆ, Miomir MIKIĆ 209*
24. ŠUMSKI POŽARI UGROŽAVAJU PROIZVODNJU BIOMASE
U EVROPSKOJ UNIJI: ISKUSTVA PORTUGALIJE, ŠPANIJE I
FRANCUSKE NAMEĆU PREVENTIVNE MERE ZA SRBIJU
FOREST FIRES THREATEN BIOMASS PRODUCTION IN THE EU:
EXPERIENCES FROM PORTUGAL, SPAIN AND FRANCE IMPOSE
PREVENTIVE MEASURES FOR SERBIA
Milan MILENKOVIĆ, Aleksandar DEDIĆ, Dejan DOLJAK 215
25. PROJEKAT ZAŠTITE ŽIVOTNE SREDINE I KORIŠĆENJA
OBNOVLJIVIH IZVORA ENERGIJE ZA POVEĆANJE ENERGETSKE
EFIKASNOSTI U OBJEKTU SREDNJE TEHNIČKE ŠKOLE „MIHAJLO
PUPIN“, KULA, VOJVODINA
PROJECT – ENVIRONMENTAL PROTECTION AND THE USE
OF RENEWABLE ENERGY SOURCES FOR INCREASING ENERGY
EFFICIENCY IN SECONDARY TECHNICAL SCHOOL “MIHAJLO
PUPIN” IN KULA, VOJVODINA
*Marjan Lj. IVANOV, Mihal KRŽAČEK, Neda MILOVIĆ,
Aleksandra HERCEG-ROKNIĆ, Željko DESPOTOVIĆ 221*
26. PLANIRANJE ENERGETSKIH ZASADA U SRBIJI
SA POSEBNIM OSVRTOM NA BRZORASTUĆE ŠUME
ENERGY CROP PLANNING IN SERBIA
WITH SPECIAL REFERENCE TO FAST-GROWING FORESTS
Tijana CRNČEVIĆ, Vesna JOKIĆ, Ljubiša BEZBRADICA 229
27. POTENCIJALI ZA ENERGETSKE ZADRUGE
U BOSNI I HERCEGOVINI
POTENTIALS FOR ENERGY COOPERATIVES
IN BOSNIA AND HERZEGOVINA
Nihad HARBAŠ, Vedad SULJIĆ 239
28. ANALIZA PRIMJENE KOGENERACIJE SA ORGANSKIM
RANKINOVIM CIKLUSOM NA BIOMASU U BOLNICAMA
ANALYSIS OF THE BIOMASS ORGANIC RANKINE CYCLE
COGENERATION HOSPITALS APPLICATION
Nihad HARBAŠ, Azrudin HUSIKA, Samra PRAŠOVIĆ 249

29. OPTIMIZACIJA GEOMETRIJE HORIZONTALNOG KROVA
POKRIVENOG FOTONAPONSKIM PANELIMA
OPTIMISATION OF GEOMETRY OF HORIZONTAL ROOF
OVERHANGS COVERED WITH PHOTOVOLTAIC PANELS
Dragan CVETKOVIĆ, Aleksandar NEŠOVIĆ 255
30. ULOGA NANOMATERIJALA U SOLARNIM ČELIJAMA
THE ROLE OF NANOMATERIALS IN SOLAR CELLS
*Mirjana RAJČIĆ-VUJASINOVIĆ, Zoran STEVIĆ,
Vesna GREKULOVIĆ, Sanja PETROVIĆ* 265
31. OBNOVLJIVA ELEKTRIČNA ENERGIJA: PARALELA IZMEĐU SRBIJE
I EVROPE
RENEWABLE ELECTRICITY: PARALLEL SERBIA-EUROPE
Zoran STEVIĆ, Misa STEVIĆ, Ilija RADOVANOVIĆ, Daniel MIJAILOVIĆ . . 271
32. KOMPARATIVNA ANALIZA METAHEURISTIČKIH METODA
ZA REŠAVANJE PROBLEMA OPTIMALNIH TOKOVA SNAGA
A COMPARATIVE ANALYSIS OF METAHEURISTIC METHODS
FOR SOLVING THE OPTIMAL POWER FLOW PROBLEM
Miloš MILOVANOVIĆ, Jordan RADOSAVLJEVIĆ, Miroљjub JEVTIĆ 277
33. ANALIZA UTICAJA TEMPERATURE AMBIJENTA NA ENERGETSKU
EFIKASNOST PV MODULA PRIMENOM EMPIRIJSKIH KORELACIJA
ZA PRIRODNU KONVEKCIJU
ANALYSIS OF THE AMBIENT TEMPERATURE EFFECT ON THE
PV MODULES EFFICIENCY USING EMPIRICAL CORRELATIONS
FOR NATURAL CONVECTION
*Bojan PEROVIĆ, Dardan KLIMENTA,
Jordan RADOSAVLJEVIĆ, Miroљjub JEVTIĆ* 291
34. UPOTREBA NOVIH FOTONAPONSKIH TEHNOLOGIJA
ZA INTEGRISANE SISTEME U ZGRADAMA
THE USE OF NEW
PHOTOVOLTAIC TECHNOLOGIES
IN THE BUILDING INTEGRATED SYSTEMS
*Jasna RADULOVIĆ, Danijela NIKOLIĆ, Jasmina SKERLIĆ,
Vesna RANKOVIĆ, Mina VASKOVIĆ* 303
35. NOVE TEHNOLOGIJE, ALGORITMI UPRAVLJANJA
I POGODNI PRIRODNI USLOVI ZA REALIZACIJU
PROJEKATA MALIH HIDROELEKTRANA
NEW TECHNOLOGIES, CONTROL ALGORITHMS AND FAVORABLE
NATURAL CONDITIONS FOR REALIZATION OF PROJECTS
FOR SMALL HYDRO POWER PLANTS
Krsta BRČIĆ, Branislav BRČIĆ 313
36. POTENCIJALI OBNOVLJIVIH IZVORA ENERGIJE
I SUNČANE ENERGIJE U SRBIJI
RENEWABLE ENERGY AND SOLAR ENERGY
POTENTIAL IN SERBIA
*Miomir MIKIĆ, Ivana JOVANOVIĆ,
Sanja PETROVIĆ, Srđana MAGDALINOVIĆ* 319

