

Četvrta međunarodna konferencija
o obnovljivim izvorima
električne energije

The 4th International Conference
on Renewable Electrical
Power Sources



ZBORNIK RADOVA PROCEEDINGS



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



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Kneza Miloša 7a/II,
11000 Beograd

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obnovljive izvore
električne energije
pri SMEITS-u**
Dr Zoran Nikolić, dipl. inž.

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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 zagadenja, 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 energetski 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.

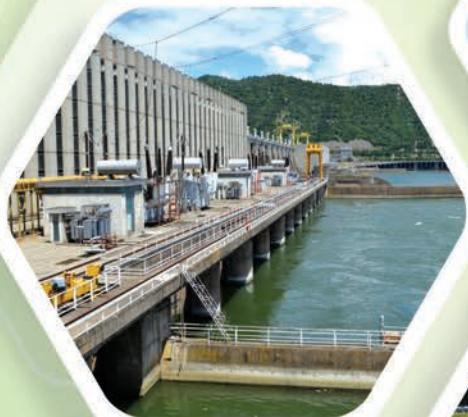
Zbog toga se veruje da će se obnovljivi izvori energije u Evropi sve više koristiti, što vodi smanjenju emisije gasova sa efektom staklene baštice i manjoj zavisnosti od nafte. U traganju za takvim rešenjima, Evropska unija je postavila ambiciozan cilj – Direktivu 2009/28/EC koja propisuje da se do 2020. 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 baštice 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*

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ENERGETSKA OPTIMIZACIJA SRPSKIH ZGRADA KORIŠĆENJEM Hooke-Jeeves ALGORITMA

ENERGY OPTIMIZATION OF SERBIAN BUILDINGS USING THE Hooke Jeeves ALGORITHM

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Danas, radikalni pristup za smanjenje potrošnje energije predstavlja koncept zgrada neto-pozitivne potrošnje energije (positive-net energy building - PNEB). Takodje, obnovljiva energija ima značajan uticaj na životnu sredinu, tako da istraživanja i razvoj obnovljivih energetskih izvora i krišćenje obnovljive energije ima suštinski značaj. U ovom radu su analizirane mogućnosti za smanjenje potrošnje energije u srpskim porodičnim zgradama. Istraživana je zgrada sa gasnim sistemom grejanja, fotonaponskim sistemom za generisanje električne energije i sa solarnim kolektorima. Glavni cilj istraživanja je analiza mogućnosti za smanjenje potrošnje primarne energije, kroz varijaciju porošnje električne energije i topanje vode u zgradama, a sve u cilju postizanja koncepta zgrade neto-pozitivne porošnje energije. Dobijeni rezultati su dali optimalne vrednosti površine fotonaponskih panela i solarnih kolektora, instaliranih na krovu zgrade. Zgrade su simulirane u okruženju softvera EnergyPlus. Open Studio plug-in u Google SketchUp-u je korišćen za dizajniranje zgrada, Hooke-Jeeves algoritm za optimizaciju, a GENOPT softver za izvršnu kontrolu softvera pri optimizaciji.

Ključne reči: PNEB; fotonaponski paneli; solarni kolektori; simulacija; optimizacija.

Nowadays, a radical approach for the mitigation of the energy demand is the concept of positive-net energy building (PNEB). Also, the renewable energy has a significant impact on the environment, so the research and development of renewable energy resources and the use of renewable energy is essential. In this paper, the possibilities to decrease energy consumption of Serbian residential buildings are analyzed. The building with gas heating system, photovoltaic array for the electricity generation and solar collectors are investigated. The major aim was to analyze the possibilities to decrease primary energy consumption, due to variation of electricity consumption and hot water consumption in building, in order to achieve positive-net energy building. The obtained results gave the optimal size of PV array and solar collectors, installed on the building roof. The buildings are simulated in EnergyPlus environment. Open Studio plug-in in Google SketchUp was used for

buildings design, Hooke-Jeeves algorithm for optimization and GENOPT software for software execution control.

Key words: PNEB, PV panel, Solar collector, Simulation, Optimization.

