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THE USE OF SOLAR COLLECTORS FOR HEATING A RESIDENTIAL BUILDING IN KRAGUJEVAC (SERBIA)

Abstract: *This paper includes the analysis of the reduction of a heating consumption of a residential building by using solar collectors. Two types of solar collectors from the group of conventional flat-plate solar collectors and the group of vacuum solar collectors were selected for space heating. The highest energy savings (17.63%) are related to the vacuum solar collector of the last generation and the lowest to the vacuum solar collector of the first generation (4.65%). As for the flat-plate solar collectors, the highest achieved energy savings are 8.34%.*
Keywords: *solar collector, space heating, simulation*

1. INTRODUCTION

By ratifying the Treaty establishing the Energy Community, the Republic of Serbia took over the obligations of Directive 2009/28 / EC which obliges the Member States of the European Union that by 2020, among other things, reduce greenhouse gas emissions by 20%. The most common measures taken in order to increase energy efficiency and thereby reduce emissions of greenhouse gases are: insulation of a building, replacement of dilapidated windows and doors, installation of measuring and regulating devices (heat meters and thermostatic valves) as well as application of renewable energy sources. The increasing need for renewable energy sources, specifically solar energy, requires that research be conducted to improve the efficiency of solar systems. The greatest limitations to increasing the use of conventional collectors is their relatively low average efficiency and high investment cost. For this reason, significant research on improving the performance of these collectors has been carried out [1,2]. This paper includes the analysis of the reduction of a heating consumption of a residential building by using solar collectors. Two types of solar collectors from the group of conventional flat-plate solar collectors and the group of vacuum solar collectors were selected and analyzed.

2. MODEL

2.1 Description of the residential building

Isometric view of the analyzed residential building is shown in Fig. 1 (left).

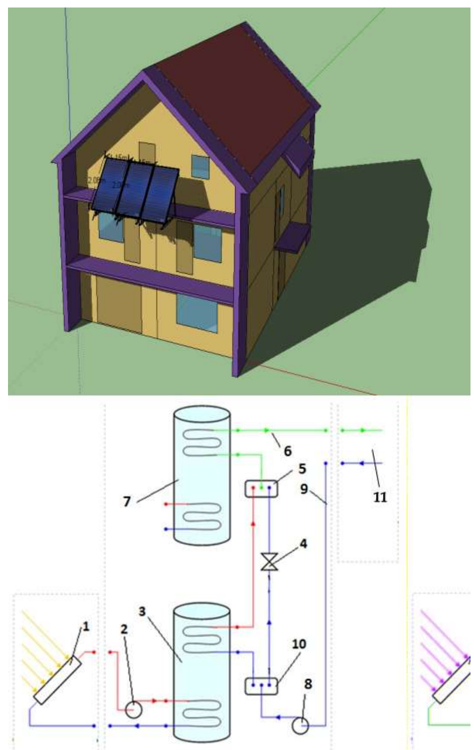

Figure 1. *Isometric view of the analyzed residential building (up) and scheme of central heating system (down) (1-solar collectors, 2-pump, 3-water tank, 4-regulating valve, 5-mixer, 6-wall heaters inlet, 7-water tank with*

gas burner, 8-pump, 9-wall heaters outlet, 10-splitter, 11-wall panel heaters)

The total useful heating area of the analyzed residential building is 152 m^2.

The physical characteristics of the building (the values of the heat transfer coefficient *U* (W/m^{2}K) of walls, window, roof, etc.) are given in Table 1.