37. METODE SINTeze BAKAR(I) OKSIDA
 KAO AKTIVNOG MATERIJALA ZA PRIMENU
 U SOLARNIM ĆELIJAMA
 METHODOLOGIES USED FOR THE SYNTHESIS
 OF CUPROUS OXIDE AS AN ACTIVE
 SOLAR CELL MATERIAL
*Sanja PETROVIĆ, Mirjana RAJČIĆ-VUJASINOVIĆ, Vesna GREKULOVIĆ,
 Ivana JOVANOVIĆ, Srđana MAGDALINOVIĆ, Miomir MIKIĆ 327*
38. MODELIRANJE PASIVNOG HLAĐENJA
 KROVNIH PV MODULA PRIMENOM MODIFIKOVANIH
 KORELACIJA ZA KOEFICIJENTE RAZMENE TOPLOTE PUTEM
 KONVEKCIJE PROUZROKOVANE VETROM
 MODELLING THE PASSIVE COOLING OF ROOF-MOUNTED PV
 MODULES BY USING THE MODIFIED CORRELATIONS
 FOR HEAT TRANSFER COEFFICIENTS DUE TO
 WIND-INDUCED CONVECTION
*Dardan KLIMENTA, Dragan ĆETENOVIĆ,
 Bojan PEROVIĆ, Jelena KLIMENTA 337*
39. ENERGETSKA VREDNOST KOLUBARSKOG LIGNITA
 – POREĐENJE SA ODABRANIM VIDOVIMA DOBIJANJA
 ELEKTRIČNE ENERGIJE (NATURALNI PARAMETRI kJ/kg, kcal)
 ENERGY VALUE OF KOLUBARA LIGNITE
 – COMPARISON WITH SELECTED ASPECTS OF ELECTRICITY
 GENERATION (NATURAL PARAMETERS, E.G. kJ/kg, kcal)
*Bogoljub VUČKOVIĆ, Hranislav STOJKOVIĆ, Miroslav IGNJATOVIĆ,
 Tomislav ŠUBARANOVIĆ, Milovan RAKIJAŠ 345*
40. SIMULACIJA IZVORA ENERGIJE
 ZASNOVANOG NA FN, AKUMULATORU, GORIVNOJ ĆELIJI
 I SUPERKONDENZATORU
 SIMULATION OF AN ENERGY SOURCE BASED ON
 PV, FC, ACCU BATTERY AND SUPERCAPACITOR
Miša STEVIĆ, Zoran STEVIĆ, Daniel MIJAILOVIĆ. 363
41. OSNOVNI ASPEKTI FUNDIRANJA VETROGENERATORA
 U NAŠIM USLOVIMA
 THE BASIC ASPECTS OF WIND TURBINE FOUNDATIONS
 IN OUR CONDITIONS
*Aleksandar SAVIĆ, Slobodanka JOVAŠEVIĆ, Milica VLAHOVIĆ,
 Sanja MARTINOVIĆ, Tatjana VOLKOV-HUSOVIĆ 371*
42. TERMOGRAFSKO OCENJIVANJE
 ENERGETSKE EFIKASNOSTI STAMBENIH ZGRADA,
 INDUSTRIJSKIH POSTROJENJA I TOPLANA
 THERMOGRAPHY ASSESSMENT OF ENERGY EFFICIENCY OF
 BUILDINGS, INDUSTRIAL PLANTS AND HEATING PLANTS
*Zoran STEVIĆ, Mirjana RAJČIĆ-VUJASINOVIĆ,
 Ilija RADOVANOVIĆ, Miša STEVIĆ 379*

