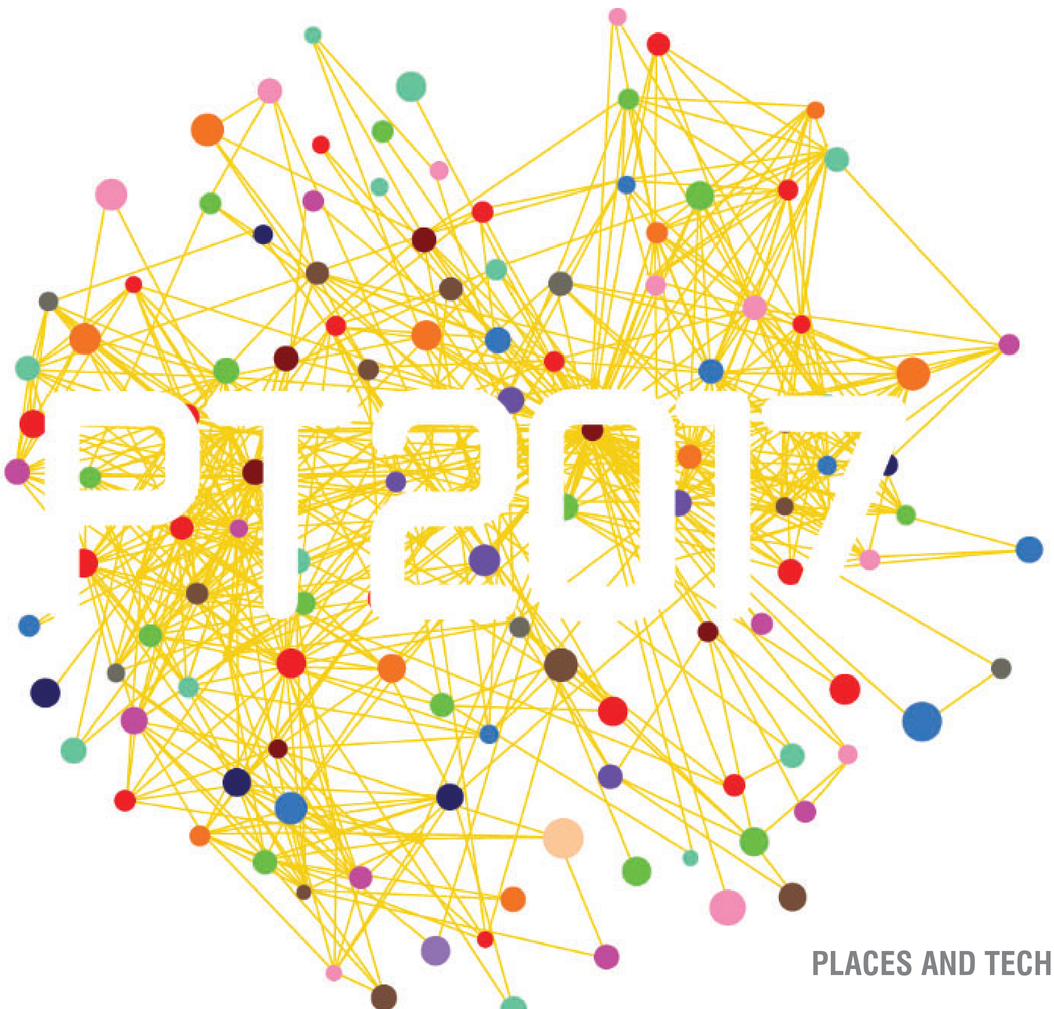
4th International Academic Conference




**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

# PLACES AND TECHNOLOGIES 2017

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

BOOK OF CONFERENCE PROCEEDINGS

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**Dženana Bijedić, Aleksandra Krstić-Furundžić, Mevludin Zečević**

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## ORGANIZATION

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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 $CO_2$ 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 $CO_2$ 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

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[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 $CO_2$ 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 $CO_2$ 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**

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 slopping 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/m$^2$ (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 overshading. 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 ($m^2$)*** | 1.8 |
| **Glazing area ($m^2$)*** | 1.8 |
| **Total area of the foreground of the chasing ($m^2$)*** | 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).

- 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 enve-lope 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).