INTRODUCTION

Energy consumption in buildings on the world level is about 40% of total energy consumption, while in Serbia this amount is as much as 50% [1]. Building energy consumption is related to the exploitation conditions, where the largest consumers are heating system, domestic hot water system, appliances etc. Reducing energy consumption can be achieved by construction of energy efficient buildings. Energy efficient building has a lower total energy consumption, lower greenhouse gas emission and their energy needs partially or completely are satisfied with the energy generated by its own systems of renewable energy sources, that do not pollute the environment. By definition Negative-Net Energy Building (NNEB) produces less energy than it consumes during year, Zero-Net Energy Building (ZNEB) produces all energy it consumes during year, while Positive-Net Energy Building (PNEB) produces more energy than it consumes during year, and the yearly electrical energy supplied to the electricity grid is higher than that received from the electricity grid [2].

Solar energy is inexhaustible and the most promising source of renewable energy and represents the most reliable source of energy because it does not bring pollution, which is disproportionately large in the use of fossil fuels.

This article reports investigations of the possibilities to decrease energy consumption of Serbian residential buildings with PV array, solar collectors and gas heating systems, through the variation of electricity consumption and hot water consumption in building. Photovoltaic (PV) technology represents the direct conversion of solar radiation into electricity, while solar collectors convert solar energy into heat energy. On the other hand, gas heating system is a low-temperature heating system. So, the building with these systems can be positive-net energy building (PNEB).

The investigated buildings were located in Kragujevac, Serbia. The building is designed with PV panels and solar collectors installed on the roof. Electricity generated by the PV array is limited with the size of PV array. Heating devices operated from 15 October to 14 April next year. The major objective of this investigation is to determine the optimal sizes of PV panels and solar collectors on the roof, in order to minimize the consumption of primary energy. In order to achieve positive net-energy building, the buildings are investigated for variable electricity consumption by electric appliances and lighting, and variable hot water consumption. In this paper, the EnergyPlus, Open Studio plug-in in Google SketchUp, Hooke-Jeeves algorithm, and Genopt were used to achieve this objective.

SIMULATION SOFTWARES

EnergyPlus software simulates the energy use in a building and energy behavior of the building for defined period. In this study, the version 8.1.0 was used. EnergyPlus is made available by the Lawrence Berkley Laboratory in USA [3] and it has been tested using the IEA HVAC BESTEST E100-E200 series of tests [4]. For PV electricity generation, EnergyPlus uses the different component, like PV array and inverter [5].

Open Studio plug-in in Google SketchUp software is a free 3D software tool that combines a tool-set with an intelligent drawing system [6]. The software enables to place models using real world coordinates. The OpenStudio is free plug-in that adds the building energy simulation capabilities of EnergyPlus to the 3D SketchUp environment. The software allows to the user to create, edit and view EnergyPlus input files within SketchUp.

GenOpt is an optimization program for the minimization of cost function evaluated by an external simulation program. GenOpt serves for optimization problems where the cost function is computationally expensive and its derivatives are not available or may not even exist. It can be coupled to any simulation program that reads its input from text files and writes its output to text files. GenOpt is written in Java so that it is platform independent. It has a library with adaptive Hooke-Jeeves algorithm [7].

Hooke-Jeeves optimization algorithm is used for the optimization, and it is direct search and derivative free optimization algorithm [8]. In this algorithm, only the objective functions and the constraint values are used to guide the search strategy. The main advantage of this algorithm is reducing the compute time.

WEATHER CONDITIONS

The investigated residential building was located in the city of Kragujevac, Republic of Serbia. Its average height above sea-level is 209 m. Its latitude is $44^{\circ}10'$ N and longitude $20^{\circ}55'$ E. The time zone for Kragujevac is GMT + 1.0 h. The city of Kragujevac has a moderate continental climate with a gradual transition between the four distinct seasons (winter, spring, summer, and autumn). The summers are very warm and humid, with temperatures as high as 37°C . The winters are cool, and snowy, with temperatures as low as -12°C . The EnergyPlus uses weather data from its own database file.