43. MATEMATIČKI MODEL KOMPONENATA NAMENSKOG
RAČUNARSKOG SISTEMA ORIJENTACIJE BUŠILICE SA
FEROSONDAMA
MATHEMATICAL MODEL OF COMPONENTS OF THE DEDICATED
COMPUTER SYSTEM OF ORIENTATION OF BORING INSTRUMENT
ON THE BASIS OF FERROPROBES
Elena PONOMARYOVA 387
44. NAVODNJAVANJE VOĆNJAKA POMOĆU HIBRIDNOG
(PV I DIZEL AGREGATSKOG) NAPAJANJA
THE IRRIGATION OF AN ORCHARD BY HYBRID
(PV AND DIESEL AGREGATE) ELECTRIC POWER SUPPLY
Žarko ŠEVALJEVIĆ, Zoran NIKOLIĆ 397
45. TEHNO-EKONOMSKA ANALIZA GREJANJA OBJEKTA
TOPLOTNOM PUMPOM, U BIVALENTNOM SISTEMU
TECHNO-ECONOMIC ANALYSIS OF HEAT PUMP BUILDING
HEATING IN BIVALENT SYSTEM
Miroslav VULIĆ, Kristijan VUJIČIN 407
46. JEDAN POGLED UNAPRED DVA POGLEDA UNAZAD
ONE LOOK FORWARD, TWO LOOKS BACK
Aleksandar SAVIĆ 413
47. PLANIRANJE SOLARNIH PARKOVA
– ISKUSTVA NEMAČKE I SRBIJE
PLANNING ASPECTS OF SOLAR PARKS – EXPERIENCE
OF GERMANY AND SERBIA
Dejan DOLJAK, Aleksandar DEDIĆ, Milan MILENKOVIĆ 421
48. ZAŠTITA ŽIVOTNE SREDINE POMOĆU SISTEMA ZA PRIPREMU
POTROŠNE TOPLE VODE PODEŠAVANJEM OPTIMALNOG NAGIBA
I AZIMUTA SUNČEVOG PRIJEMNIKA POMOĆU ALGORITMA
HOOKE JEEVES
ENVIRONMENTAL GAINS OF DHW SYSTEM THROUGH OPTIMUM
SOLAR COLLECTOR SLOPE AND AZIMUTH ANGLES USING
THE HOOKE JEEVES ALGORITHM
*Jasmina SKERLIĆ, Danijela NIKOLIĆ,
Nebojša LUKIĆ, Jasna RADULOVIĆ* 429
49. ENERGETSKA OPTIMIZACIJA SRPSKIH ZGRADA
KORIŠĆENJEM HOOKE-JEEVES ALGORITMA
ENERGY OPTIMIZATION OF SERBIAN BUILDINGS
USING THE HOOKE JEEVES ALGORITHM
*Danijela NIKOLIĆ, Nebojša LUKIĆ,
Jasna RADULOVIĆ, Jasna SKERLIĆ* 443
50. MOGUĆNOSTI KORIŠĆENJA FOTONAPONSKIH ČELIJA
U BEOGRADU I JEDAN METOD EKOLOŠKOG NAPAJANJA
REPUBLIKE SRBIJE ELEKTRIČNOM ENERGIJOM
POSSIBILITIES OF USING PV CELLS IN BELGRADE AND ONE
METHOD OF ECO SUPPLY OF THE REPUBLIC SERBIA WITH
ELECTRICITY
Zoran NIKOLIĆ, Dušan NIKOLIĆ 453

51. METODE TESTIRANJA SUPERKONDENZATORA
 SUPERCAPACITORS TEST METHODS
*Zoran STEVIĆ, Mirjana RAJČIĆ-VUJASINOVIĆ,
 Ilija RADOVANOVIĆ, Daniel MIJAILOVIĆ, Miša STEVIĆ 461*
52. KAPACITIVNE KARAKTERISTIKE ELEKTRODA OD POROŽNOG
 UGLJENIKA ISPITANE NOVIM ELEKTROHEMIJSKIM SISTEMOM
 TESTIRANJA SUPERKONDENZATORA
 THE CAPACITIVE PERFORMANCES OF POROUSCARBON
 ELECTRODES INVESTIGATED BY NOVEL SYSTEM FOR
 ELECTROCHEMICAL TESTING OF SUPERCAPACITORS
*Daniel MIJAILOVIĆ, Zoran STEVIĆ, Vladimir PANIĆ,
 Marija VUKČEVIĆ, Dušica STOJANOVIĆ, Petar USKOKOVIĆ 467*
53. EKSTRAPOLACIJA PODATAKA DOBIJENIH SA STANICE ZA
 VETAR KORISTEĆI IMPLIMENTACIJU CFD MODELA U OKVIRU
 SOFTVERSKOG PAKETA WINDSIM
 EXTRAPOLATION OF THE MEASURED WIND DATA USING CFD
 MODEL IMPLEMENTED IN THE WINDSIM SOFTWARE PACKAGE
*Đorđe KLISIĆ, Miodrag ZLATANOVIĆ,
 Ilija RADOVANOVIĆ, Ivan POPOVIĆ 473*
54. ENERGETSKI SISTEM KOJI KORISTI PRIBLIŽNO
 100% OBNOVLJIVE ENERGIJE. SLUČAJ OSTRVA SVETA JELENA
 NEAR 100% RENEWABLE ENERGY POWER SYSTEM.
 A CASE OF ST. HELENA ISLAND
Aleksandar IVANČIĆ, Oriol GAVALDÀ 481

