

4th International Academic Conference

View metadata, citation and subscription information provided by RA



PLACES AND TECHNOLOGIES 2017
KEEPING UP WITH TECHNOLOGIES IN THE CONTEXT OF URBAN AND RURAL SYNERGY
Book of Conference Proceedings

Sarajevo, Bosnia and Herzegovina, June, 08th - 09th, 2017

4th International Academic Conference
PLACES AND TECHNOLOGIES 2017

KEEPING UP WITH TECHNOLOGIES IN THE CONTEXT OF URBAN AND RURAL SYNERGY

08 & 09 JUNE

SARAJEVO

BOSNIA AND HERZEGOVINA

BOOK OF PROCEEDINGS

PLACES AND TECHNOLOGIES 2017
KEEPING UP WITH TECHNOLOGIES IN THE CONTEXT OF URBAN AND RURAL
SYNERGY

BOOK OF CONFERENCE PROCEEDINGS

Editors:

Dženana Bijedić, Aleksandra Krstić-Furundžić, Mevludin Zečević



Sarajevo, Bosnia and Herzegovina

Title :

**PLACES AND TECHNOLOGIES 2017 - KEEPING UP WITH TECHNOLOGIES IN THE CONTEXT OF URBAN AND RURAL SYNERGY
BOOK OF CONFERENCE PROCEEDINGS**

For publisher:

Prof.Mr.Sci Mevludin Zečević

Chef editors:

Prof.Dr Dženana Bijedić, Prof.Dr Aleksandra Krstić-Furundžić, Prof.Mr.Sci Mevludin Zečević

Editorial board:

Prof.Dr Eva Vaništa Lazarević, Prof. Dr Aleksandra Djukić, Dr Milena Vukmirović

Publisher:

Arhitektonski fakultet Univerziteta u Sarajevu

Year of publishing:

2017

CIP - Katalogizacija u publikaciji
Nacionalna i univerzitetska biblioteka

Bosne i Hercegovine, Sarajevo

711.3/.4(063)(082)

INTERNATIONAL Academic Conference Places and Technologies (4 ; 2017 ; Sarajevo)

Keeping up with technologies in the context of urban and rural synergy [Elektronski izvor] : book of conference proceedings / [4th International academic conference] Places and technologies 2017, Sarajevo, June, 08th - 09th, 2017 ; editors Dženana Bijedić, Aleksandra Krstić-Furundžić, Mevludin Zečević. - El. zbornik. - Sarajevo : Arhitektonski fakultet, 2017. - 1 USB fleš memorija

Sistemski zahtjevi: Nisu navedeni. - Nasl. sa nasl. ekrana

ISBN 978-9958-691-56-0

COBISS.BH-ID 24131590

CONTENTS

ORGANIZATION	ix
ABOUT	xiv
TOPICS	xiv
KEY NOTE SPEAKERS	xv
WORD OF THE P&T_2017 CONFERENCE DIRECTORS	xvii
OPENING AND SPECIAL PAPERS' TOPICS	1
URBAN AND RURAL CONNECTION BETWEEN GLOBAL AND LOCAL – BETWEEN ROLE AND REALITY. WHAT DESIGN CAN DO TO ACHIEVE THE SYNERGY?	3
SPACES OF LOW AND HIGH-INTENSITY CHANGES	4
DECENTRALISING CITIES: TECHNOLOGY, THE NEW CLIMATE AND THE FUTURE OF PERI-URBAN GROWTH	13
TOPIC I: IMAGE, IDENTITY AND QUALITY OF PLACE	27
LIGHT AND ARCHITECTURE IN THE CASE OF ADIL BEY AND KUWAIT MOSQUE IN SARAJEVO	28
THE HOMEOSTASIS AND THE SYNERGY IN THE CONTEMPORARY AND FUTURE LANDSCAPING	38
PRINCIPLES OF ARCHITECTURAL REGIONALISM AS MEANS OF BUILT FORM IMPROVEMENT IN BOKA BAY, MONTENEGRO	48
INVESTMENT OPPORTUNITIES IN SERBIA: KIKINDA CASE STUDY	57
FREE ZONE IN KIKINDA	64
DEVELOPMENT CONCEPTS OF <i>UrbRur</i> AREAS	68
COMPLEX PATTERNS OF SYNERGY BETWEEN URBAN AND RURAL SPACES	77
THE IMPORTANCE OF IDENTITY AND QUALITY OF LIFE, THE CITY OF BANJALUKA	88



