

SUSTAINABLE BUILDING REFURBISHMENT BY INTEGRATION OF SOLAR THERMAL COLLECTORS

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Abstract

Improvement of energy performances of the existing building in suburban settlement Konjarnik in Belgrade, by application of solar thermal systems is presented in the paper. Hypothetical models of building improvement are created with aim benefits of solar thermal collectors application on residential buildings in Belgrade climate conditions to be estimated. The case study shows different design variants of integration of solar thermal collectors in envelope of a multifamily building. The following aspects of solar thermal systems integration are analyzed in the paper: energy, architectural, ecological and economic aspects. The results show that in Belgrade climatic conditions significant energy savings and reduction of CO₂ emissions can be obtained with application of solar thermal collectors.

Introduction

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 facades and roofs that become multifunctional structures [2]. Implementation of renewable energy sources and rational use of energy in building design can reduce energy use in buildings, consumption of pollutant energy sources and thereby reduce CO₂ emissions.

Application of mainly neglected, renewable energy sources, for which there is a high potential in Serbia, but are not researched and technologically improved, is one of the solutions which strives towards the preservation of remaining resources and the environment [3]. Main target on which this paper is directed is achieving energy savings through building refurbishment, more exactly by application of solar thermal collectors achievement of solar energy gains and reduction of fossil fuels consumption.

Belgrade's building stock has a significant number of buildings which energy performances have to be improved. Lot of suburban settlements had been built in Belgrade after World War II. Due a few prefabricated systems were in use, significant number of similar buildings in architectural sense is present. They are also characterized by poor energy performances. Settlement "Konjarnik" is one of representatives of such architecture. The residential building in this settlement is selected as the model on which possibilities for improvements of energy performances by application of active solar systems are analysed in the paper.

METHODOLOGY

The analysis in the paper is hypothetical and it aims to show benefits of solar thermal systems application on residential buildings in Belgrade climate conditions. Methodological access includes treatments of:

- existing state,
- consumer,
- solar thermal system,
- architectural integration of solar system,
- reduction of CO₂ emissions,
- simple payback period.

Existing State

Settlement “Konjarnik” is about 4 km far from the city center (Fig.1). Due to the city development, nowadays it is part of the urban city zone. It is settlement consisted mainly of typical buildings built in 1960s and 1970s.



Fig. 1: „Konjarnik” on the map of Belgrade



Fig. 2: Buildings disposition in “Konjarnik”

Belgrade is the city with global irradiance of 1341.8 kWh/m² (Polysun 4), and 2123.25 sunny hours per year [5].

The settlement is characterized by large rectangular shaped residential buildings. The building that is the subject of analysis, is situated on the south oriented hillside with typical south-north orientation, more exactly deviation of 10° to southwest is present (Fig. 2).



Fig. 3: Typical south-west facade

Facades oriented south and north consist rows of windows and parapets, which represent 70% and verticals of loggias, which represent 30% of facade surfaces (Fig.3).

As the building consisted number of lamellas, the analyses in the paper were done for one lamella. Possibilities for solar thermal collectors application on south-west oriented facade and south-west oriented part of roof were analyzed.

Consumer

There are 28 apartments in one 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 energy consumption was taken into consideration. Thermal energy for hot water: 80l of hot water per person per day, 80l x 90 = 720l (20-50°C) per day for one lamella which presents 251 kWh per day, i.e. 91618.3 kWh per year for one lamella.

Solar Thermal 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 – solar thermal collectors (AKS Doma – manufacturer), with the auxiliary system powered by electricity.

Architectural Integration of Solar System

The design of integration of solar systems was 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, the style 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 positions on building envelope for solar thermal collectors were selected:

- I Design Variant: roof 40°, area of 100 m² (Fig. 4-a) - solar panels with slope of 40° applied on the roof,
- II Design Variant: parapet 90°, area of 90 m² (Fig. 4-b) - vertical position of solar panels,
- III Design Variant: parapet 45°, area of 120 m² (Fig. 4-c) - solar panels with slope of 45° applied on parapets,
- IV Design Variant: sun shading 0°, area of 55 m² (Fig. 4-d) - horizontal position of solar panels.