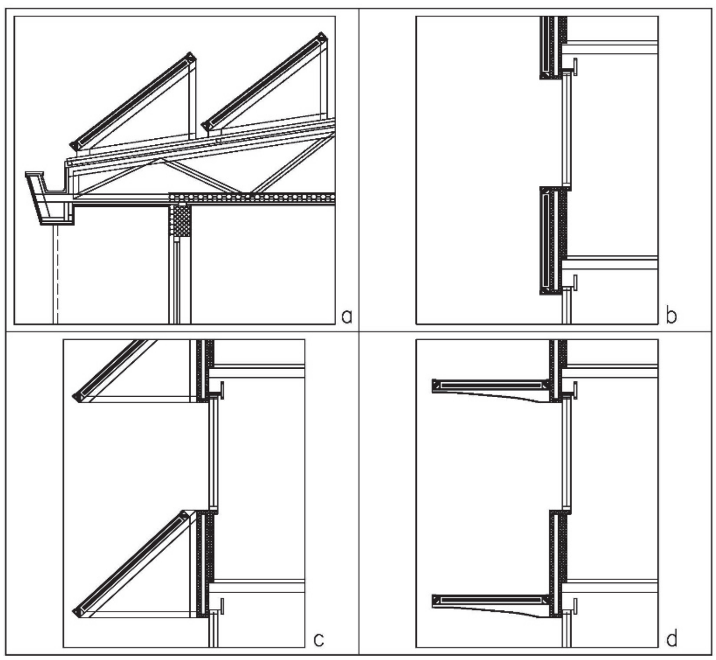
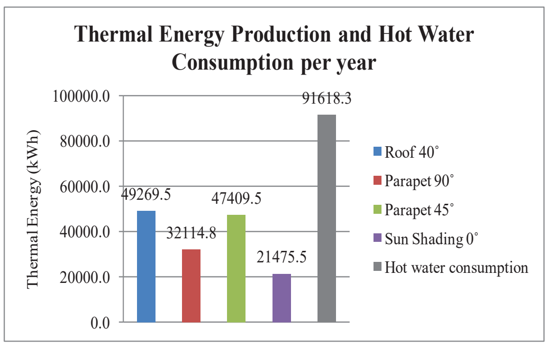



**Figure 5: Design Variants I – IV (a - d) cross-sections**

## 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 $CO_2$ 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



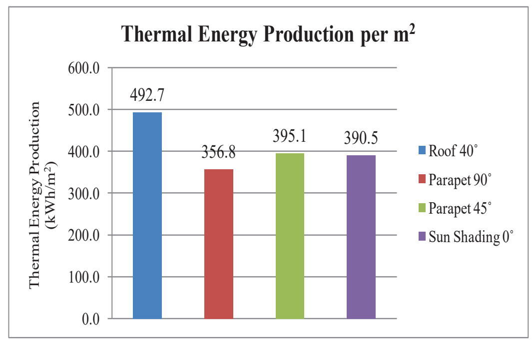




**Figure 6: TE production and HW consumption per year**

**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 $m^2$ 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 $m^2$ varies from min 356.8 kWh/$m^2$ (Parapet 90˚) to max 492.7 kWh/$m^2$ (Roof 40˚).

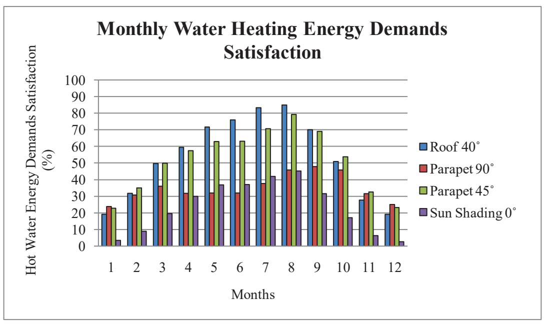
## Benefits of predicted improvements

Benefits of integration of solar thermal collectors can be identified through satisfaction of water heating energy demands, i.e. energy savings and $CO_2$ 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;

- 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.



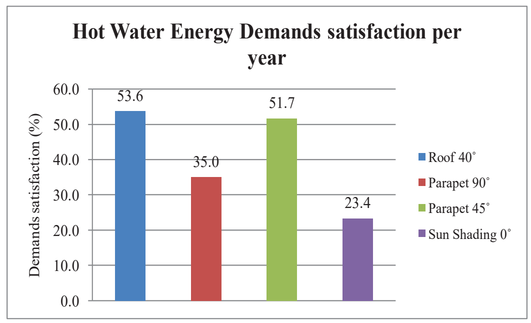




**Figure 8: Satisfaction of energy demands for HW heating per months**

**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 $CO_2$ 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, $CO_2$ 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: $CO_2$ 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.

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.

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## 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. Kolagirou, 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/.