OPTIMIZACIJA GEOMETRIJE HORIZONTALNOG KROVA POKRIVENOG FOTONAPONSKIM PANELIMA

OPTIMISATION OF GEOMETRY OF HORIZONTAL ROOF OVERHANGS COVERED WITH PHOTOVOLTAIC PANELS

Dragan CVETKOVIĆ, Aleksandar NEŠOVIĆ,
Faculty of Engineering, University of Kragujevac
dragan_cw8202@yahoo.com

Овај рад представља опис два примера истраживања везаних за фотонапонске ћелије и резултате оптимизације величине (дубине) надстрешница покривених са фотонапонским панелима за различите комбинације кућа. Све куће имају надстрешнице покривене фотонапонским панелима. Куће су симулиране и оптимизоване коришћењем EnergyPlus-а и Hooke Jeeves алгоритма. Затим су добијене оптималне дубине надстрешница при чему је минимизиран збир потрошње примарне енергије на грејање и хлађење просторија и уграђене енергије за надстрешнице и фотонапонске ћелије. Резултати показују да дубина надстрешница зависи од њихове оријентације.

Кључне речи: *fotonaponski paneli, nadstrešnice, ugrađena energija, EnergyPlus*

This paper present description of two examples of research related to photovoltaic cells and the results of the optimization of the size of overhangs with photovoltaic panels for different combinations of houses. All the houses have overhangs covered by photovoltaic panels. They are simulated and optimized by using EnergyPlus and Hooke Jeeves algorithm. Then, optimal depths of the overhangs are found. The objective function serves to minimize the primary energy for heating and cooling of the house, and amount of embodied energy in overhangs and photovoltaic panels. Results show that overhangs depth depends on their orientation.

Keywords: *Photovoltaic panels, Overhangs, Embodied Energy, EnergyPlus*

1. INTRODUCTION

Of the total energy consumed by a household consumes in a year, more than three-quarters of the energy is spent on heating, cooling and lighting, while the rest is spent on household electrical appliances (electric equipment). Reducing energy consumption is of great importance not only for the individual, but also globally, as the burning of fossil fuels into the atmosphere emit significant amounts of greenhouse gases, primarily carbon dioxide. It also fossil fuels are a limited resource, which in nature is less and it should be used very cautiously.

By applying the principles of building with passive energy elements which include elements of shading horizontal roof overhangs that is improving the indoor comfort, reduces the consumption of primary energy and hence reduce greenhouse gas emissions. When designing strive to (aspire to) better insulation of the building from outside influences, to reduce energy exchange, on the other hand it is necessary in the best way to utilize energy from the environment in order to achieve even better results. The implementation of these principles in the stage of designing buildings, is the most effective way to achieve good results in reducing the energy required for heating, cooling and lighting.

In the published works that explore the impact of installing roof overhangs on the energy consumption was not investigated how installation roof overhangs influence on the common consumption of energy for heating, cooling and lighting. In this paper, the effect of shadowing by horizontal roof overhangs covered with photovoltaic panels was investigated on the primary energy consumption for heating, cooling and lighting of the residential building throughout the year. Optimization is performed with the simultaneous operation of the program EnergyPlus and GenOpt to optimize the obtained optimal size horizontal roof overhangs placed over all four walls (east, west, north and south). This is performed with respect to the primary energy consumption for heating, cooling and lighting, and at the same time takes into account the energy that is spent for the construction of concrete horizontal roof overhangs (embodied energy) of the appropriate dimensions [1].

2. DESCRIPTION OF A HOUSE

The house (figure 1) had a plane roof. The house was used by one family, and had the living area of 116.64 m². The house had 4 air-conditioned rooms (figure 2). Their floor area was 92.88 m². The unconditioned building area was 24 m² (the area of anterooms and bathrooms that were not air-conditioned).

