ANALYSIS OF A SOLAR PLANT FOR THE PRODUCTION OF HOT CONSUMPTION WATER FOR THE HOSPITAL

UDC:621.311.243
Original scientific paper https://doi.org/10.46793/adeletters.2022.1.1.4

Nenad Blagojević[1], Djordje Dihovični[2*], Vladovo Krunić[3]

[1]General Hospital Subotica, Subotica, Republic of Serbia
[2]The Academy of Technical Applied Sciences, Bulevar Zorana Djindjica 152a, Belgrade, Republic of Serbia
[3]Faculty of Natural Sciences and Mathematics, Mladena Stojanovića 2, Banja Luka, Bosnia and Herzegovina

Abstract:
The paper presents and analyzes the efficiency of a solar plant for the production of thermal energy, ie the preparation of hot water (DHW) in the hospital in Subotica. At the analyzed facility, solar collectors provide the complete needs of the hospital for hot water from spring to autumn, while in the second part of the year, the required thermal energy is obtained from additional sources. The solar plant consists of 144 solar collectors, where the total gross area of the collector is 362.6 m^2 and the installed power of the plant is 253.8 kW. During the analyzed period from 2014 to 2017, a total of 558 MWh of thermal energy was produced, ie energy equivalent to 58,613.43 kg of fuel oil was saved. This thermal energy was used for the needs of the kitchen, laundry, central sterilization, heating of the operating room, and etc.

ARTICLE HISTORY
Received: 17.11.2021.
Accepted: 22.02.2022.
Available: 31.03.2022.

KEYWORDS
Solar energy, solar collectors, hot water, renewable energy sources, hospital

1. INTRODUCTION

Energy and energy consumption is continuously growing in both developed and developing countries [1], so that dependence on imported fossil fuels continues to increase, which has a negative impact on security of energy supply. This increased consumption of fossil fuels also has a negative impact on the environment and the global warming process [2,3]. In order to reduce these impacts, all countries should invest in renewable energy sources and energy efficiency [4].

In Europe, heat demand in the industrial sector has exceeded 27% [5], while the building sector consumes about 55% of heat energy for heating and cooling [6]. In the sector of hospital buildings, they continuously consume large amounts of energy for the needs of heating, cooling, lighting, etc. [7-10]. For example, hospitals in America consume 2.6 times more energy than other office buildings [11]. Thus, in some countries in Australia, hospitals consume more than half of the energy of the entire public sector [12], while in Spain, for example, the need for hospitals for solid waste is approximately 15% of heat consumption in hospitals [13].

Solar energy is a renewable resource that is available for the use and substitution of significant quantities of conventional energy forms, but its use is limited by technological, economic and geographical categories. Technological categories are reflected in the fact that for now the highest coefficient of utilization of solar systems is to convert the heat of solar energy radiation into the heat of heating solid waste through solar collectors. Solar thermal installations are mainly used in agriculture (for drying various agricultural products) and hospitals (for the preparation of solid waste, sterilization of medical equipment [14,15], heating swimming pools for rehabilitation, space heating and other thermal processes in which operating temperatures move up to 100 ° C).

*CONTACT: Dj. Dihovični, e-mail: dihovicni@visokatehnicka.edu.rs

Solar energy is a huge energy source that can meet energy needs for a very long time. The energy of the Sun, which reaches the surface of the Earth and is free for only 6 hours, is enough to meet all the world's needs on an annual basis. Ecologically speaking, solar energy is clean energy whose energy technologies are not polluting the environment and is a resource that every country has at its disposal without import dependence. The average annual solar radiation in the Republic of Serbia is around 1,200 kWh/m^2 in the north of the country, in the central part about 1,400 kWh/m^2, and in the south of the country about 1,550 kWh/m^2 per year. [16,17]. The Republic of Serbia has more than 2,000 hours of sunshine a year, which is significantly more than the average in European countries, and solar energy is used much less in practice compared to European countries [14].