Table 1 - The characteristics of the constructions used in the building

Constructions with layers	*U* (W/m^{2}K)
1. Interior wall: Lime mortar (2 cm), Clay block (25 cm), Lime mortar (2 cm)	1.536
2. Exterior wall: Lime mortar (2 cm), Expanded polystyrene foam (15 cm), Clay block (25 cm), Lime mortar (2 cm)	0.235
3. Ceiling between heated rooms (with hardwood): Lime mortar (2 cm), Lightweight concrete (20 cm), Hardwood (2.2 cm)	1.745
4. Ceiling between heated rooms (with tiles): Lime mortar (2 cm), Lightweight concrete (20 cm), Ceramic tile (0.8 cm)	2.096
5. Ceiling below unheated rooms: Lime mortar (2 cm), Lightweight concrete (20 cm), Expanded polystyrene foam (4 cm), Cotton (1 cm)	0.583
6. Floor with tiles: Stone (25 cm), Gravel (10 cm), Lightweight concrete (10 cm), Waterproofing (0.2 cm), Lightweight concrete (4 cm), Ceramic tile (0.8 cm)	1.597
7. Floor with hardwood: Stone (25 cm), Gravel (10 cm), Lightweight concrete (10 cm), Waterproofing (0.2 cm), Lightweight concrete (4 cm), Hardwood (2.2 cm)	1.403
8. Exterior door: Wood	2.5
Window and balcony door: Glass (4 mm), Air (12 mm), Glass (4 mm)	3

The building has a total of 9 heated zones (rooms) distributed on 2 levels (Fig. 2). It is assumed that the building located in the city of Kragujevac (Serbia) is not surrounded with any object. Use of lighting, electric equipment and occupancy in the building is defined by the schedules. Total number of people that accommodates this building is 5.

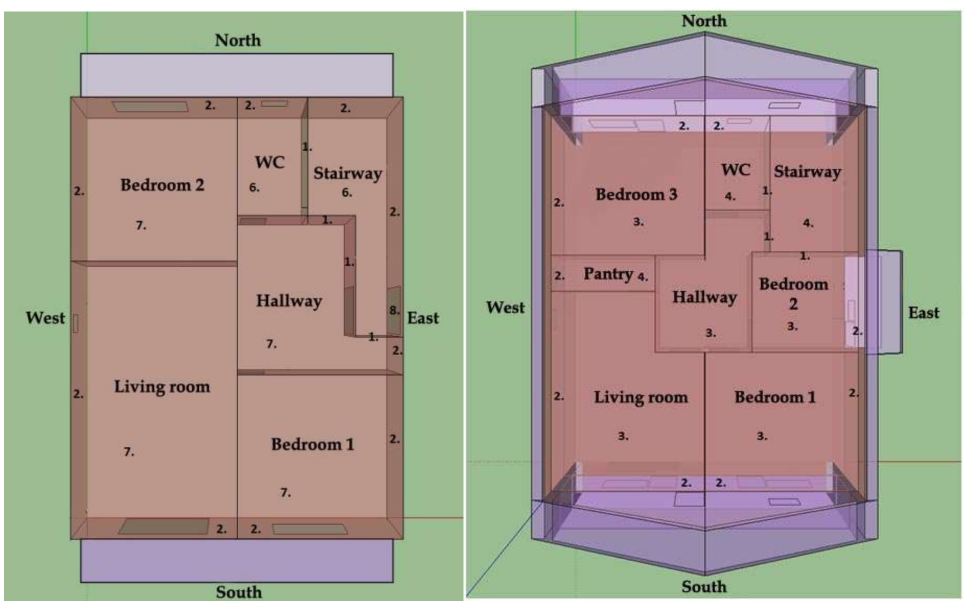

Figure 2. *Distribution of apartments per levels of the analyzed residential buildin: first level (left) and second level (right)*

The building is heated by hot water from the central heating system shown in Fig. 1 (right). It consists of a two hydraulic loops. The first loop includes solar collectors (1), pump (2) and water tank (3). The second loop includes water tank with gas burner (7), wall panel heaters (11) and pump (8). The water panel heaters are put in each of the heated rooms. The solar collectors, are used for preheating of the supply water. They are inclined at the angle of *G* = 37.5° and oriented toward the south (the optimum yearly position of a solar collector for Kragujevac, Serbia). The total area of the solar collectors is approximately 9 m^2. Two types of solar collectors from the group of conventional flat-plate solar collectors (Enerworks Inc and Solene) and the group of vacuum solar collectors (American Solar Works Holding and Viessmann Manufacturing) were selected. The first type of solar collectors in each group relates to the solar collectors of the first generation and second type to the solar collectors of the last generation. Their characteristics are given in Table 2.