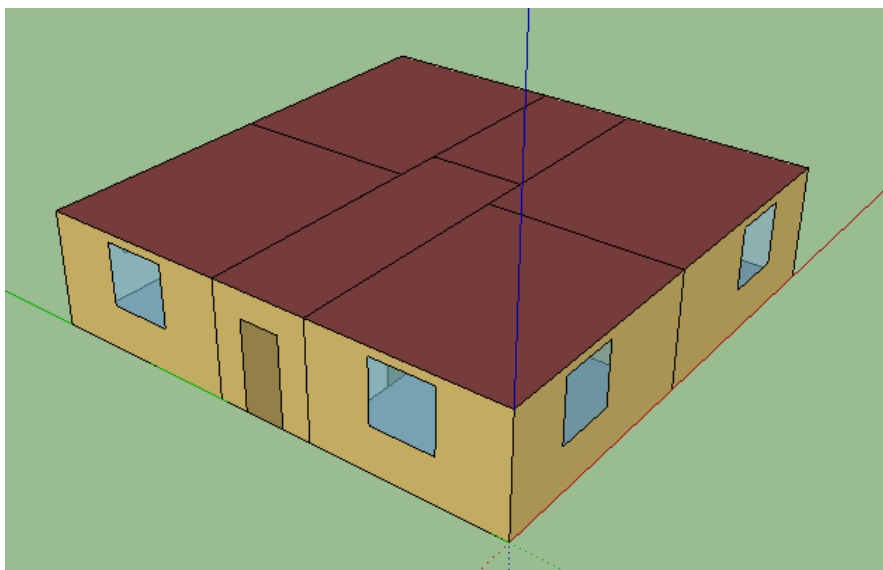


Figure 1 – Model of house

Each air-conditioned room had exterior walls, external windows, interior walls, ceilings, and floors of the same size and composition. In each room, all windows were set to the identical geometrical position relative to the boundaries of room.

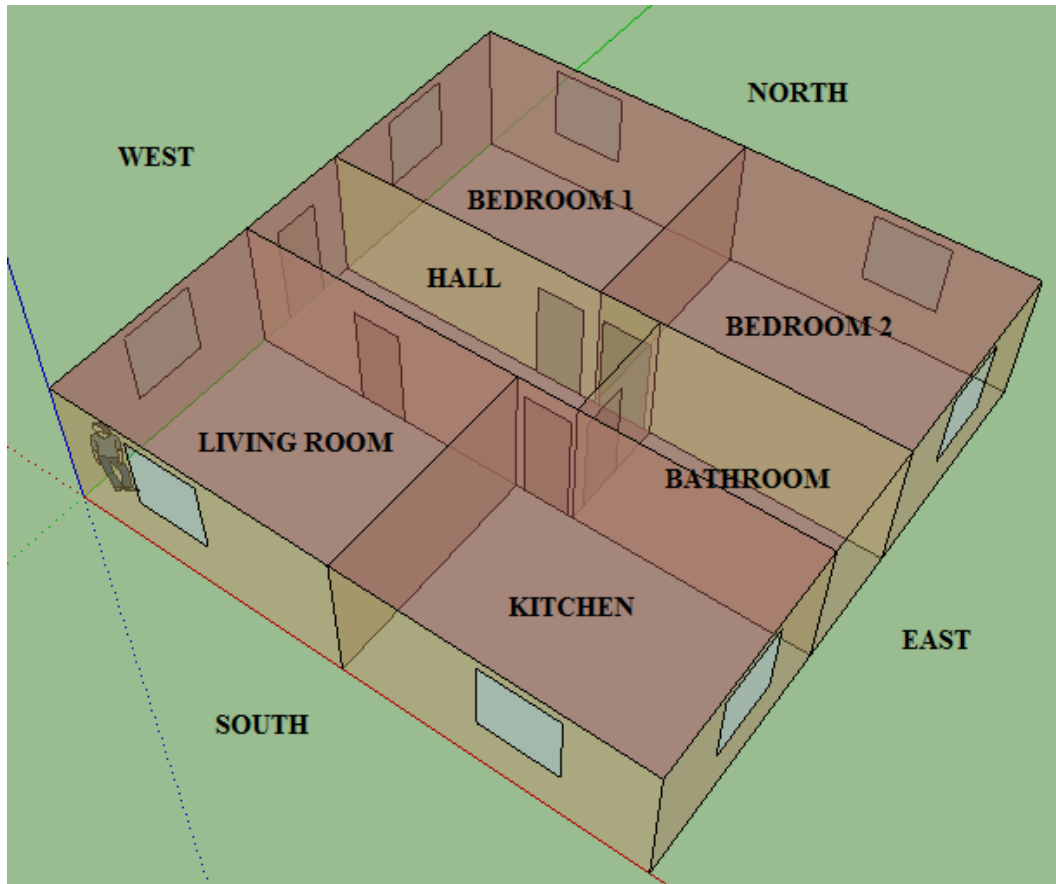


Figure 2 – Room layout

The exterior walls were made (from inside to the outside) by using 0.015 m of lime mortar, 0.19 m of clay block, 0.15 m of polystyrene, and 0.015 m of lime mortar. They had the U-value of 0.24 W/(m²K). The interior walls were made by using 0.015 m of lime mortar, 0.19 m of clay block, and 0.015 m of lime mortar. They had the U-value of 1,53 W/(m²K). The windows were double glazed with the air gap of 13 mm having U-value of 2.72 W/(m²K). The roof was made (from top to bottom) by using 0.04 m of cement screed, 0.08 m of glass wool, 0.16 m of brick, 0.015 m of lime mortar. They had the U-value of 0.4 W/(m²K). The floor was made (from the outside to the inside) by using 0.2 m of sand, 0.15 m of concrete, 0.00015 m of PVC foil, 0.05 m of polystyrene, 0.04 m of cement screed, 0.02 m of carpet. They had the U-value of 0.43 W/(m²K).

The ratio of glass to the surface of the outer wall layer is 13.96%, and the total area of exterior walls is 112.32 m² and window area is 15.68 m².