MODELED BUILDING

The modeled residential building is shown in Figure 1. The building has the south-oriented roof with a slope of 37.5° , and PV array installed on the roof. Also, there are solar collectors on the roof. The building has two floors and 6 conditioned zones. The total floor area of the building is 160 m^2 and total roof area 80.6 m^2 . The windows are double glazed. The concrete building envelope, roof, and the floor were thermally insulated by polystyrene. In this investigation, the polystyrene thickness was 0.15m.

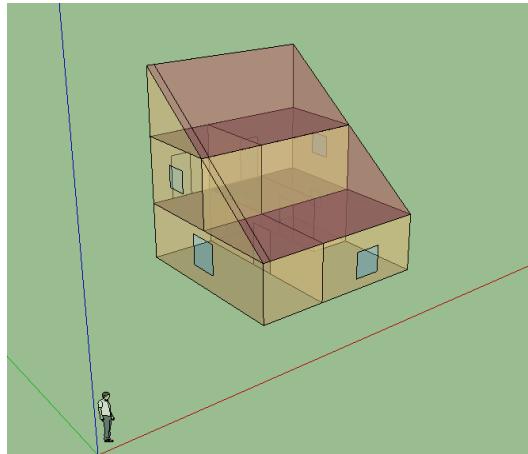


Figure 1. Modeled residential building

Air temperatures in the heated rooms are set to 20°C from 07:00-09:00 and from 16:00-21:00, and to 15°C from 09:00-16:00. The simulation time step is 15 min.

Electricity is consumed for lighting, domestic hot water (DHW), and appliances (E_{EL^*}). In the case of gas heating, the main part of electricity was consumed by appliances. Gas heating energy is marked with E_{GH} .

The PV system consisted of the PV array and an inverter. It was an on-grid system. The life cycle of PV array was set to 20 years, and the embodied energy of PV panels to 3.75 GJ/m² [9, 10]. The PV array was represented by the mathematical model of Photovoltaic: Simple from EnergyPlus [3], which describes a simple model of PV that may be useful for early phase design analysis.

OPTIMIZATION PROCEDURE

Mathematical optimization was performed according to the buildings energy needs. This optimization had the major goal to determine the optimal size of PV array and solar collector, which will yield the minimal primary energy consumption of the building. The primary energy saving (E_{PRIM}) consists of the primary energy covered by energy generated by PVs (E_{PV}) and energy generated by solar collectors (E_{COLL}), embodied energy in the PV array ($E_{em,PV}$), embodied energy in the solar collectors ($E_{em,COLL}$) and embodied energy of the thermal insulation ($E_{em,ISO}$) [11]. For the optimization, the following objective function was used [12]

$$E_{PRIM} = R_{EL}(E_{PV} + E_{COLL}) - C_m((E_{em,PV} + E_{em,COLL})C_{inst}) - C_{m1}E_{em,ISO}$$

where: E_{PRIM} – the yearly avoided operative primary energy consumption due to operation of the PV array and solar collectors (J); $R_{EL} = 3.04$ - primary conversion multiplier [11]; E_{PV} – yearly electrical energy generated by PV array (J); E_{COLL} – yearly heat energy generated by solar collectors (J); $E_{em,PV}$ – PV array embodied

energy (J); $E_{em, COLL}$ – solar collectors embodied energy (J); $C_m=1/LC$; where LC is life cycle of PV and solar collectors, in years, $C_{m1}=1/LC_{ISO}$; where LC_{ISO} is life cycle of thermal isolations, in years, $E_{em, ISO}$ – insulation embodied energy (J) and C_{inst} – coefficient of instalation and maaintenance of solar systems during their life cycle (-) [13]. The primary energy of total building consumption is

$$E_{primary, CONS} = p_{EL} E_{EL} + p_{GH} E_{GH}$$

where E_{EL} stands for the yearly total electricity consumption by building (J); $p_{GH}=1.1$ stands for the primary conversion multiplier for gas heating and E_{GH} stands for the yearly district heating energy consumption in a building (J).

The roof area covered by the PV array is marked by y . The value y exists in the calculated total embodied energy and electrical energy generated by PV.

