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Short or preliminary report

IMPROVEMENT OF ENERGY PERFORMANCES OF EXISTING BUILDINGS BY APPLICATION OF SOLAR THERMAL SYSTEMS

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Improvement of energy performances of the existing buildings in the suburban settlement Konjarnik in Belgrade, by the application of solar thermal systems is the topic presented in this paper. Hypothetical models of building improvements are created to allow the benefits of applying solar thermal collectors to residential buildings in Belgrade climate conditions to be estimated. This case study presents different design variants of solar thermal collectors integrated into a multifamily building envelope. The following aspects of solar thermal systems integration are analyzed in the paper: energy, architectural, ecological and economic. The results show that in Belgrade climatic conditions significant energy savings and reduction of CO_2 emissions can be obtained with the application of solar thermal collectors.

Keywords: building refurbishment, solar thermal collectors application, architectural integration, improvement of energy performances, reduction of CO_2 emissions.

INTRODUCTION

Building refurbishment aims to improve living conditions, reduce consumption of fossil fuels and environmental pollution. It demands methodological access that includes the application of appropriate phases, procedures and measures, depending on targets. A survey of the elements of methodological access to building refurbishment is given in the scheme in *Figure 1*.

A sustainable approach to building refurbishment represents methodology that includes decision-making based on coordination between demands, targets, building refurbishment technologies and capacity to change indicator (Krstić-Furundžić, 1997).

Different measures aimed to improve the energy performance of the building envelope can be listed. Modern architectural concepts, which are based on the 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 (Krstić-Furundžić, 2006). The implementation of renewable energy sources and the rational use of energy in building design can reduce the energy use in buildings, the consumption of pollutant energy sources and thereby reduce CO_2 emissions.

The application of mainly neglected, renewable energy sources, for which there is a high potential in Serbia, has been little researched or technologically improved, but is one of the solutions that strives towards the preservation of remaining resources and the environment (Pucar and Nenković-Riznić, 2007). The main target to which this paper is directed is achieving energy savings through building refurbishment, more exactly by the application of solar thermal collectors to achieve solar energy gains and a reduction in the consumption of fossil fuels.

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

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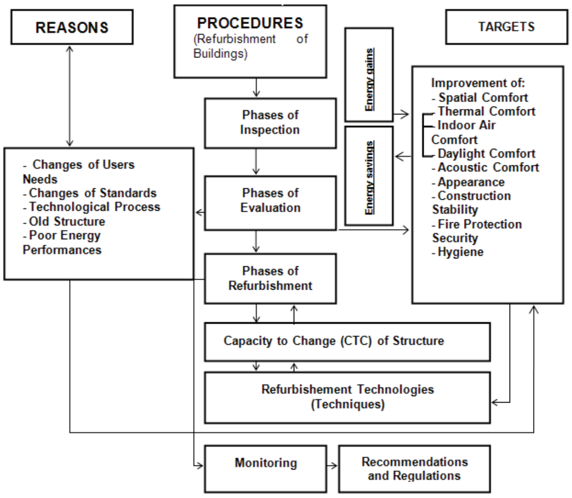

Figure 1: Methodological access to building refurbishment (Krstić-Furundžić, 2005)

Figure 2: Location of „Konjarnik" on the map of city of Belgrade

Figure 3: Building's disposition in the "Konjarnik" settlement

Figure 4: Tipical south-west facade

METHODOLOGY

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

- existing state,
- consumer,
- solar thermal system,
- architectural integration of solar system,
- reduction of CO_2 emissions,
- simple payback period.

Existing State

Location

Settlement "Konjarnik" is about 4 km far from the city center (*Fig.2*). Due to the city's development, today it is part of the urban city zone. It is a settlement that consists mainly of buildings typical to those built in the 1960s and 1970s.

Belgrade is a city with global irradiance of 1341.8 kWh/m^2 (Polysun 4), and 2123.25 sunny hours per year (Republic Hydrometeorological service of Serbia, 2009).

Building

The settlement is characterized by large rectangular shaped residential buildings. The building that is the subject of this analysis, is situated on the south oriented hillside with a typical south-north orientation; more exactly a deviation of 10˚ to the southwest is present (*Fig. 3*).

