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# AN IMPLEMENTATION STUDY OF A SOLAR WATER HEATING SYSTEM IN HIGH SCHOOL OF FOOD AND HOSPITALITY IN CACAK, SERBIA

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**ABSTRACT**
*This paper presents an analysis of solar water heating system of High School of Food and Hospitality in Cacak, Serbia. Solar panels for hot water are made up of 40m² of highly selective flat-plate collectors that heat 2m³ of water per day. The paper presents the basic elements of the solar system and the techno-economic feasibility of using solar energy that can satisfy the needs for hot water during a year. The results show that* solar energy substitutes *85% of the electricity used for water heating. Payback period of the presented solar water heating system, which worked at 50% of its capacity during the analysis, is 10.7 years.*
**Keywords:** solar energy**,** solar water heating, techno-economic analysis, school object

## 1. INTRODUCTION

The analyzed solar water heating system has been installed in High School of Food and Hospitality in Cacak. Cacak is a town located 140 km south from Belgrade, Serbia, at a latitude of 43.87 $^{o}$N, longitude 20.33 $^{o}$E, and an altitude 250 m. The climate in Cacak is moderate continental, with an average daily temperature of 10.47$^{o}$. Cacak is mostly exposed to north and north-west wind. The average speed of north wind is 2.3 m/s, and of north-west wind 1.4 m/s. The average annual insolation is about 4 hours. The highest insolation of about 12 hours a day is in June and July, while December and January are the cloudiest months [1].

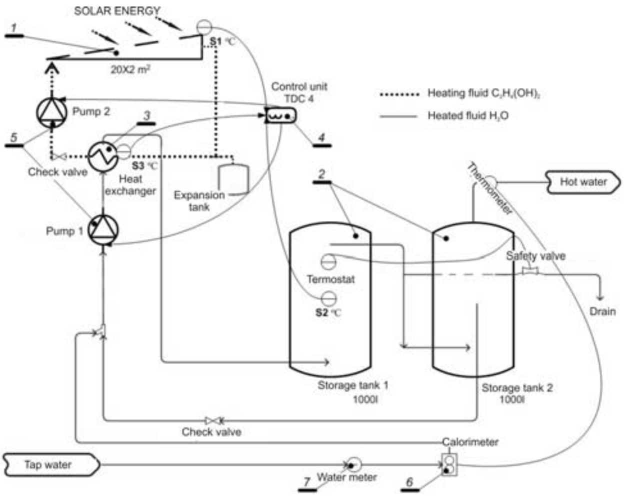
The analyzed system is made up of 40 m² of highly selective flat-plate collectors that heat 2m³ of water per day. The system consists of 20 collector plates that are oriented to the South-East. The angle of inclination of a collector is 35 °, whereas the angle between roof plane and collector is 10 °. This system is a so called closed system with heat exchanger, where water is heated indirectly (heating fluid is ethylene-glycol).

*Figure 1. Solar system of High School of Food and Hospitality in Cacak, Serbia.*

## 2. DESIGN OF SOLAR WATER HEATING SYSTEM

The solar system consists of flat-plate solar collectors, Stibetherm-S 78 Selective, Greece [2]. The cover is made of polished, prismatic, high-permeability, safety glass which covers a selective absorber that provides maximum absorption of direct and indirect solar radiations. The absorber is coated with selective coating placed in aluminum case and which, in combination with isolation of high density, ensures minimum energy loss. The total height of the collector is 78 mm.

Figure 2 presents a diagram of the solar water heating system. The entire process is managed by a controller which has both control and measuring function. Two independent measuring devices are placed on the circuit: one of them displays the amount of consumed water (water meter) while the other displays the amount of thermal energy which has been transferred to the consumer area by the system (calorimeter). The facilities which used hot water heated by the analyzed solar system are gym, kitchen, toilets and a living area built as a part of the school.




1. Collector
2. Water warehouse
3. Heat exchanger
4. Control unit
5. Pumps
6. Calorimeter
7. Water meter
8. Sensor S1, S2, S3

*Figure 2. Diagram of solar water heating system.*

The analyzed system includes two hot water tanks of 1000 liters, flat-plate exchanger of Alfa Laval [3] type, two circulation pumps used for the transport of heating fluid, i.e. the mixture of ethylene-glycol and heated fluid, i.e. water. The pumps are of Biral M 15-2 and Biral MX 13-1 types. Proper system functioning is ensured by a control unit (controller) „Sorel TDC 4“ type. The controller collects the incoming system parameters, processes available parameters and gives signals to the active devices in the system.

## 3. TECHNO-ECONOMIC ANALYSIS OF SOLAR WATER HEATING SYSTEM

In order to present the possibility of the application of solar systems for water heating in terms of energy savings, we have conducted the analysis of solar irradiation data measured by the automatic meteorological station during spring, summer and autumn, and the analysis of the water consumption in the solar water heating system of High School of Food and Hospitality in the same period. The available meteorological data were supplied by automatic Meteorological station Meteos, which had been set next to the school object in early 2010.

In the system process water can be pre-heated, while the final temperature of water is regulated in electric boilers located at places where the water is used. The savings is reflected in the fact that water coming into the electric boilers is heated up to 75 °C during summer. For analyzing collected data on solar system functioning, own electricity consumption for functioning of the controller and centrifugal pumps must be taken into account. Own electricity consumption in the research period amounts to 4% of the total absorbed solar energy.