3. LOCATION AND CLIMATIC CONDITIONS OF THE OBJECT

Within EnergyPlus software package was used meteorological file SER Belgrade 132720 IWEC.epw describing Meteorological characteristics of Belgrade, Serbia [2]. The average elevation of Belgrade is 99m, and is latitude 44°82N and longitude 20°28E. Belgrade has a moderate continental climate with four seasons of winter, spring, summer and autumn.

4. THE MATHEMATICAL MODEL

To simulate the energy performance of a building EnergyPlus software was used, in which architecture is shaped himself and set all system parameters corresponding to his physical condition (thermal, lighting condition, etc.) and energy exchange with the environment in a given period of time. Finding the optimal size horizontal roof overhangs with photovoltaic panels was made with Hooke Jeeves optimization method with the help of GenOpt, so that the objective function that minimizes the consumption of primary energy for heating, cooling and lighting of the building and when it is taken in the calculation of the energy expended to build a horizontal roof overhangs with photovoltaic panels. The program works by GenOpt is coupled with the two programs EnergyPlus one of them with fixed parameters, and the other with variable parameters in which the optimization is performed. The “.ini” file defined the objective function and all necessary parameters and variables that are required for optimization as well as input, output and configuration files. The command file is given as the pattern of the traits that are necessary for the execution of the optimization algorithm (in this case Hooke Jeeves Algorithm).

To ensure adequate thermal comfort in winter, electric heaters was used. Heating thermostat is used to set the appropriate temperature in winter mode. In summer mode to maintain proper thermal comfort in rooms is used room air conditioners with the appropriate thermostat. Room air conditioners are also supplied with electricity. To maintain an appropriate light level, the combined impact of daylight and electric lighting, using DayLightingControls function (this function is implemented in EnergyPlus), which is available by entering the appropriate parameters set dimmer room in a given time interval [2].

The simulation results are obtained in the output file, and that the optimum horizontal roof overhangs size with photovoltaic panels and power consumption of heating, air conditioning, lighting and total consumed primary energy.

5. ENERGY

5.1 Primary energy consumption

Primary energy consumption of the analyzed object is calculated by the following equation:

$$E_{\text{prim}} = (E_{\text{ac}} + E_{\text{eh}} + E_{\text{eq}} + E_{\text{el}} - E_{\text{pp}})K_{\text{ec}} \quad (1)$$

Where the E_{ac} stand for electricity consumption in the indoor air conditioners, E_{eh} - electricity consumption of the electric heating, E_{eq} - electricity consumption for the electric equipment, E_{el} electricity consumption for lighting, E_{pp} - energy produced from photovoltaic panels and K_{ec} - primary energy factor (PEF). This factor is defined as the ratio of total primary energy consumption by energy sources (hydro, coal, oil, heavy oil and natural gas) and the total supplied electricity when not taking into account the imported electricity. For Serbia, the value of manufactured and supplied electricity on average in 2010th and 2011th amounts $K_{ec} = 3.04$ [3] (this value varies from year to year and depends on the season hydrological situation).

$$K_{ec} = (m_{c1}H_{d1} + m_{c2}H_{d2} + m_{c3}H_{d3}) / E_{ec,f} \quad (2)$$

5.2 Embodied energy

Embodied energy for horizontal roof overhangs depends on size and type of material, given in the third equation:

$$E_{emb} = \rho \delta l h s_{ec} / f_n \quad (3)$$

The optimization was performed in respect to the length of the exhaust horizontal roof overhangs h , where ρ stand for material density for roof overhangs (concrete, $\rho = 2150 \text{ kg/m}^3$), l stands for the width of the roof overhangs that relies on the buildings wall (10.8 m), δ thick of roof overhangs (0.18 m), h length of roof overhangs, s_{ec} roof overhangs specific embodied energy (1.924 MJ/kg) [4], f_n roof overhangs lifecycle (20 years).

5.3 The total energy

The total energy is equal to the sum of the primary energy and embodied energy as shown in Equation 4:

$$E_{tot} = E_{prim} + E_{emb} \quad (4)$$

Equation 4 is the objective function.

5.4 The achieved energy savings

Realized savings of primary energy for heating, cooling and lighting is calculated for the house with the roof overhangs set in relation to an object without roof overhangs installed:

$$e_{psav} = 100(E_{p0} - E_{pmin}) / E_{p0} \quad (5)$$

Where is e_{psav} - achieved primary energy savings in %, E_{pmin} - primary energy consumed in house before installation the roof overhangs, E_{p0} - primary energy consumed in a facility without roof overhangs.

6. RESULTS

6.1. Results before optimization

As already noted, the house most of the energy spent on heating, cooling and interior lighting. House without horizontal roof overhang spent annually 183 kWh/m²a to heating, 101 kWh/m²a to cooling, while interior lighting spent annually 40 kWh/m²a.

The results also show that power consumption can be reduced if the house has a horizontal roof overhangs (depth 1 m) covered with photovoltaic panels. Table 1. shows the results for different combinations.