Facades oriented south and north consist of rows of windows and parapets, which represent 70% of the surface and verticals of loggias, which represent 30% of facade surfaces (*Fig. 4*).

As the building consists of a number of lamellas, the analyses in the paper were done for one lamella.

The possibilities for the application of solar thermal collectors on the 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 the potential effects of a solar system based on solar thermal collectors to meet the energy demands for hot water. In these calculations, the real thermal energy consumption was taken into consideration. Thermal energy for hot water: 80 l of hot water per person per day, 80 l x 90 = 720 l (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 conducted in Polysun 4 Version 4.3.0.1. In these 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 the integration of the solar systems was defined consequently according to the actual characteristics of:

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

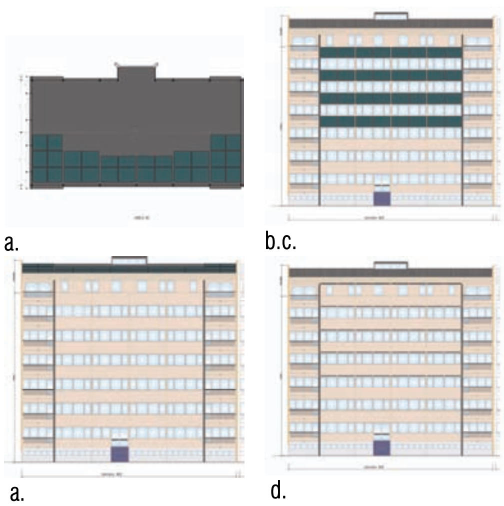

Figure 5: Analyzed design variants: a. I Design Variant: roof 40˚ (roof and facade layouts), b. II Design Variant: parapet 90˚, c. III Design Variant: parapet 45˚, d. IV Design Variant: sun shading 0˚

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

For analysis, four distinctive variants of the positions of the solar thermal collectors on the building envelope were selected:

- I Design Variant: roof 40˚, area of 100 m^2 (*Fig. 5-a*) - solar panels with slope of 40˚ applied to the roof,
- II Design Variant: parapet 90˚, area of 90 m^2 (*Fig. 5-b*) - vertical position of solar panels,
- III Design Variant: parapet 45˚, area of 120 m^2 (*Fig.5-c*) - solar panels with slope of 45 applied to parapets,
- IV Design Variant: sun shading 0˚, area of 55 m^2 (*Fig. 5-d*) - horizontal position of solar panels.

Reduction of CO_2 Emissions

In calculations of CO_2 emissions of the consumer, for cases in which the solar system substitutes an electricity based system, 0.81 kg CO_2/kWh reduction is used (Krstić-Furundžić and Kosorić, 2008).

Simple Payback Period

For calculations of simple payback period for the analyzed design variants, the following parameters were used: 700 EUR - total system costs per 1 m^2 of solar thermal collectors, 0.45 EUR/kWh – price of energy produced from solar systems (The Croatian Parliament, 2007).

RESULTS

The results of solar thermal integrations were considered and presented through the reduction of energy consumption, reduction of CO_2 emissions, simple payback period and the evaluation of the proposed design variants.

Reduction of Energy Consumption

For comparative analysis of energy performance for the design variants of integrating solar thermal collectors, monthly thermal energy production, hot water demands satisfaction and thermal energy production per m^2 of solar thermal collector were calculated and presented in Figures 6, 7 and 8. It is evident that different positions of solar thermal collectors provide different results regarding these parameters:

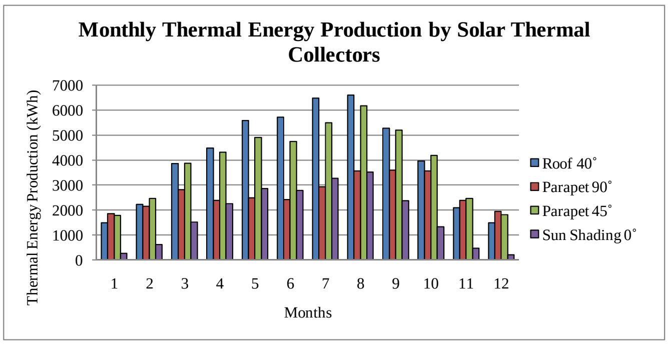

Figure 6: Monthly Thermal Energy Production by Solar Thermal Collectors

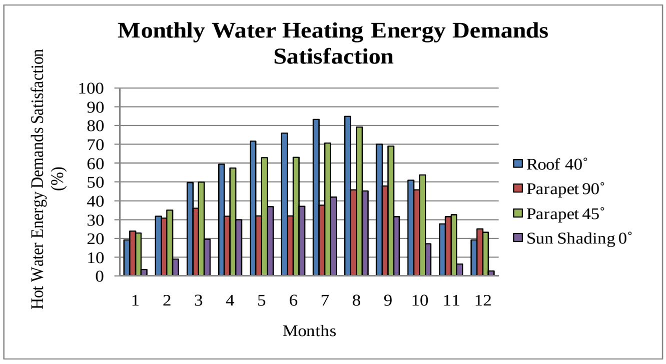

Figure 7: Monthly Water Heating Energy Demands Satisfaction

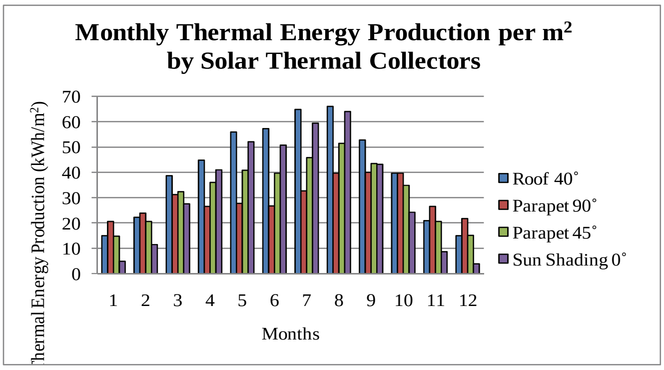

Figure 8: Monthly Thermal Energy Production per m^2 by Solar Thermal Collectors

- Solar thermal collectors integrated onto the roof at 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 m^2 is from min 14.9 kWh/m^2 in December to max 66.1 kWh/m^2 in August;
- Solar thermal collectors integrated into the parapets at 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 into parapets at 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 at 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.

Reduction of CO_2 Emissions

In *Table 1*, values for CO_2 emissions reduction are presented for all proposed design variants.

Table 1: CO_2 reduction achieved by solar thermal collectors

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

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 this paper the evaluation of proposed design variants is based on aesthetics, mounting options, energy, economic and ecological criteria. As aesthetical criteria might be characterized by subjectivity, they are adopted according to the solar thermal collector's compatibility to the facade and roof's technical characteristics (dimensions, form, color, material), for which reliable evaluation can be established. Generally, such evaluation is based on the fact that experts make decisions in the design process, and some of them are polled in order for criteria values to be established. The following evaluation criteria have been 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/m^2),
- c5: Energy Demands Satisfaction per year (%),
- c6: Reduction of CO_2 emissions (kg/year).

Every criteria (c1-c6) from the design variant with the highest value of that criteria gets 5 points, and other variants get points proportionally. The weights of all adopted criteria were defined and the Evaluation Value (E) is calculated as: E=0.3xc1+0.2xc2+0.2xc3+0.1xc4+0.1xc5 +0.1xc6. The design variant with the highest evaluation value is conceived as the optimal solution.

According to this established evaluation system, Design Variant I has the highest evaluation value (E), as presented in *Table 2*, and therefore it is the optimal solution.

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

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	

CONCLUSION

The contribution of application variants of solar thermal systems to improve the energy performance of existing buildings is estimated through a comparative analyzes of predictive variants.

For comparative analysis of energy performances of integrating solar thermal design variants, an annual calculation of thermal energy production, along with the setisfaction of hot water energy demands and the average thermal energy production per m^2 per year were carried out and shown in Figures 9, 10 and 11.

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

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

Through the design variants presented and discussed in the paper, it can be concluded that through the application of solar thermal collectors in building refurbishment, numerous benefits can be achieved over a short period of time and which can be identified to decrease conventional energy consumption and environmental pollution to improve comfort inside buildings, and provide opportunities for new aesthetic potentials in the refurbishment of 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 settlement Konjarnik, indicating that significant energy savings and CO_2 emission reductions can be obtained. In addition, the results presented in this paper can popularize the application of solar systems in building refurbishment.

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