SELF-ORGANIZED PATTERNS OF RURAL SETTLEMENTS VS. PLANING AND DESIGNING THE BUILT ENVIRONMENT	96
KNEZ (PRINCE) MIROSLAV SQUARE IN OMIŠ (CROATIA)	105
IMAGE, IDENTITY AND QUALITY OF <i>CVJETNO NASELJE</i> HOUSING DEVELOPMENT IN ZAGREB.....	115
THE SMALL-SCALE APPROACH AS A GENERATOR FOR URBANITY INCREASE OF BANJA LUKA CITY	126
SPATIAL, TECHNOLOGICAL AND STYLISTIC PATTERNS OF PRODUCTION OF THE BUILT ENVIRONMENT IN BOSNIA AND HERZEGOVINA	135
TOPIC II: URBAN AND RURAL PLACES TOWARD HUMAN COMFORT, HEALTH AND INCLUSION	144
THE EXPERIENCE OF SMART CITY IN LIGURIA, ITALY. THE CASE STUDIES OF THE MUNICIPALITIES OF LA SPEZIA AND SAVONA	145
HEALTHY URBAN ENVIRONMENT AND DESIGN: THE OUTDOOR SPACES	155
TENDENCIES IN NEWLY-BUILT MULTI-FAMILY HOUSING IN SERBIA: OUTLOOK OF URBAN EXPERTS.....	169
DECODING URBAN FRAGMENTATION: MORPHOGENETIC PROCESSES IN THE SHAPING OF A SUBURBAN TERRITORY IN LISBON'S METROPOLIS.....	180
RETHINKING ARCHITECTURE AND RELATED ENERGY EFFICIENCY IN WESTERN BALKAN CITIES “Case study of the housing developments in city of Sarajevo”	189
THE ZONE OF TRANSITION: BETWEEN CITY AND LANDSCAPE	204
INNOVATIVE APPROACHES IN THE PROOCESS OF RE-INTEGRATION OF CITY AND VILLAGE.....	215
PERSPECTIVES THAT ARISE FOR PREVENTIVE MEDICINE FROM THE SYNERGY OF URBAN AND RURAL AREAS.....	227
WATER PROTECTION IN URBAN AREAS	236
RELATION BETWEEN PLANNING AND REALIZATION OF OPEN SPACES IN NEW BELGRADE SUPER-BLOCKS: CASE STUDIES OF BLOCKS 45 AND 70	244
IMPACTS OF EARTHQUAKE ACTIONS ON URBAN AND RURAL AREAS	253
TOPIC III: SUSTAINABLE COMMUNITIES AND PARTICIPATION.....	263
THE ARCHITECTURE OF GARDEN AS NEW RECREATION FIELD OF EVERYDAY URBAN LIFE	264
THE SCIENCE OR ART OF MAPPING? - ELABORATING THE PROCESS OF TIS CREATION IN CITY OF NIŠ.....	273

THE ROLE OF SOCIAL MEDIA IN THE PROCESS OF ENHANCING COMMUNITY PARTICIPATION THROUGH BOTTOM-UP APPROACH IN THE CONTEXT OF URBAN REGENERATION.....	284
CREATIVE CITY CHALLENGING CONCEPT “ALL FOR ONE – ONE FOR ALL”	295
HOUSING QUALITY OF SOCIALLY VULNERABLE CATEGORIES AND AFFORDABILITY OF CURRENT SOCIAL HOUSING PROGRAMMES.....	304
TOWARDS SUSTAINABLE REGIONAL DEVELOPMENT THROUGH SOCIAL NETWORKING – „NEGOTINSKA KRAJINA “CASE.....	312
COOPERATIVE GIS PLATFORM FOR IMPROVING RESILIENCE TO HOUSEHOLD RISKS – CASE STUDY OF ADA MEDJICA ON SAVA RIVER IN BELGRADE.....	323
MULTILEVEL GOVERNANCE INSTRUMENTS FOR ACHIEVING BALANCED URBAN-RURAL DEVELOPMENT	332
SMART CITY CONCEPT IN THE STRATEGIC URBAN PLANNING PROCESS. CASE STUDY OF THE CITY OF BELGRADE, SERBIA	341
INTEGRATIVE AND LOCALLY SENSITIVE APPROACH TO THE COMMUNITY PLANNING IN SERBIA.....	350
THE “DYNAMIC EDGE”: RE-CONCEPTUALIZATION OF THE URBAN FRINGE	359
TOPIC IV: ARCHITECTURE AND BUILDING TECHNOLOGIES.....	370
SUSTAINABILITY IN HIGHER EDUCATION AND RESEARCH: THE ROLE OF THE ARCHITECT	371
INTEGRATION OF SOLAR THERMAL COLLECTORS INTO THE BUILDING ENVELOPE OF THE MULTIFAMILY HOUSING BUILDING IN BELGRADE	379
TESTING THE MOST OPTIMAL SCENARIO OF IMPROVING ENERGY PERFORMANCES OF RESIDENTIAL BUILDINGS IN SERBIA, CONSTRUCTED IN THE PERIOD OF 1971-1980.....	389
DAYLIGHT AND ENERGY ENHANCEMENT WITH VENTILATED FAÇADE SYSTEMS FOR RENOVATION PROJECTS	399
INTEGRATED DESIGN IN THE PROCESS OF ARCHITECTURAL EDUCATION	408
EVALUATION OF WALL THERMAL PERFORMANCE FOR VEGETATION WALL.....	417
MONOCULTURE FACTORY BUILDING PROJECT - Facility relaying on energy efficient technologies in order to prevent abandonment and decay of rural communities in Vojvodina	418
NEGOTIATING SUSTAINABILITY IN URBAN DEVELOPMENT: THE ROLE OF TECHNICAL BUILDING EQUIPMENT AT DAS ECKWERK, BERLIN	427