For decades, the design of solar energy receivers has been focused mainly on maximizing energy efficiency while minimizing production costs. To this end, dozens of different types of solar collectors with different design characteristics have been developed, one such collector Vitosol 100 - F, type: SH1 manufactured by "Viessmann" is presented in the paper.

2. MATERIAL AND METHOD OF WORK

The aim of the research in this paper is to show the amounts of thermal energy that can be obtained from the solar thermal system (in the hospital in Subotica) for the production of solid waste in the period from 2014-2017 years. This research sought to show the justification of the solar system and the savings that can be achieved in relation to equivalent tons of fuel oil.

2.1. Solar collectors

For the needs of solid waste production in the hospital, the Vitosol 100 - F solar collector, type: SH1, manufactured by "Viessmann", was used. The absorber area of this collector is 2.32 m^2 (gross area 2.51 m^2). These types of solar collectors can provide up to 60% of the need for solid waste during the year.

The project of installing solar collectors for the production of solid waste in the hospital in Subotica was financed by the Secretariat for Energy and Mineral Resources of the Autonomous Province of Vojvodina. The basic characteristics of a solar plant are:

- ✓ consists of 144 solar collectors,
- ✓ the total gross area of the collector is 362,6 m^2,
- ✓ the total heating surface of the collector is 335,4 m^2 and
- ✓ the installed power of the plant is 253,8 kW.

From spring to autumn, solar collectors provide the complete needs of the hospital for solid waste, while in the winter period, when there is no solar yield, the needs for solid waste are provided from additional sources. In the winter period, the heating of solid waste is done with the help of block boilers "BKG 25 TPK Zagreb" which uses fuel oil as an energy source and the steam boiler "Viessmann 200 HS" which uses natural gas as an energy source. These boilers produce technological steam for the needs of kitchen work, laundry, central sterilization, heating of the operating block, etc.

In the winter period, the inflow of steam from the boiler room (to natural gas) is automatically opened via an electric motor valve, which heats the water in the boilers via pipe exchangers.

The complete project of the solar plant is made in such a way that the space under the solar collectors is used for parking for cars of employees and patients, Fig.1. The parking lot designed in this way protects vehicles from the strong influence of the sun's rays, rain, etc.

Fig. 1. Solar collectors and car parking

2.2. Other equipment in the solar system

It is used in the system as a working fluid - typhoid circulating in the system. The working fluid drives the pump from the solar collectors to the plate heat exchangers. Thermal energy is stored in the accumulation tank for storage of solid waste with a volume of 18 m^3, Fig.2. The temperature is measured in the tank by probes where the signal is sent to the PLC controller in which the measured temperature is compared with the setpoint and an order is given to turn on the circulation pump that delivers water to the pre-boiler which further distributes water to TPV boilers.

Fig. 2. In the system as a working fluid is used - typhoid which Accumulation tank of hot water heated via solar panels

Sensors with thermometers are located on solar collectors and they record the temperature of solar radiation, ie measure the temperature of the working fluid (tifokor) from where the signal is sent to the control unit where the data is processed via PLC and based on the set temperature difference to turn on and start the working fluid.

Of the other control equipment it is used:

- ✓ electronic solar controller - VITOSOLIC 200 SD4 and
- ✓ digital regulator of solar circuits- ТПВ VITOTRONIC 200-H.

The regulation of TPV temperature is performed on the basis of sensor readings in the supply and return lines that are forwarded to the PLC memory, which is based on the program set temperature, and difference gives a signal to turn on or stop circulating pumps that forward set temperature to consumers [18]. Schematic representation of the connection of solar collectors with boilers for the preparation of solid waste, is shown in Fig.3.