Alsema [9, 10] reported that the embodied energy in crystalline silicon modules varies between 2400 and 7600 MJ/m² for mc-Si, and between 5300 and 16500 MJ/m² for sc-Si technology (the module efficiencies were 13% and 14%, respectively) and the average PV life time is 30 years. Sanchez [14] reported that the embodied energy in a frameless a-Si module was in the range of 710 - 1980 MJ/m² (the module efficiency of 7 %). Thermal insulation had the embodied energy of 86.4 MJ/kg, the density of 16 kg/m³ and the thermal conductivity of 0.037 W/mK [15].

RESULTS AND DISCUSSION

6.1 Different hot water consumption

In these simulations, the analyzed buildings had different hot water consumption - 8 m³, 11.5 m³ (referent case), 19 m³ и 27 m³ (monthly). Each building had the thermal insulation thickness of 0.15 m.

With the increasing of hot water consumption, the electricity required for its heating increasing too, and there is a small increase in the consumption of electricity required for the operation of electrical devices. All this resulted in different electricity consumption - Table 1. This table shows the energy needed for heating the building by using the gas heating system and the annually total consumption of primary energy in the building. The energy needed for heating the building remains the same value in the reference case because there were no influences that could cause its change. Obtained results showed that with the increase of the monthly hot water consumption, the total annual consumption of final or primary energy consumption increasing too.

For different of hot water consumption in the building with gas heating system, compared to the lowest consumption of 8m³, increasing of primary energy consumption for hot water consumptions of 11.5 m³, 19 m³ and 27 m³ is 11.61 GJ (9.4%) 41.04 GJ (33.3%) and 70.86 GJ (57.4%), respectively. The reason for such a large increase in primary energy consumption is that with the increase of hot water consumption significantly increases total final energy consumption, which has a large coefficient of conversion to primary energy. Figure 2 provides an overview of energy parameters in case of gas heating building.

Table 1. Final and primary energy consumption in buildings, for different hot water consumption

| Electricity consumption (GJ) | Hot water consumption (m ³) | | | |
|-------------------------------|---|--------------|--------------|--------------|
| | 8 | 11,5 - Ref | 19 | 27 |
| Lighting | 1,02 | 1,02 | 1,02 | 1,02 |
| Electrical devices | 6,90 | 6,91 | 6,95 | 6,98 |
| Water heating | 19,08 | 22,89 | 32,53 | 42,31 |
| SUM | 27,00 | 30,82 | 40,50 | 50,31 |
| Heating (gas) (GJ) | 37,52 | | | |
| TOTAL CONSUMPTION (GJ) | | | | |
| Final energy | 64,52 | 68,34 | 78,02 | 87,83 |
| Primary energy | 123,35 | 134,96 | 164,39 | 194,21 |

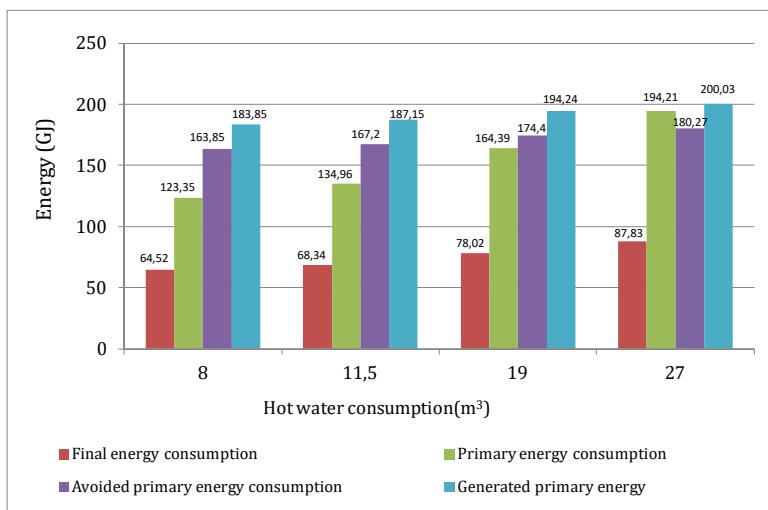


Figure 2. Final energy consumption, primary energy consumption, primary energy of generated energy and maximum of avoided primary energy for buildings with different hot water consumption and gas heating system (Yearly values)

Results obtained by the optimization for building with gas heating and different hot water consumption are given in Table 2. All the buildings were PNEB with or without embodied energy, except the building with the highest hot water consumption. It was NNEB according to the approach with embodied energy.