TOPIC V: ENVIRONMENTALLY FRIENDLY MODES OF TRANSPORT AND COMMUTE... 438

WEARABLE DEVICES HELP THE WALKER TO EXPLORE THE CITY 439

EXPLORING THE CITY WITH THE BICYCLE AND TECHNOLOGY HELP TO IDENTIFY HAZARDS MET THEREBY 445

AIRCRAFT TECHNOLOGY ENHANCING ENVIRONMENTAL PROTECTION WITHIN URBAN AREAS 455

CARSHARING – USING INSTEAD OF OWNING 461

CONCEPT OF THE REGIONAL PUBLIC TRANSPORT SYSTEM DEVELOPMENT 470

TOPICS VI: CLIMATE CHANGE..... 477

ENERGY SAVING POTENTIAL OF THE REFURBISHMENT OF BUILDING ENVELOPE OF THE EXISTING SINGLE-FAMILY HOUSES IN URBAN AND RURAL AREAS OF BOSNIA AND HERZEGOVINA..... 478

(R)URBAN SYNERGY RECONSIDERED: THE ROLE OF INFORMATION NETWORKS IN CLIMATE CHANGE ADAPTATION AND MITIGATION..... 489

TOPICS VII: GEOGRAPHY AS DEVELOPMENT FACTOR 499

ROLE OF TWIN CITIES AND SATELLITE TOWNS IN INTENSIFYING REGIONAL DEVELOPMENT 500

SMALL URBAN CENTERS AS DRIVERS OF DAILY MIGRATIONS AND AGENTS OF TRANSFORMATION OF RURAL BACKGROUND: EXAMPLE OF BLACE MUNICIPALITY 512

TOPIC VIII & IX: CULTURAL PATTERNS AND SENSITIVITY; SUSTAINABILITY LESSONS FROM VARNICULAR ARCHITECTURE 525

USING SPACE SYNTAX MODEL IN TYPO MORPHOLOGICAL STUDIES - UNDERSTANDING THE TRANSFORMATION OF URBAN FORM AND URBAN LIFE OF THE EDGE BLOCKS OF NEW BELGRADE 526

THE FUNCTION OF GREENERY IN A SKYSCRAPER: THE PLACEMENT AND ITS INFLUENCE 536

Moshe Safdie 539

THE IMPORTANCE OF THE APPLICATION OF CO-DESIGN WITHIN THE REDESIGN OF THE CULTURAL CENTERS IN B&H 544

LEARNING FROM THE TRADITIONAL MEDITERRANEAN ARCHITECTURE: MICROCLIMATIC AND LIVEABILITY CONDITIONS IN INTERMEDIATE OUTDOOR SPACES..... 553

SUSTAINABILITY AND RESILIENCE IN TRADITIONAL BOSNIAN AND HERZEGOVINIAN ARCHITECTURE - LEARNING FROM TRADITION FOR BETTER FUTURE 563