Table 1 – Results of energy consumption for different combinations

| House | [kWh/m ² a] | | |
|---|------------------------|---------|-------------------|
| | Heating | Cooling | Interior lighting |
| Without overhangs and photovoltaic panels | 183,5 | 101,4 | 40,5 |
| All four sides | 199,5 | 69,7 | 42,2 |
| East – West | 190,7 | 84,2 | 41,1 |
| North – South | 191,9 | 86,8 | 41,5 |

6.2 Results of optimization

Optimal depth horizontal roof overhangs covered with photovoltaic panels in different variants are shown in table 2.

Table 2 – Optimal depth horizontal roof overhangs covered with photovoltaic panels

| House | Depth | | | |
|---------------|-------------|-------------|-------------|-------------|
| | East [m] | West [m] | North [m] | South [m] |
| Without | / | / | / | / |
| All four | 2.41 | 2.51 | 1.81 | 2.74 |
| East – West | 2.84 | 2.74 | / | / |
| North – South | / | / | 2.81 | 2.78 |
| East | 3 | / | / | / |
| West | / | 1.31 | / | / |
| North | / | / | 1.22 | / |
| South | / | / | / | 1.91 |

Houses without horizontal roof overhangs covered with photovoltaic panels consumes the most primary energy (409,1 kWh/m²a), then the total energy is equal to

the primary. House with horizontal roof overhangs covered with photovoltaic panels on all four sides spends at least primary (and total) energy ($E_{tot}=135.2 \text{ kWh/m}^2\text{a}$, $E_{p-rim}=123.9 \text{ kWh/m}^2\text{a}$), but then embodied energy consumption is highest (figure 3).

Figure 3 - Energy consumption for different combinations

House with horizontal roof overhangs covered with photovoltaic panels on all four sides produces the most energy ($77 \text{ kWh/m}^2\text{a}$). House with horizontal roof overhang covered with photovoltaic panels on east side produces more energy than house with horizontal roof overhang covered with photovoltaic panels on west (or south, or north) side, because it is the deepest (table 3).

Figure 4. shows the production of energy for different combinations.

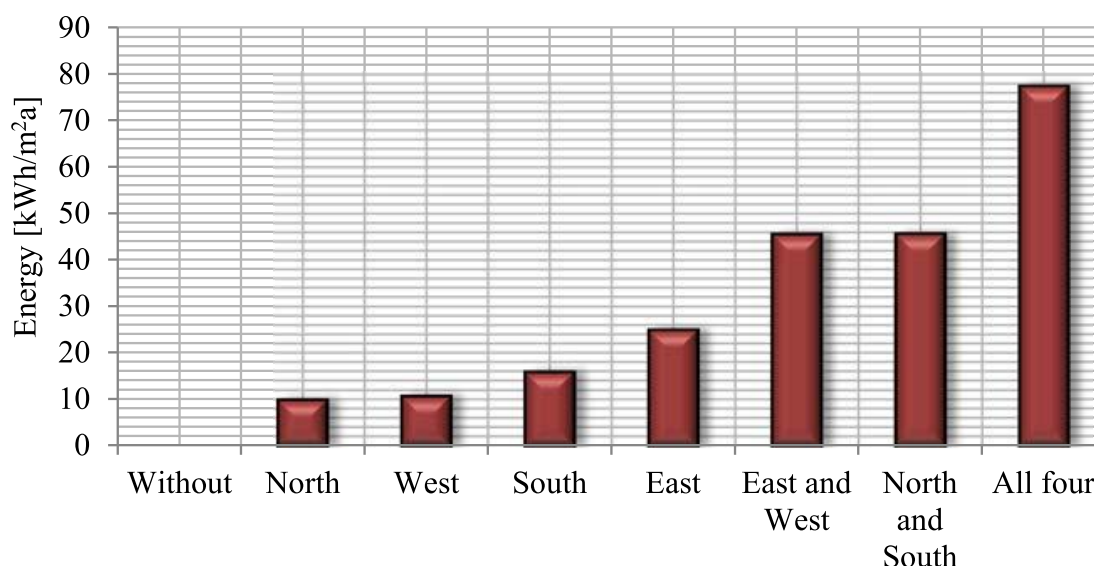


Figure 4 – Production energy from photovoltaic panels

7. ENERGY SAVING

The results show that it is possible to save up to 67% if the house owns horizontal roof overhangs covered with photovoltaic panels on all four sides (figure 5). If the house owns horizontal roof overhangs covered with photovoltaic panels on east and west, when possible savings of up to 45.6%, or 45.7% if the house owns horizontal roof overhangs covered with photovoltaic panels on north and south. If the house owns horizontal roof overhang covered with photovoltaic panels on south side, when possible savings of up to 20.4%.