Table 2. Energy consumption, generated energy, fraction of PV panels and avoided primary energy consumption of the buildings (Yearly values)

| | Hot water consumption (m^3) | | | |
|--|--|-------------|-------------|-------------|
| | 8 | 11,5 –Ref | 19 | 27 |
| Fraction of PV panels on the roof (%) | 93,13 | 91,88 | 89,38 | 87,5 |
| Total generated electricity by PV (GJ) | 49,47 | 48,81 | 47,48 | 46,48 |
| Total generated heat energy (GJ) | 11,01 | 12,75 | 16,41 | 19,31 |
| Primary energy of generated energy (GJ) | 183,86 | 187,15 | 194,24 | 200,03 |
| EPRIM – avoided primary energy (GJ) | 163,86 | 167,20 | 174,4 | 180,27 |
| Embodied energy in solar systems (GJ) | 17,83 | 17,78 | 17,67 | 17,59 |
| Embodied energy in thermal insulation (GJ) | 2,17 | 2,17 | 2,17 | 2,17 |
| Total primary energy consumption (GJ) | 123,35 | 134,96 | 164,39 | 194,21 |
| Building type (without embodied energy) | PNEB | PNEB | PNEB | PNEB |
| Building type (with embodied energy) | PNEB | PNEB | NNEB | |

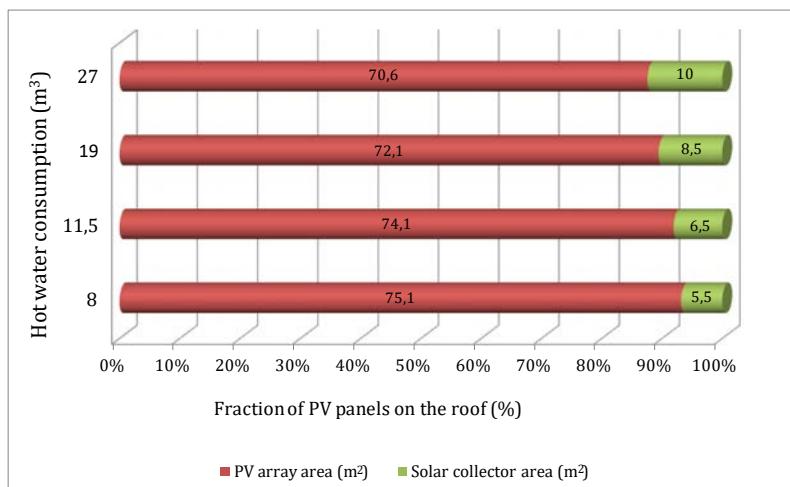


Figure 3. Area ratios of PV panels and solar collectors for different hot water consumptions

Fraction of PV panels on the roof decreases with increase of the hot water consumption, while the fraction of solar collectors on the roof increases. For hot water consumption of 8 m^3 , fraction of PV panels on the roof is 93.13% (area of PV array is 75.1 m^2 while the other 5.5 m^2 of the roof are covered with solar collectors). For hot water consumption of 11.5 m^3 , 19 m^3 and 27 m^3 , fraction of the PV panels on the roof is 91.88%, 89.38% and 87.5% respectively (Figure 3).

6.2 Different electricity consumption in residential building

In these simulations, the analyzed buildings had different electricity consumption for electrical equipment. Each building had the thermal insulation thickness of 0.15 m, the hot water consumption of 11.5 m³/month, where the yearly electricity consumption by the water system was 6.52 GJ/a.