TOPIC X: TOURISM FOR URBAN-RURAL SYNERGIES 572

FLUIDITY: NETWORKED CONTEXT AND CONTEMPORARY METHODOLOGIES OF ARCHITECTURE IN TOURISM	573
ICT POTENTIAL FOR ENTREPRENEURSHIP IN RURAL AREAS	582
FOOD TOURISM CONCEPT - CREATING SYNERGY BETWEEN URBAN AND RURAL PLACES - CASE STUDY OF MAGLIČ, SERBIA	582
STRATEGIES FOR RURAL TOURISM DEVELOPMENT IN NIŠAVA DISTRICT IN SOUTHEASTERN SERBIA AS MAIN HUB FOR URBAN AND RURAL SYNERGY	608
TOPIC XI: RESILIENCE OF PLACES	624
APPLICATION OF ICT FOR URBAN REGENERATION, ENVIRONMENTAL PROTECTION AND SOCIAL EQUALITY IN SCOTLAND	625
METHODS AND TECHNIQUES TO SUPPORT COGNITIVE PROCESSES OF TERRITORIAL RESILIENCE IN DEVELOPING COUNTRIES – CASE STUDY OF SERBIA	634
CONTINUOUS PERFORMATIVE LANDSCAPES FOR RESILIENT CITY OF SKOPJE	644
AGILE METHODS IN FORMATION OF METROPOLIS NEIGHBOURHOOD	654
REVITALIZATION OF VAST CITY SPACES THROUGH THE MEANS OF SOUND	663
“URBAN RENEWAL UNDER THE SCOPE OF SECURITY ISSUES” - CASE STUDY OF BELGRADE – GLOOMY PARTS OF THE CITY	669
DISASTER RISK REDUCTION IN URBAN SETTLEMENTS – COMBINED MORPHOLOGICAL ANALYSIS AND SYSTEM DYNAMICS APPROACH	681
COMBINED GMA AND SD DISASTER RISK REDUCTION MODEL	688
TOPICS XII: HISTORY AND PHILOSOPHY OF TECHNOLOGY AND PLACES	694
REDESIGNING COMFORT	695
TOPICS XIII: BIOMIMICRY AND SMART INNOVATIONS TO HUMAN CHALLENGES	706
REVERSE BIOMIMETIC ANALOGIES IN DESIGN OF ARCHITECTURAL STRUCTURES	707
TOPICS XIV: PARTICIPATORY AND CRITICAL DESIGN IN URBAN DECISION-MAKING PROCESSES	718
MODERN SPATIAL CONCEPTS, PROGRAMMES AND TECHNOLOGIES AIMED AT SUSTAINABILITY OF HISTORICAL NUCLEI – THE CASE OF THE TOWN OF BUJE	719



PLACES AND TECHNOLOGIES 2017

4th International Academic Conference

KEEPING UP WITH TECHNOLOGIES IN THE CONTEXT OF URBAN AND RURAL SYNERGY

ORGANIZATION

Organizers:

University of Belgrade, Faculty of Architecture, Serbia

University of Sarajevo, Faculty of Architecture, Bosnia and Herzegovina

Dr Vladan Đokić, Dean

University of Belgrade, Faculty of Architecture, Serbia

MSc Mevludin Zečević, Dean

University of Sarajevo, Faculty of Architecture, Bosnia and Herzegovina



TOPIC IV:
ARCHITECTURE AND BUILDING TECHNOLOGIES

INTEGRATION OF SOLAR THERMAL COLLECTORS INTO THE BUILDING ENVELOPE OF THE MULTIFAMILY HOUSING BUILDING IN BELGRADE

Prof. Dr Aleksandra Krstić-Furundžić ⁸²

Faculty of Architecture, University of Belgrade, Bul. kralja Aleksandra 73/II, akrstic@arh.bg.ac.rs

Dr Tatjana Kosić

Faculty of Architecture, University of Belgrade, Bul. kralja Aleksandra 73/II, tkosic@arh.bg.ac.rs

Dr Vesna Kosorić

ABSTRACT

Application of solar thermal collectors as one of the modern architectural concepts, which are based on reduction of energy consumption in buildings and the use of solar energy as a renewable energy source, give the new and significant role to the roofs and facades that become multifunctional structures. The purpose of this paper is to show different design solutions and benefits of integration of solar thermal collectors into the envelope of multifamily housing building in Konjarnik settlement, Belgrade. Considering complexity of integration of active solar systems, the following aspects of integration of solar thermal collectors are discussed: energy, architectural and ecological aspects.

Hypothetical models of integration of solar thermal collectors into the existing building envelope are created in order to reduce energy demands for water heating, and thus reduce CO₂ emissions.

Methodological approach entails the following steps: creation of different models of solar thermal collector integration in terms of position and slope, evaluation of the reduction of energy consumption for water heating and thus CO₂ emissions for different models and their combinations, and comparison of the results (models).

Keywords: Energy savings, Solar thermal collectors, CO₂ reduction.

INTRODUCTION

New energy-efficient buildings represent a small percentage in relation to the total building stock. Until 1970s, buildings were designed without consideration of energy demands and consumption. According to the data collected by Serbia's Statistical Office, about 55 percent of the total of 583,908 existing housing units in Belgrade was built in this period (Krstić-Furundžić and Bogdanov, 2003). This figure reveals that Belgrade's building stock has a significant

⁸² Corresponding author

number of buildings whose energy performance has to be improved. It should not be disregarded because significant energy savings and reduction of fossil fuels consumption can be achieved. At the other hand, the Renewable Energy Framework Directive sets a 20% target for renewables by 2020. According to Soteris A. Kalogirou (2013), one way to achieve energy savings and to reduce fossil fuel dependence in our buildings is the use of renewable energy systems (RES), both integrated photovoltaics (PV) and solar thermal systems (STS), which are generally environmentally clean. To confirm this claim, he states that in some mediterranean countries, such as Cyprus, renewable energy systems and in particular solar water heaters are used extensively, with almost all domestic dwellings currently equipped with one of such systems.