Table 2 - The characteristics of the solar collectors

	Enerworks Inc	Solene	American Solar Works	Viessmann Manufacturing
Aperture area [m^2]	2.8741	2.8149	2.8638	2.83
Optical efficiency η_0 [-]	0.7166	0.704	0.474	0.825
Heat loss coefficient a_1 [W/(m^{2}K)]	-4.0141	-1.7983	-0.8937	-1.19
Heat loss coefficient a_2 [W/(m^{2}K)]	-0.01872	-0.04697	-0.01177	-0.009

The gas burner within the water tank (3) reheats the supply water before it passed through the wall heaters. The heating system operates each day from 7:00 am to 10:00 pm during the heating season from 15th of October to 15th of April. Air temperatures in the heated rooms are set to 20 °C for living rooms and bedrooms and 24 °C for bathrooms.

2.2 EnergyPlus software

To simulate thermal behavior of the analysed building and have accurate calculation results, software EnergyPlus (version 7.1.0) was used. This program is very useful tool for modeling of energy and environmental behavior of buildings [3, 4]. EnergyPlus takes into account all factors that influence thermal loads in the building, such as electricity devices, lighting, people in the building, solar radiation, wind, infiltration, and shading of open rooms. In this direction, the complex schedules of heating and cooling can be defined together with schedules for use of lighting, internal energy devices and occupancy in the building.

3. RESULTS AND DISCUSSION

In this paper the analysis of the reduction of the consumption of energy used for space heating of a residential building by using solar collectors is conducted. The monthly heating consumption of a residential building with and without solar collectors is shown in Fig. 3 (left). From this figure it can be seen that the highest heating consumption is in January and the lowest in March. The highest impacts on heating consumption of a certain residential building are related to the outdoor temperature, solar irradiation and wind velocity. The monthly energy production from the solar collectors is shown in Fig. 3 (right). The highest energy production from the solar collectors and in the same time energy savings are achieved in March. On the other side, the lowest energy savings are achieved in December. These conclusions are made neglecting the heating consumption and energy production in October and April. During these months the heating system operates only 15 days.

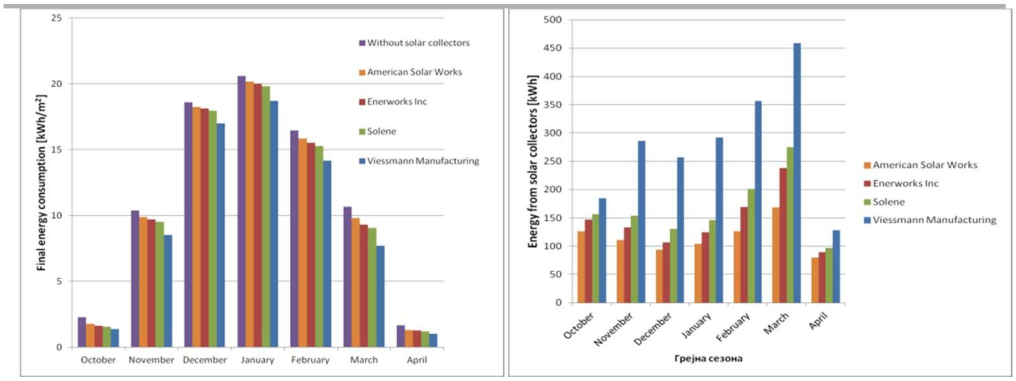

Figure 3. *Monthly final energy consumption (gas consumption) of a residential building with and without solar collectors (left) and monthly energy production from the solar collectors (right)*

The heating consumption of a residential building with and without solar collectors for entire heating season and energy savings from the solar collectors are shown in Fig. 4.