In the case 1, the considered building had the yearly electricity consumption of 6.26 GJ/a by the electric equipment, and 1.02 GJ/a by lighting. In the case 2, the considered building had higher electricity consumption by electric equipment (7.4 GJ) and lighting (1.96 GJ). The results were shown in Table 3.

Table 3. Yearly values of energy characteristics for building with gas heating system: different electricity consumption for other electricity services

| | Case 1 | Case 2 |
|---|-------------|-------------|
| Electricity consumption | 14.43 GJ | 15.89 GJ |
| Space gas heating energy | 37.52 GJ | 37.52 GJ |
| Total building energy consumption | 68.34 GJ | 69.9 GJ |
| Primary energy of total energy consumption | 134.96 GJ | 139.24 GJ |
| Fraction of PV panels on the roof | 0.92 | 0.92 |
| E _{PV} - Total generated electricity by PV | 48.81 GJ | 48.81 GJ |
| Generated heat energy | 12.75 GJ | 12.75 GJ |
| Primary energy of generated energy | 187.15 GJ | 187.15 GJ |
| E _{primary, PV} – avoided primary energy | 167.2 GJ | 167.2 GJ |
| Embodied energy in solar systems (GJ) | 17.78 GJ | 17.78 GJ |
| Embodied energy in th. (GJ) | 2.17 GJ | 2.17 GJ |
| Building type (without embodied energy) | PNEB | PNEB |
| Building type (with embodied energy) | PNEB | PNEB |

In all cases, the fraction of PV panels on the roof is $y=0.92$ and the avoided operative primary energy consumption 187.15 GJ/a (including the embodied energy of thermal insulation and PV), i. e. 167.2 GJ without the embodied energy of thermal insulation and PV array were obtained. All buildings are PNEB.

CONCLUSION

The major aim of this investigation was optimization to determine the optimal area of PV array of PV array and solar collectors on the roof, due to achieving the concept of positive net-energy building. All the considered buildings had the gas heating system.

In the cases of different hot water consumption, fraction of PV panels on the roof decreases with increase of the hot water consumption, while the fraction of solar collectors on the roof increases. Four investigated buildings were PNEB, with or without embodied energy, except the building with the highest hot water con-

sumption by the approach with embodied energy. Buildings with different electricity consumption are also PNEB, with or without embodied energy.

Obtained results showed that concept of PNEB can be easily achieved, if the building has the low-energy heating system and its own systems of renewable energy, which generate electricity and heating energy.

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REFERENCES

- [1] Bojić M., Nikolić N., Nikolić D., Skerlić J., Miletić I., A simulation appraisal of performance of different HVAC systems in an office building, Energy and Buildings, Volume 43 - Issue 6, 2011, p. 2407-2415
- [2] D. Nikolić, M. Bojić, J. Radulović, J. Skerlić, S. Jovanović, Energy optimization of Serbian buildings with pv panels and district heating system,, 12th International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology DEMI 2015, Бања Лука, 30. мај – 1. јун 2015. год., ISBN 978-99938-39-46-0, p. 703-708
- [3] Anonymous, ENERGYPLUS, Input Output Reference - The Encyclopedic Reference to EnergyPlus Input and Output, University of Illinois & Ernest Orlando Lawrence Berkeley National Laboratory, 2009
- [4] Henninger R.H., Witte M.J., Crawley D.B., Analytical and comparative testing of EnergyPlus using IEA HVAC BESTEST E100-E200 test suite, Energy and Buildings 36 (8), (2004), p. 855–863
- [5] Lawrence Berkeley National Laboratory. EnergyPlus - Engineering documentation: the reference to EnergyPlus calculations. University of Illinois & Ernest Orlando Lawrence Berkeley National Laboratory; 2001
- [6] Bojić M., Skerlić J., Nikolić D., Cvetković D., Miletić M, Toward future: positive net-energy buildings, Proceedings 4thRenewable Energy Sources, EXPRES 2012, March 9-10, 2012., Subotica, Serbia, p. 49-54 IEEE International Symposium on Exploitation of
- [7] Wetter, M., 2004. GenOpt, Generic Optimization Program, User Manual, Lawrence Berkeley National Laboratory, Technical Report LBNL- 54199, p. 109.
- [8] Hooke R., Jeeves T.A., Direct search solution of numerical and statistical problems, Journal of the Association for Computing Machinery, Volume 8 (1961), pp. 212–229
- [9] Alsema, E.A., Nieuwlaar, E., Energy viability of photovoltaic systems, Energy Policy, Volume 28(14), 2000, pp. 999–1010