In the paper, solutions for reducing energy consumption for water heating in existing housing are proposed and examined from energy and ecological point of view.

The methodological approach includes creation of different models of the solar thermal collectors' integration, thermodynamic simulations of the models, evaluation of reduction of energy consumption and CO₂ emissions, as well as a comparative analysis of achieved results (models). Criteria for the energy and ecological analysis include the energy consumption for water heating before and after integration of solar thermal collectors, and thus energy demands reduction, as well as reduction of CO₂ emissions. According to the adopted criteria, the most suitable models are selected. This approach could generally be applicable for building refurbishment, but generalization of technical solutions and possible benefits have to be carefully individually considered.

METHODOLOGY

During 1950's to 1970's, lot of suburban settlements had been built in Belgrade. The typical residential building in settlement "Konjarnik" (Fig. 1 and 2) is selected as the model on which possibilities for improvement of energy performances by application of solar thermal collectors (STC) are analysed in the paper.



Figure 1: Location of Konjarnik on the Belgrade map



Figure 2: Typical building disposition



TOPIC IV:
ARCHITECTURE AND BUILDING TECHNOLOGIES

The analysis in the paper is hypothetical and it aims to show energy and ecological benefits of solar thermal collector system application on residential buildings in Belgrade climate. Methodological access includes description of the models-design variants of STC application, evaluation of energy and ecological efficiency of variants and comparative analysis of achieved results.

Existing building state and consumer

Settlement “Konjarnik” begins 4 km south-east of downtown Belgrade and stretches itself over 2 km (Fig. 1). It is selected for analyzes as settlement consisted mainly of typical buildings built in 1960s and 1970s (Fig. 2). Existing refurbishment strategies applying on these residential buildings are transformations of flat roofs into sloping roofs by attic annex, which is municipality organized action (Fig. 3 and 4) and glazing of loggias, which is usually realized by tenants as illegal action.



Figure 3: Typical building before attic annex



Figure 4: Typical building after attic annex

Belgrade is the city with global irradiance of 1,341.8 kWh/m² (Polysun 4). According to data provided by Republic Hydro meteorological Service of Serbia, the number of sunny hours/year is 2,123.25 and the highest insolation of about 10 hours/day is in July and August, while December and January are the cloudiest, with insolation of 2 to 2.3 hours/day.

The subject of the analyses is typical multifamily housing (the 8-storey building – ground floor, 6 floors and attic), which has rectangular and compact form and consists of 5 lamellas (Fig. 3). It is located in a semi-closed block, on the south oriented hillside. Its longer, east-west axis is parallel to the isohypses. The neighbouring buildings are sufficiently far to prevent overshadowing. Facades are consisting of rows of windows and parapets and verticals of loggias.

Possibilities for solar thermal collectors application on south-west oriented facade and roof surfaces were analyzed for selected lamella. There are 28 apartments in the lamella and 90 occupants inside them altogether. The initial idea was to explore potential and effects of solar system based on solar thermal collectors to meet energy demands for hot water. In calculations, real thermal and electrical energy consumption were taken into consideration. Amount of hot water consumption is 7,200l (20-50 °C) per day for one lamella which presents 251 kWh per day, i.e. 91,618.3 kWh/year for lamella (Krstic-Furundzic and Kosoric, 2009b).

Solar thermal collectors system

Calculations and simulations of solar thermal systems for all design variants were done in Polysun 4 Version 4.3.0.1. In calculations, the existing water heating system fully based on electricity was substituted with the new system – flat solar thermal collectors with liquid working medium (Table 1), with the auxiliary system powered by electricity.

Table 1: Characteristics of flat solar thermal collectors with liquid working medium used for integration in building envelope (*the type dimension from catalogue-is different for different examples and can be changed)

	Institut fur Solartechnik SPF
Absorber area (m²)*	1.8
Glazing area (m²)*	1.8
Total area of the foreground of the chasing (m²)*	2
Max temperature (°C)	220
Max flow rate (l/h)	2,000
Heat capacity (J/K)	5,000

Models of architectural integration of solar thermal collectors

Modern architectural concepts, which are based on rational energy consumption of buildings and the use of solar energy as a renewable energy source, give the new and significant role to the roofs and facades that become multifunctional structures (Krstic-Furundzic, 2006). Due to functional complexity, building envelopes with integrated STC and PV modules can be treated as multifunctional structures (Krstic-Furundzic et al., 2017).

In the case of Konjarnik case study, the design of integration of solar thermal collectors is defined consequently according to the actual characteristics of:

- The building location – the context (considering urban planning, social, climatic and geographical aspect).
- The building (considering the compatibility in respect to the building construction type, building materials, the shape, the function and design of the building).