Fig. 4: Analyzed design variants: a. I Design Variant: roof 40° (roof and facade layouts), b. II Design Variant: parapet 90°, c. III Design Variant: parapet 45°, d. IV Design Variant: sun shading 0°

Reduction of CO₂ Emissions

In calculations of CO₂ emissions of the consumer, for case in which solar system substitutes electricity based system, 0.81 kg CO₂/kWh reduction is used [1].

Simple Payback Period

For calculations of simple payback period for analyzed design variants following parameters were used: 700 EUR - total system costs per 1 m² of solar thermal collectors, 0.45 EUR/kWh – price of energy produced from solar systems [4].

RESULTS

Results of solar thermal integrations were considered and presented through reduction of energy consumption, reduction of CO₂ emissions, simple payback period and evaluation of proposed design variants.

Reduction of Energy Consumption

For comparative analysis of energy performances for design variants of solar thermal collectors integrations, monthly thermal energy production, hot water demands satisfaction and thermal energy production per m² of solar thermal collector were calculated and presented in Figures 5, 6 and 7. It is evident that different positions of solar thermal collectors give different results regarding mentioned parameters:

- Solar thermal collectors integrated on the roof 40° can produce monthly thermal energy from min 1492 kWh in December to max 6605 kWh in August; they can meet demands for hot water from min 19.6% in December to max 84.9% in August; thermal energy production per m² is from min 14.9 kWh/m² in December to max 66.1 kWh/m² in August;
- Solar thermal collectors integrated in parapets 90° can produce monthly thermal energy from min 1858 kWh in January to max 3603 kWh in September; they can meet demands for hot water from min 23.9% in January to max 47.8% in

September; thermal energy production per m^2 is from min 20.6 kWh/m^2 in January to max 40 kWh/m^2 in September;

- Solar thermal collectors integrated in parapets 45° can produce monthly thermal energy from min 1780 kWh in January to max 6169 kWh in August; they can meet demands for hot water from min 22.9 % in January to max 79.3 % in August; thermal energy production per m^2 is from min 14.8 kWh/m^2 in January to max 51.4 kWh/m^2 in August;
- Solar thermal collectors integrated as sun shadings 0° can produce monthly thermal energy from min 208 kWh in January to max 3524 kWh in August; they can meet demands for hot water from min 2.7 % in January to max 45.3 % in August; thermal energy production per m^2 is from min 3.8 kWh/m^2 in January to max 64.1 kWh/m^2 in August.