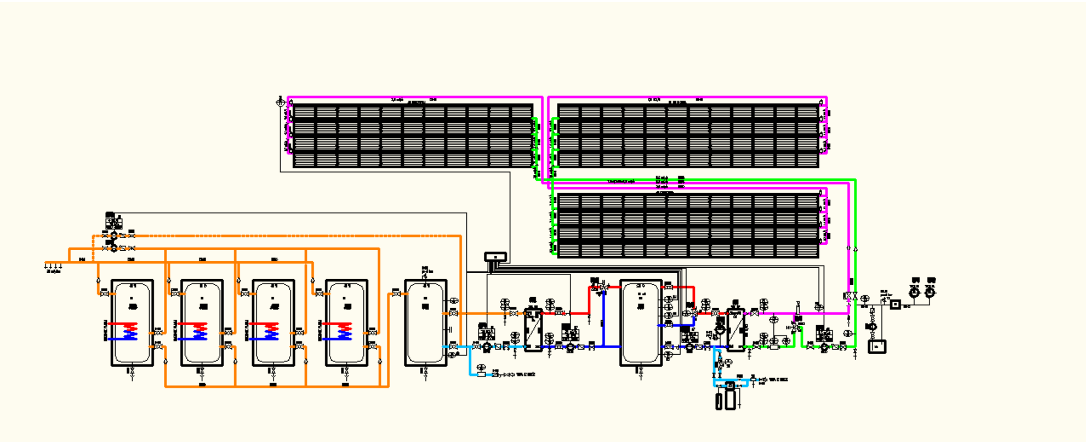

Fig. 3. Schematic representation of the functioning of the solar system [19,20]

According to the same principle, hot water from the storage boiler transfers the heat taken from the working fluid through another plate exchanger from the so-called the second solar circuit in the third circuit, ie. it is transferred to the water that is distributed to consumers through the boiler. Boilers that distribute water to consumers also have sensors connected to the control unit that read the temperature of the outgoing water to the consumers and the return water or recirculation temperature.

When the weather conditions are unfavorable, the water is heated through a heat exchanger in a boiler that receives heat from an external gas boiler room. The solar plant is also operational in winter, so that when it is a sunny day, a lower heat yield is obtained compared to summer, but it is still significant amount to reheat all the necessary hot water from external sources.

3. RESEARCH RESULTS

The total production of thermal energy from the solar plant in the analyzed period from 2014 to 2017 amounted to 558 MWh, ie 58,613.43 kg of fuel oil were saved, Fig.4. During 2014, heat energy was produced in the amount of 125 MWh (savings of 13,130.25 kg of fuel oil.) - Fig.5, during 2015, 123 MWh of heat energy was produced (savings of 12,920.16 kg of fuel oil.) - Fig.6, during 2016, 146 MWh of thermal energy was produced (saving 15,336.13 kg of fuel oil.) - Fig.7, and during 2017, 164 MWh of thermal energy was produced (saving 17,226.89 kg of fuel oil.) - Fig.8.

The energy produced for the needs of hot water from solar collectors in the observed period in the hospital amounted to 33% of the total needs for the same, while the rest was provided from additional sources.