TOPIC IV:
ARCHITECTURE AND BUILDING TECHNOLOGIES

- The facade and roof (considering the building physics characteristics, mounting, physical and appearance characteristics of solar systems).

For analysis four distinctive variants of position of solar thermal collectors on building envelope are selected and shown in Figure 6 (Krstić-Furundžić and Kosorić, 2009a):

- I Design Variant: solar panels mounted on the roof and tilted at 40° , area of 100 m^2 (Fig. 5-a),
- II Design Variant: solar panels integrated in parapets (vertical position- 90°), area of 90 m^2 (Fig. 5-b),
- III Design Variant: solar panels integrated in parapets and tilted at 45° , area of 120 m^2 (Fig. 5-c),
- IV Design Variant: solar panels integrated as sun shadings (horizontal position- 0°), area of 55 m^2 (Fig. 5-d).

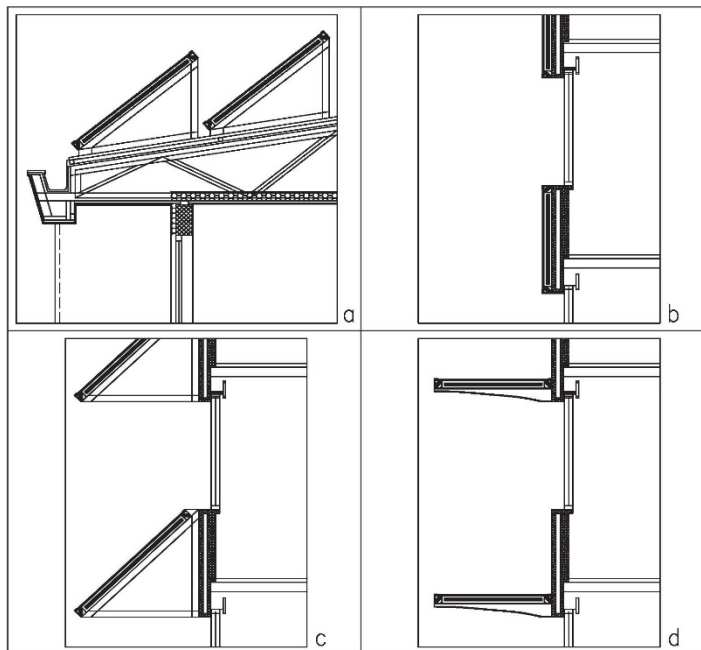


Figure 5: Design Variants I – IV (a - d) cross-sections

RESULTS OF SOLAR THERMAL COLLECTORS INTEGRATION INTO THE BUILDING ENVELOPE

Results of numerical simulation (Krstić-Furundžić and Kosorić, 2009a) of solar thermal integration into the building envelope include thermal energy production, hot water energy demands satisfaction, annual energy savings for water

heating and reduction of CO₂ emissions. Contribution of application variants of solar thermal collectors to energy performance improvement of the existing building is estimated through comparative analysis of predicted variants.

Comparison of achieved results

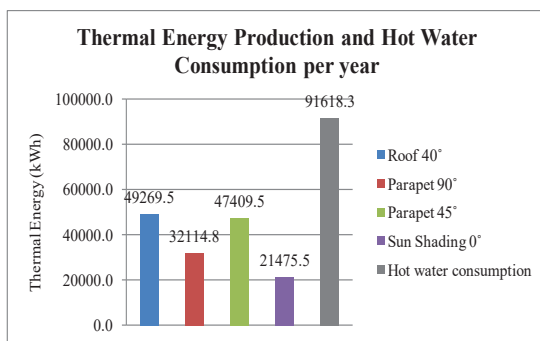


Figure 6: TE production and HW consumption per year

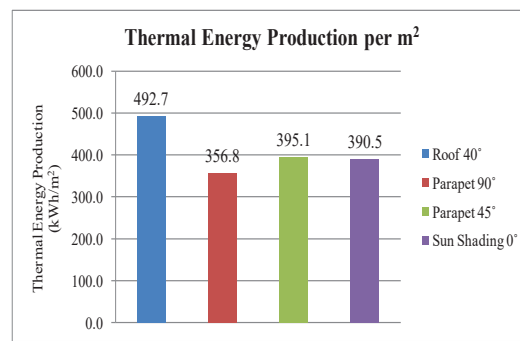


Figure 7: TE production per m² by STC

For comparative analysis of energy performances of collector integration design variants at the yearly basis, calculation of thermal energy (TE) production and hot water (HW) consumption, as well as average thermal energy (TE) production per m² per year are carried out and shown in Figures 6 and 7.