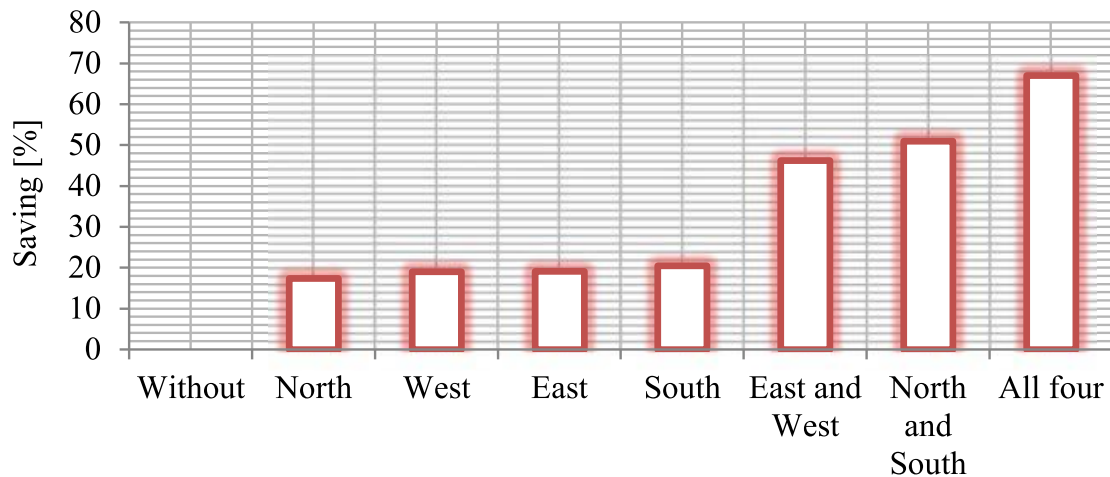


Figure 5 – Energy saving for different combinations

8. CONCLUSION

Installing overhangs optimal depth and photovoltaic panels that cover them completely, has a positive impact on energy saving houses with overhangs and photovoltaic panels in relation to the house without them.

By analyzing the results of optimization can be concluded that in the case of installing horizontal roof overhangs covered with photovoltaic panels on all four sides, the depth of overhang on the south side is 2.74 m, 1.81 m to the north, on the east side 2.41 m, while on the west 2.51 m.

A house that has horizontal roof overhangs covered with photovoltaic panels on the north and south, north overhang is 2.81 m, and the south is 2.78 m.

A house that has horizontal roof overhangs covered with photovoltaic panels on the west and east, west overhang is 2.74 m, and the east is 2.84 m.

If the house has only eastern horizontal roof overhang covered with photovoltaic panels, its optimal depth is the largest (3 m), while the lowest depths of the north (1.22m).

Modern development requires turning to energy efficiency, energy savings, cost effectiveness and renewable energy sources.

Design shading, canopies optimal combination of architecture depth covered with photovoltaic panels, a modern expression and response to issues of energy independence and efficiency of the house, as well as independence from fossil fuels.

ACKNOWLEDGMENT: This paper is a result of two investigations: (1) project TR33015 of Technological Development of Republic of Serbia, and (2) project III 42006 of Integral and Interdisciplinary investigations of Republic of Serbia. The first project is titled “Investigation and development of Serbian zero-net energy house”, and the second project is titled “Investigation and development of energy and ecological highly effective systems of poly-generation based on renewable energy sources. We would like to thank to the Ministry of Education and Science of Republic of Serbia for their financial support during these investigations.

NOMENCLATURE

- E_{prim} – annual consumption of primary energy,
 E_{ac} – annual electricity consumption of the air conditioners,
 E_{eh} – annual electricity consumption of the electric heating,
 E_{eq} – annual electricity consumption of the electric equipment,
 E_{el} – annual electricity consumption of the electric lighting,
 E_{pp} – annual energy produced from photovoltaic panels,
 E_{emb} – embodied energy,
 E_{tot} – total annual energy,
 K_{ec} – primary energy factor (PEF),
 h – length of roof overhangs,
 ρ – material density for roof overhangs,
 l – length of the exhaust horizontal roof overhangs,
 δ – thick of roof overhangs,
 s_{ec} – specific embodied energy,
 f_{n} – roof overhangs lifecycle,
 $e_{\text{psav}\%}$ – achieved primary energy savings in %,
 E_{pmin} – primary energy consumed in house afther installation the roof overhangs,
 E_{p0} – primary energy consumed in house without roof overhangs,
 E_{popt} – primary energy consumed in house afther installation the roof overhangs optimal dimensions,
 $e_{\text{p}\%}$ – reduction of primary energy.

LITERATURE

- [1] Manish Kumar Dixit, José L. Fernández-Solís, Sarel Lavy, Charles H. Culp, Identification of parameters for embodied energy measurement, *Energy and Buildings* 42 (2010) 1238–1247 A literature review.
- [2] EnergyPlus Energy Simulation Software http://apps1.eere.energy.gov/buildings/energyplus/on_februar_2012.cfm/weather_data2.cfm/region=6_europe_wmo_region_6
- [3] Interunit Heat Flows in a Residence during District Heating in a Multistory Residential Building, M. Bojic, Slobodan Djordjevic, Jovan Malesevic, Dragan Cvetkovic, and Marko Miletic
- [4] Review on life cycle assessment of energy payback and greenhouse gas emission of solar photovoltaic systems, Jinqing Peng, LinLu n, HongxingYang, Renewable Energy Research Group (RERG), Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong, China, 7 November 2012