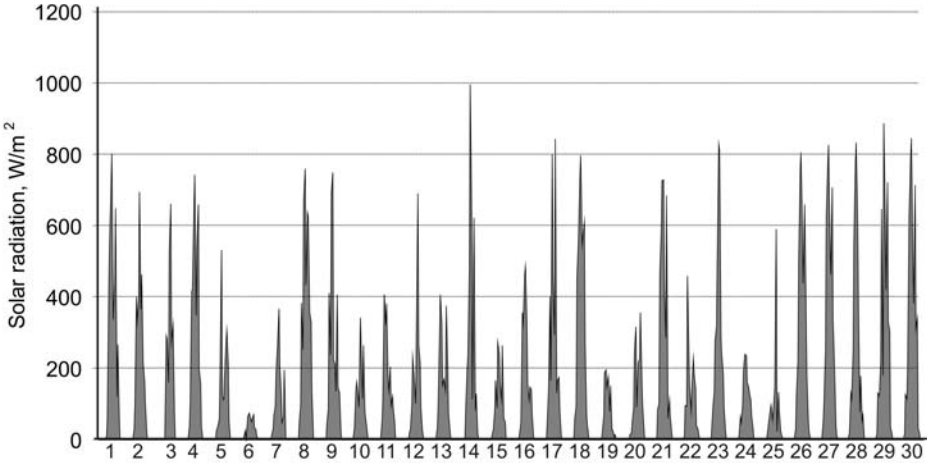



*Figure 3. Measured daily solar radiation data, April 2010.*

Table 1 presents the energy measured by calorimeter $Q_S$, electricity consumption $E_E$, the amount of consumed water per month *V* and the difference between absorbed solar energy and consumed electricity in the system *Q*.

*Table 1. Results of one-year measuring and analysis of solar energy consumption.*

| ***Month/Year*** | ***$Q_S$ , kWh*** | ***$E_E$ , kWh*** | ***Q, [kWh*** | ***V, $m^3$*** | ***Substituted electricity, %*** |
|---|---|---|---|---|---|
| 5/2009 | 998 | 28 | 970 | 21.49 | 85 |
| 6/2009 | 843 | 23 | 820 | 23.74 | 65 |
| 7/2009 | 2580 | 51 | 2529 | 88.56 | 54 |
| 8/2009 | 562 | 21.5 | 540.5 | 25.27 | 40 |
| 9/2009 | 1012 | 25.1 | 986.9 | 32.66 | 57 |
| 10/2009 | 795 | 20.1 | 774.9 | 28.86 | 51 |
| 11/2009 | 514 | 16.1 | 497.9 | 23.29 | 38 |
| 12/2009 | 162 | 5.5 | 156.5 | 23.26 | 11 |
| 1/2010 | 215 | 7 | 208 | 22.11 | 16 |
| 2/2010 | 291 | 9.7 | 281.3 | 28.62 | 17 |
| 3/2010 | 762 | 16.9 | 745.1 | 27.14 | 47 |
| 4/2010 | 686 | 17 | 669 | 21.22 | 54 |

According to solar collector characteristics. it is assumed that the usable area of collector is $1.77m^2$. According to the daily solar radiation energy per 1 m². the absorbed solar energy is calculated. Figure 4 shows the relation between absorbed solar energy and the useful system energy. i.e. electricity saving. according to the values measured by the calorimeter.

Measurements of water temperature in reservoirs have shown that the water temperature reached a value of 68°C in April. whereas the value reached in November was 58°C. According to the daily analyses of energy savings for certain days. the savings. which is greater than solar radiation potential for that day. is obtained due to the large accumulation of thermal energy from the previous period when the water consumption was low. Presented thermo-solar system with reservoirs of hot water was proved to be able to function effectively even during short cloudy periods in which enough hot water for consumers can be obtained.

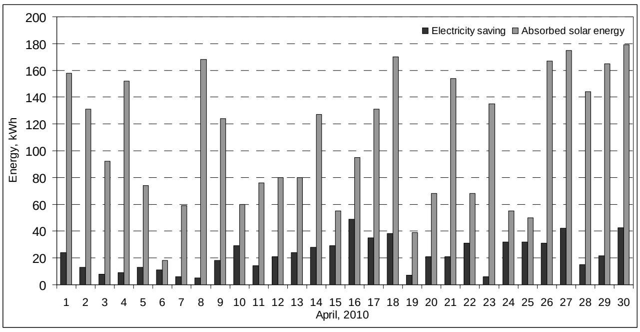



*Figure 4. Daily values of electricity savings and absorbed solar energy. April 2010.*

High School of Food and Hospitality received the analyzed system as a gift through a donation. so that the school as a user had no real investment costs. Being considered from this point the system is cost-effective because the electricity savings. achieved by using solar system. are significantly higher than the costs of maintenance and energy that is required for the functioning of circulation pumps and controllers. Therefore. the analysis of cost-effectiveness of the system was made on the basis of the measured data and market value of the system. The value used for economic analysis is the value of the installed solar system and annual system maintenance costs that amounts to 15280 Euros. The crucial fact taken into consideration for electricity savings plan is that the system worked at 50% of its capacity during the period from May 2009 to May 2010. According to the adopted data it is calculated that the system achieves annual energy savings of 18 000 kWh. or the annual electricity savings of 1700 Euros. The investment's payback period is 10.7 years.

## 4. CONCLUSION

The paper presents a techno-economic analysis of the solar system used for water heating in High School of Food and Hospitality in Cacak. According to the conducted analysis it has been calculated that the system's payback period is 10.7 years. Better efficiency of the analyzed system can be achieved with more favorable position of the collectors. which means that the receivers should be placed at a larger angle. taking into consideration the characteristics of solar radiation in the given location. with the aim of more efficient use of solar energy in spring and autumn when the need for hot water is the biggest.

## 5. ACKNOWLEDGEMENTS

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