At the yearly basis, it is evident that design variants with integrated solar thermal collectors can produce thermal energy from min 21,475.5 kWh (Sun shading 0°) to max 49,269.5 kWh (Roof 40°). Thermal energy production per m² varies from min 356.8 kWh/m² (Parapet 90°) to max 492.7 kWh/m² (Roof 40°).

Benefits of predicted improvements

Benefits of integration of solar thermal collectors can be identified through satisfaction of water heating energy demands, i.e. energy savings and CO₂ reduction. Satisfaction of monthly water heating energy demands is related to integration variants and amounts (Fig. 8):

- Solar thermal collectors mounted on the roof and tilted at 40° can meet demands for hot water from min 19.6% in December to max 84.9% in August;
- Solar thermal collectors integrated in parapets (vertical position-90°) can meet demands for hot water from min 23.9% in January to max 47.8% in September;
- Solar thermal collectors integrated in parapets and tilted at 45° can meet demands for hot water from min 22.9% in January to max 79.3% in August;



TOPIC IV:
ARCHITECTURE AND BUILDING TECHNOLOGIES

- Solar thermal collectors integrated as sun shadings (horizontal position-0°) can meet demands for hot water from min 2.7 % in January to max 45.3 % in August.

At the yearly basis, it is evident that design variants of solar thermal collectors' integration can meet from min 23.4% (Sun Shading 0°) to max 53.6% (Roof 40°) hot water demands, as shown in Figure 9.

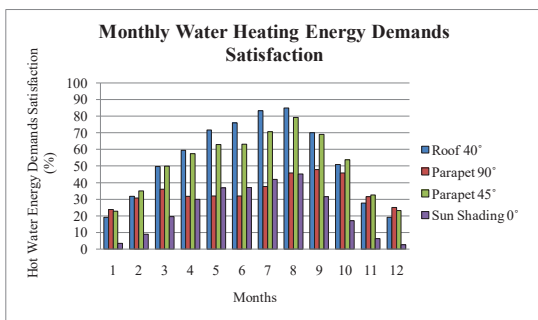


Figure 8: Satisfaction of energy demands for HW heating per months

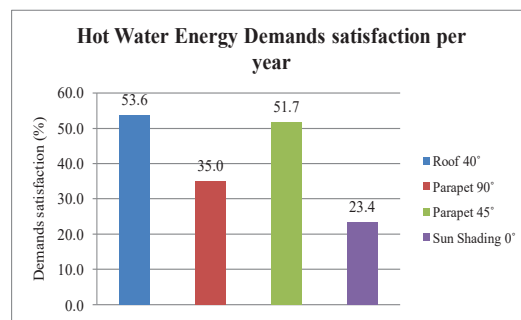


Figure 9: Satisfaction of energy demands for HW heating per year achieved by STC

The application of solar thermal collectors significantly contributes to energy savings, i.e. enables reduction of energy consumption. Annual energy consumption for domestic water heating, which could not be substituted by solar thermal system, is shown in Table 2. The design variant I of solar thermal collectors' integration into building envelope, in which panels are 40° tilted on the roof, is indicated as optimal. This variant is selected as optimal considering preferable angle of collector surface for maximum solar gains in the climate of Belgrade and less shading effect present on the roof than on the facade (Krstić-Furundžić and Kosić, 2017). At the same time, combination of design variant I and II provides the greatest energy savings of 89% (Table 2). Even more energy saving is achieved by combining the roof (40°) and facade (45°) solar thermal panels providing energy surplus of 6% or by combining the roof (40°), facade (90°) and sun shading (0°) solar thermal panels providing energy surplus of 12% (Table 2).

Values for CO₂ emissions reduction are presented in Table 3 for all proposed design variants of thermal collectors' integration and their combinations. The problem of emissions is analysed with assumption that mentioned consumer heats hot water by electrical energy. Estimation of emissions of the electrical power networks is based on the fact that for production of 1 kWh, CO₂ emission amounts 0.53 kg in Serbia (according to the Regulations on energy efficiency of buildings).

Table 2: Annual energy savings for water heating according to the design variants and their combinations

Design variants (and their combinations) of STC integration into the building envelope	Annual energy consumption for hot water (kWh)	Energy savings (kWh)	Reduction of energy consumption (%)
Existing building	91,618		
Design Variants I - Roof collectors 40°	42,349	49,269	54
Design Variants II - Facade collectors 90°	59,503	32,115	35
Design Variants III - Facade collectors 45°	44,209	47,409	52
Design Variants IV - Sun shading 0°	70,143	21,475	23
Design Variants I and II (combination)	10,234	81,384	89
Design Variants I and III (combination)	--	+5,060 energy surplus	100 (6% en. surplus)
Design Variants I, II and IV (combination)	--	+11,241 energy surplus	100 (12% en. surplus)

Table 3: CO₂ emissions and reductions according to the design variants and their combinations