- [10] Alsema E.A., Energy pay-back time and CO₂ emissions of PV systems, Progress in Photovoltaics: Research and Applications 8(1), (2000), pp. 17–25
- [11] Nikolić D., Skerlić J., Miletić M., Radulović J., Bojić M., Energy optimization of PV panels size at Serbian ZNEB and PNEB, Proceedings 23th Conference Nationala cu Participare Internationala INSTALATII PENTRU CONSTRUCTII SI CONFORTUL AMBIENTAL, 11-12 April, Timisoara, Romania, pp. 267- 278
- [12] Nikolić D., Bojić M., Skerlić J., Radulović J., Energy optimization of serbian buildings with solar collectors and different pv systems, CD Conference proceedings и Зборник радова, ISBN 978-86-81505-79-3, 46th International HVAC&R congress, Beograd, decembar 2015
- [13] Cabeza L.F., Rincón L., Vilariño V., Pérez G., Castell A., Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review, Renewable and Sustainable Energy Reviews, Volume 29, 2014, 394–416
- [14] Justine Sanchez, PV Energy Payback, www.homepower.com
- [15] Bojić M., Miletić M., Marjanović V., Nikolić D., Skerlić J., Optimization of thermal insulation to achieve energy savings, 25. International conference on efficiency, cost, optimization, simulation and environmental impact of energy systems-ECOS 2012, Perugia, Italy, Jun 26-29.2012, paper 174, p. 174-1-174-10

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Ministarstvo prosvete, nauke i tehnološkog razvoja



BOSCH

Tehnologija za život

BOSCH nudi liniju kolektora izuzetnih performansi, kao i setove opreme koji obuhvataju sve što je potrebno za izvođenje jednog solarnog sistema



Inženjerska komora Srbije, Beograd

VIESSMANN

Viessmann predstavlja kolektor sa ThermProtect – patentiranim "inteligentnim" premazom apsorberskog sloja koji se, sa promenom u svojoj kristalnoj strukturi u zavisnosti od temperature, automatski prilagođava promenama Sunčeve svetlosti i trošenju toplove

Weishaupt nudi solarne kolektore koji su idealni za dopunu kondenzacionog sistema ili toplotne pumpe. Kolektori su robusni i otporni na vremenske uticaje. Pogodni su kako za zagrevanje sanitарне toplice vode, tako i za podršku grejanju. Do 30% godišnje potrošnje goriva se može uštedeti kombinovanim sistemom sa podrškom grejanju/zagrevanjem sanitарne vode.



messe frankfurt

ZODAX®

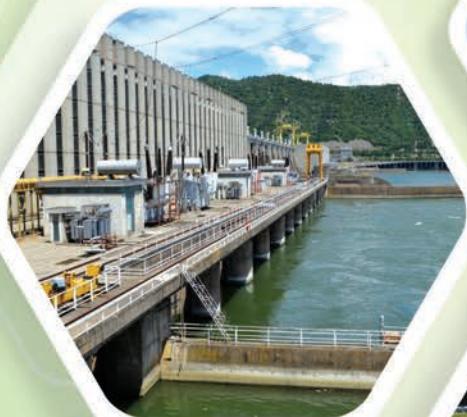
ISH light+building

Zodax je zastupnik Frankfurtskog sajma za Srbiju, Crnu Goru i Makedoniju. Ovo preduzeće nudi organizaciju poseta i izlaganja na sajmovima koje Frankfurtski sajam organizuje širom sveta.

FLIR

Zodax je zvanični zastupnik, distributer i sistem integrator kompanije Flir Systems – najvećeg svetskog proizvođača termalnih kamera.

ЕПС



ЕПС