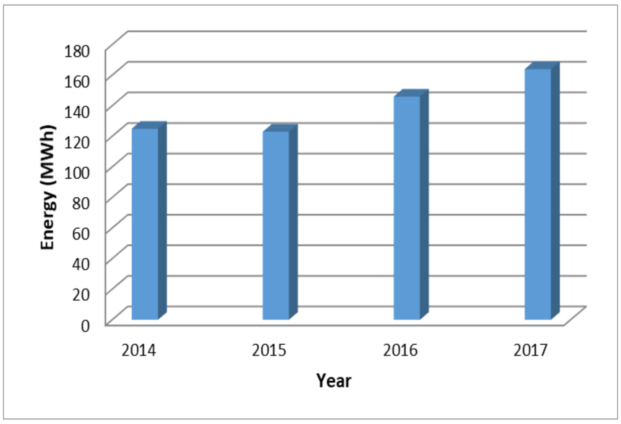

Fig. 4. Total solar yield from installation to breakdown

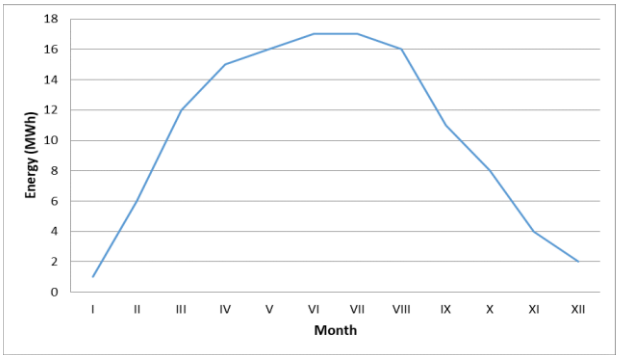

Fig. 5. Annual performance of the solar system in 2014

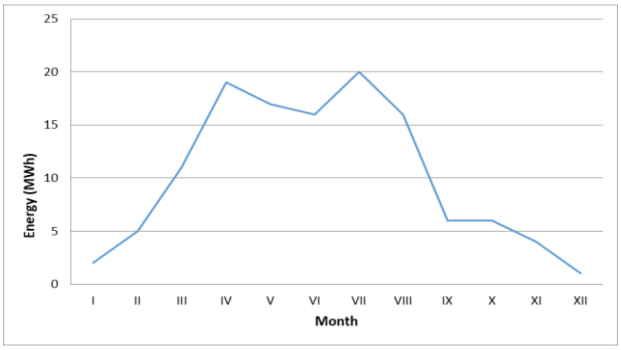

Fig. 6. Annual performance of the solar system in 2015

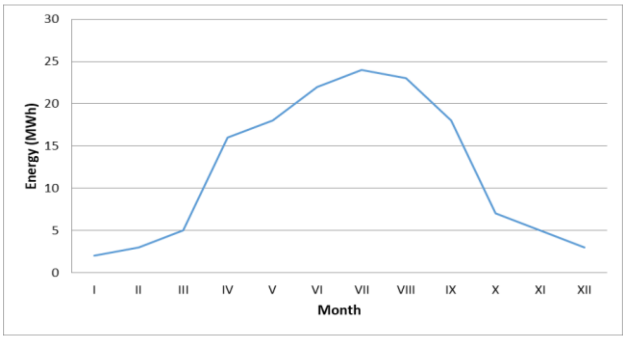

Fig.7. Annual performance of the solar system in 2016

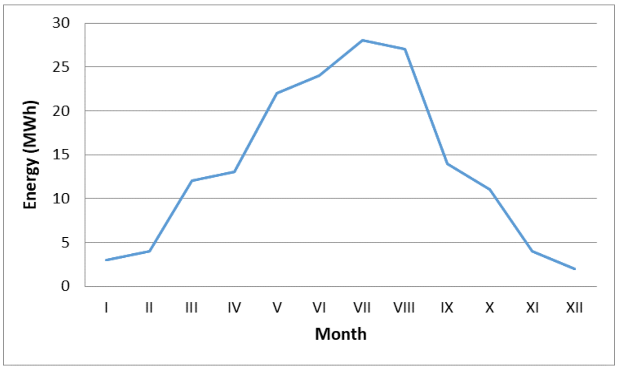

Fig. 8. Annual performance of the solar system in 2017

4. CONCLUSION

In the modern world in which we live, energy is a crucial factor that affects the development of the overall economy of each country, so consumption is becoming more and more important. The directives of the European Union, of which our country is a potential member, limit the production of energy sources that emit a large amount of carbon dioxide, so that is one of the reasons for forcing clean energy technologies.

The solar plant with 144 solar panels in the period May - September fully met all the needs of patients, employees and the needs of medical and non-medical staff in the technological process of work for hot sanitary water. During the analyzed four-year period from 2014 to 2017, a total of 139.5 MWh of thermal energy was produced annually, ie energy equivalent to 14,653.36 kg of fuel oil was saved annually.