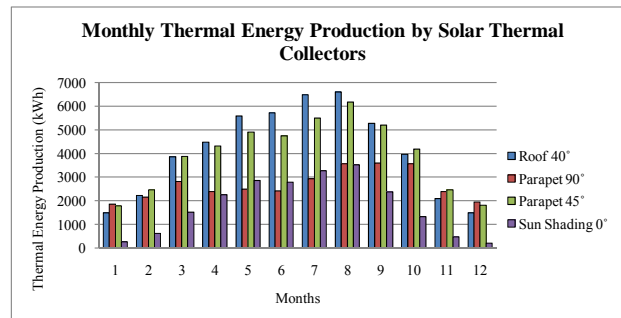


Figure 5: Monthly Thermal Energy Production by Solar Thermal Collectors

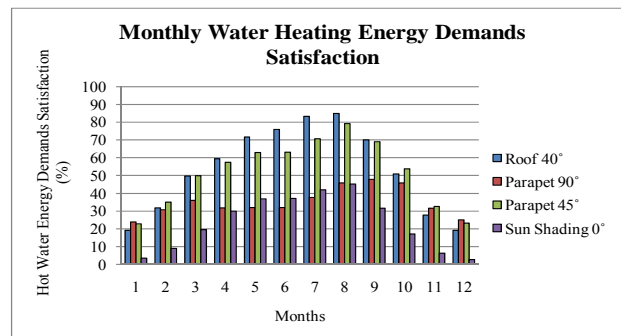


Figure 6: Monthly Water Heating Energy Demands Satisfaction

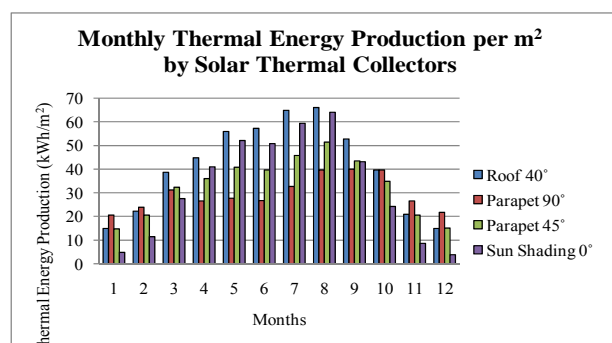


Figure 7: Monthly Thermal Energy Production per m^2 by Solar Thermal Collectors

Reduction of CO₂ Emissions

In Table 1, values for CO₂ emissions reduction are presented for all proposed design variants.

	Roof 40°	Parapet 90°	Parapet 45°	Sun Shading 0°
kg/year	39908	26013	38402	17395

Table 1: CO₂ reduction achieved by solar thermal collectors

Simple Payback Period

Simple payback periods for Design Variants 1, 2, 3 and 4 are sequentially 7, 9, 8 and 8 years.

Evaluation of proposed design variants

In the paper the evaluation of proposed design variants is based on aesthetical, mounting options, energy, economic and ecological criteria. As aesthetical criteria might be characterized by subjectivity, it is adopted to be related to solar thermal collector's compatibility to the facade and roof technical characteristics (dimensions, form, color, material), for which reliable evaluation can be established. Generally, evaluation is based on the fact that experts make decisions in the design process, and some of them are polled in order criteria values to be established. Following evaluation criteria are established:

- c1: Aesthetic characteristics (1 (lowest)-3 (highest)),
- c2: Mounting options (1 (lowest)-3 (highest)),
- c3: Energy Production per year/total system costs (kWh/EUR),
- c4: Energy Production per year/Panel area (kWh/m²),
- c5: Energy Demands Satisfaction per year (%),
- c6: Reduction of CO₂ emissions (kg/year).

Every criterion (c1-c6), to the design variant with highest value of that criterion gets 5 points, and other variants get points proportionally. Weights of all adopted criteria were defined and Evaluation Value (E) is calculated as: $E=0.3c_1+0.2c_2+0.2c_3+0.1c_4+0.1c_5+0.1c_6$. The design variant with the highest evaluation value is conceived as optimal solution.

According to established evaluation system, evaluation of Design Variants (I-IV) is carried out and evaluation values (E) are presented in Table 2.

c	I		II		III		IV	
	p	e	p	e	p	e	p	e
1	3	5	3	5	2	3.3	1	1.7
2	3	5	2	3.3	2	3.3	2	3.3
3	0.7	5	0.5	3.6	0.6	4.3	0.6	4.3
4	492.7	5	356.8	3.6	395.1	4	390.5	3.9
5	53.6	5	35	3.3	51.7	4.8	23.4	2.2
6	39908	5	26013	3.3	38402	4.8	17395	2.2
E	5		3.9		3.87		2.86	

Table 2: Evaluation of Design Variants (I-IV) with solar thermal collectors integration

CONCLUSION

Contribution of application variants of solar thermal systems to improvement of energy performances of existing buildings is estimated through comparative analyzes of predictive variants.

For comparative analysis of energy performances of solar thermal integrations design variants at the yearly basis, calculation of thermal energy production, hot water energy demands satisfaction and average thermal energy production per m² per year were carried out and shown in Figures 8, 9 and 10.