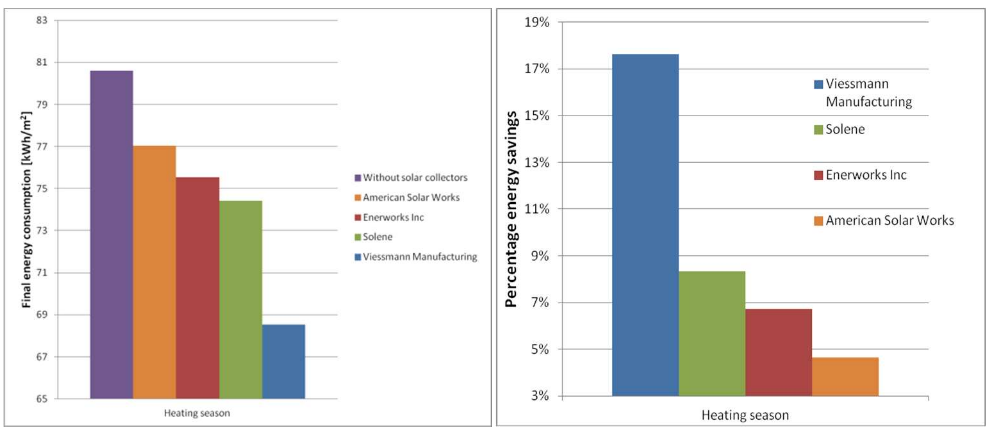

Figure 4. *Final energy consumption (gas consumption) of a residential building with and without solar collectors for entire heating season (left) and percentage energy savings (right)*

The highest energy savings and the lowest heating consumption of a analyzed residential building are achieved using the vacuum solar collector of type Viessmann Manufacturing with percentage savings of 17.63% and heating consumption of 68.54 kWh/m^2. On the other side, the lowest energy savings and the highest heating consumption are related to the vacuum solar collector of type American Solar Works with percentage savings of 4.65% and heating consumption of 77.04 kWh/m^2. This can be explained by the fact that the first solar collector has the highest efficiency (the lowest heat losses) and second one the lowest efficiency (the highest heat losses) (Table 2). As for the flat-plate solar collectors, the higher contribution has type Solene with energy savings of 8.34%. In relation to the previously mentioned solar collector, the solar collector of type Enerworks Inc has lower efficiency and thereby lower contibution to energy savings (6.71%).

4. CONCLUSIONS

In this paper the heating consumption of a residential buiilding by using solar collectors is analyzed. Simulation of the energy behavior of the residential building located in the city of Kragujevac (Serbia), with useful heating area of 152 m^2, was performed by using software EnergyPlus. Two types of solar collectors from the group of conventional flat-plate solar collectors (Enerworks Inc and Solene) and the group of vacuum solar collectors (American Solar Works Holding and Viessmann Manufacturing) were analyzed. The percentage energy savings achieved by using mentioned solar collectors are, respectively: 6.71%, 8.34%, 4.65% and 17.63%. The value of the energy savings strongly depends on the efficiency of the solar collector. The highest energy savings are related to the vacuum solar collector of the last generation (Viessmann Manufacturing) and the lowest to the vacuum solar collector of the first generation (American Solar Works). As for the flat-plate solar collectors, the higher energy savings (8.34%) have the solar collector of the first generation (Solene). According to the prize of the analyzed solar systems (2600 €, 8700 €, 2100 € and 2200 €) and achieved energy savings the simple economic analysis shows that the payback period for the same systems is high. The reason is that, in this analysis the solar collectors are used only for space heating. The situation would be better if they are used to provide the domestic hot water during the summer period. Anyway the government subsidies are of great significance for the wider use of solar collectors.

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