Design variants (and their combinations) of STC integration into the building envelope	Annual CO ₂ emissions (kg/year)	CO ₂ reduction (kg/year)	CO ₂ reduction (%)
Existing building	48,558		
Design Variants I - Roof collectors 40°	22,445	26,113	54
Design Variants II - Facade collectors 90°	31,536	17,022	35
Design Variants III - Facade collectors 45°	23,430	25,128	52
Design Variants IV - Sun shading 0°	37,176	11,382	23
Design Variants I and II (combination)	5,424	43,134	89
Design Variants I and III (combination)	--	+2,682 carbon credits	100 (6% carb. credits)
Design Variants I, II and IV (combination)	--	+5,958 carbon credits	100 (12% car. credits)

CONCLUSIONS

This paper has highlighted the problems of poor energy performances of existing Belgrade's building stock and necessity and possibilities of energy performance improvement of buildings and thereby ecological impact. Through design scenarios given and discussed in the paper, it can be concluded that building energy performances improvement, achieved by application of solar thermal collectors, provides numerous benefits which can be identified briefly as reduction of conventional energy consumption, reduction of environmental pollution and obtaining opportunities for new aesthetic potentials in refurbishment of existing buildings.



TOPIC IV:
ARCHITECTURE AND BUILDING TECHNOLOGIES

The results presented in the paper can popularize the application of solar thermal systems in building refurbishment. As in other parts of Serbia, as well as Europe, there is a significant number of housing settlements with the same or similar prefabricated buildings, the presented improvement measures can be transferred into the regions with similar climatic conditions.

ACKNOWLEDGMENTS

The research is done within the COST Action 1205 “Building integration of Solar Thermal Systems (BISTS)” supported by European Cooperation in the field of Scientific and Technical Research and the scientific research project “Physical, environmental, energy, and social aspects of housing development and climate change–mutual influences” (TR36035), financed by Ministry of Education, Science and Technological Development of the Republic of Serbia.

REFERENCES

- Kalogirou, A. Soteris. 2013. “Building integration of solar thermal systems.” In Proceedings of ELCAS 3, edited by Coroneos J. Christopher, Dimitrios C. Rovas and Paris Th. Dompros, 217-224. Nisyros: COST.
- Krstic(-Furundzic), Aleksandra. 2006. “Multifunkcionalne krovne strukture energetski efikasnih zgrada.” (Multifunctional roof structures of the energy efficient buildings) *Arhitektura i urbanizam*, no. 18/19: 34-47.
- Krstic-Furundzic, Aleksandra, and Ana Bogdanov. 2003. “Collected data formation of building stock in Belgrade, Serbia.” (Formiranje baze podataka o gradjevinskom fondu u Beogradu) In *Energy Optimization of buildings in context of sustainable architecture* (Energetska optimizacija zgrada u kontekstu održive arhitekture), Part 1, 59-77. Belgrade: Faculty of Architecture, University of Belgrade.
- Krstić-Furundžić, Aleksandra and Vesna Kosorić. 2009a. “Improvement of energy performances of existing buildings by application of solar thermal systems”, *Spatium International Review*, No. 20: 19-22.
- Krstic-Furundzic, Aleksandra, and Vesna Kosoric. 2009b. “Improvement of Energy Performances of Existing Buildings in Suburban Settlements.” In *Architecture, Energy and the Occupant's Perspective*, Proceedings of the PLEA 2009, edited by Demers Claude and Andre Potvin, 597-602. Quebec City: Les Presses de l'Universite Laval, Canada.
- Krstić-Furundžić, A., and Kosić, T., 2017. Multicriterial optimization of the selection of the best measures for energy performances improvement of the multifamily housing in Belgrade. In: Proceedings of the 1st International Conference on Building integrated renewable energy systems-BIRES, Eds: Soteris A. Kolagiriou, COST-European Cooperation in Science and Technology, paper 13. Accessed March 16, 2017. <http://www.tu1205-bists.eu/wp-content/uploads/sites/13/2017/03/Proceedings-of-BIRES-2017-01-01.pdf>

Krstic-Furundzic, Aleksandra, Andreas Savvides, Gerald Leindecker, Constantinos Vassiliades. 2017. "Architectural planning/integration". In: *COST Action TU1205 BISTS – Design and Applications Handbook*, edited by Soteris A. Kalogirou, 251-262. Brussels: COST-European Cooperation in Science and Technology.

Regulations on energy efficiency of buildings, *Official Gazette RS*, no. 72/09, 81/09 – revise, 64/10 and 24/11: 58–59.

Republic Hydrometeorological Service of Serbia, Basic climate characteristics for the territory of Serbia, Accessed October 25, 2012. Accessed December 15, 2016. <http://www.hidmet.gov.rs/>.