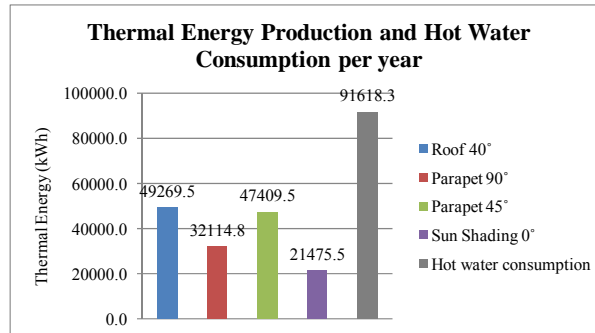


Figure 8: Thermal Energy Production and Hot water Consumption per year

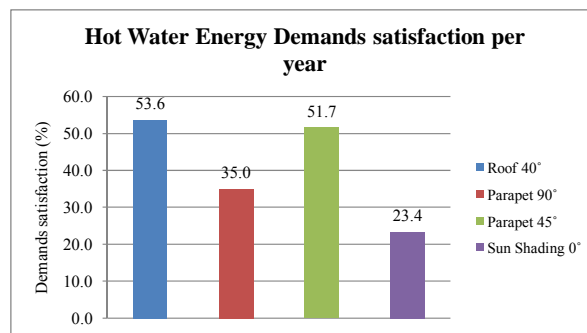


Figure 9: Hot Water Heating Energy Demands Satisfaction per year achieved by solar thermal collectors

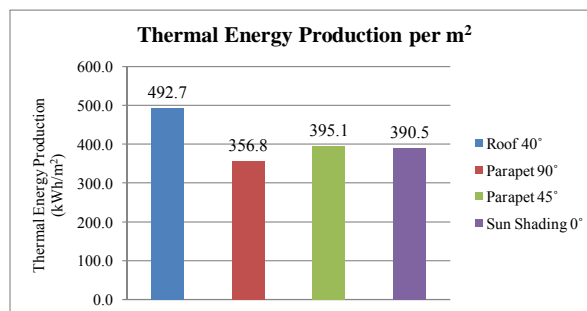


Figure 10: Hot Water Energy Production per m² by Solar Thermal Collectors

At the yearly basis, it is evident that design variants with solar thermal collectors can produce thermal energy from min 21475.5 kWh (Sun shading 0°) to max 49269.5 kWh (Roof 40°); these design variants can meet from min 23.4 % (Sun Shading 0°) to max 53.6 % (Roof 40°) hot water demands; thermal energy production per m² varies from min 356.8 kWh/m² (Parapet 90°) to max 492.7 kWh/m² (Roof 40°).

In order to achieve adequate comprehensive approach for analysis of proposed design solutions with solar thermal collectors, multi-criteria decision making method is included in the process of evaluation and selection of design solutions. According to established evaluation system in the paper, I design variant, in which panels are 40° tilted on the roof of building, was indicated as optimal. This variant was expected to be selected as optimal considering optimal tilted angle for Belgrade and less shading effect present on the roof than on the facade.

Through design variants given and discussed in the paper, it can be found out that by application of solar thermal collectors in building refurbishment, numerous benefits can be achieved which can be identified shortly as decreasing of conventional energy consumption, environmental pollution reduction and obtaining of opportunities for new aesthetic potentials in refurbishment of the existing buildings. In Belgrade, as well as in Serbia, there are a large number of housing settlements with the same or similar prefabricated buildings, as in the case of settlement Konjarnik, indicating that refurbishment of existing buildings by integration of solar thermal collectors can rapidly be applied in practice, resulting in significant energy savings and CO₂ emission reductions. Results presented in the paper can popularize the application of solar thermal systems in building refurbishment.

Acknowledgments

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References

1. Krstić-Furundžić A., Kosorić V., “Reduction of CO₂ emissions through solar thermal collectors application on student housings in Belgrade”, in *Low Carbon Urban Built Environments Conference*, (Munich, Germany, 2008) 3-14.
2. Krstić-Furundžić A., “Multifunkcionalne krovne strukture energetske efikasne zgrada” (“Multifunctional roof structures of the energy efficient buildings”), *Rev. Arhitektura i urbanizam*, **18/19**, (IAUS, Beograd, 2006) 34-47.
3. Pucar, M., Nenković-Riznić M., “Legislative and policy in energy efficient designing and renewable energy sources: Application in Serbia”, *Spatium - International Review*, **15/16**, (IAUS, Beograd, 2007) 66-71.
4. Tarifni sustav za proizvodnju električne energije iz obnovljivih izvora energije i kogeneracije, Narodne novine, br. 33/07. Vlada Republike Hrvatske (2007) (Tariff System for Electricity Production from Renewable Energy Sources and Cogeneration, Official Gazette, No. 33/07. The Croatian Parliament (2007).
5. Data provided by Republic Hydro meteorological Service of Serbia.