The energy produced for the needs of hot water from solar collectors in the observed period in the hospital amounted to 33% of the total needs for the same, while the rest was provided from additional sources.

REFERENCES

[1] A. Inayat, H.H. Ang, M. Raza, B.A.A. Yousef, C. Ghenai, M. Ayoub, S.I.U.H. Gilani, Integration and simulation of solar energy with hot flue gas system for the district cooling application. *Case Studies in Thermal Engineering*, 19, 2020: 100620. https://doi.org/10.1016/j.csite.2020.100620

[2] Y.H. Bardineh, F. Mohamadian, M. H. Ahmadi, N. Akbarianrad, Medical and dental applications of renewable energy systems. *International Journal of Low-Carbon Technologies*, 13(4), 2018: 320-326. https://doi.org/10.1093/ijlct/cty040

[3] T.P. Lima, J.C.C. Dutra, A.R. M. Primo, J. Rohatgi, A.A.V. Ochoa, Solar water heating for a hospital laundry: A case study. *Solar Energy*, 122, 2015: 737-748. https://doi.org/10.1016/j.solener.2015.10.006

[4] N. Tsvetkov, S. Boldyryev, A. Shilin, Y. Krivoshein, A. Tolstykh, Hardware and Software Implementation for Solar Hot Water System in Northern Regions of Russia. *Energies*, 15, 2022: 1446. https://doi.org/10.3390/en15041446

[5] R. Ghabour, Lj. Josimović, P. Korzenszky, Two analytical methods for optimising solar process heat system used in a pasteurising plant. *Applied Engineering Letters*, 6(4), 2021: 166-174. https://doi.org/10.18485/aeletters.2021.6.4.4

[6] M. Rawat, R.N. Singh, Thermal performance of building prototype with different cool roof structures in composite climate. *International Journal of Sustainable Energy*, 41 (4), 2022. (In press) https://doi.org/10.1080/14786451.2022.2055558

[7] A. Franco, M. Shaker, D. Kalubi, S. Hostettler, A review of sustainable energy access and technologies for healthcare facilities in the Global South. *Sustainable Energy Technologies and Assessments*, 22, 2017: 92-105. https://doi.org/10.1016/j.seta.2017.02.022

[8] J. Vourdoubas, Possibilities of Using Sustainable Energy Technologies including CHP Systems, Solar Photovoltaics and Heat Pumps in Hospitals. *European Journal of Energy Research*, 2(2), 2022: 1-8. https://doi.org/10.24018/ejenergy.2022.2.2.52

[9] J. Vourdoubas, Use of Renewable Energy Sources for Heat and Cooling Generation in Hospitals. *American Scientific Research Journal for Engineering, Technology and Sciences*, 79(1), 2021: 98-112.

[10] S.M. Vaziri, B. Rezaee, M.A. Monirian, Utilising Renewable Energy Sources Efficiently in Hospitals using Demand Dispatch. *Renewable Energy*, 151, 2019: 551-562. https://doi.org/10.1016/j.renene.2019.11.053

[11] K. Bawaneh, F. Ghazi Nezami, M. Rasheduzzaman, B. Deken, B. Energy Consumption Analysis and Characterization of Healthcare Facilities in the United States. *Energies*, 12, 2019: 3775. https://doi.org/10.3390/en12193775

[12] H. Burch, M.H. Anstey, F. McGain, Renewable energy use in Australian public hospitals. *Med. J. Aust.*, 2021: 1-10.

[13] G. Sánchez-Barroso, J. González-Domínguez, J. García-Sanz-Calcedo, Potential Savings in DHW Facilities through the Use of Solar Thermal Energy in the Hospitals of Extremadura (Spain). *International journal of environmental research and public health*, 17(8), 2020: 2658. https://doi.org/10.3390/ijerph17082658

[14] S. Prvulovic, D. Tolmac, M. Matic, Lj. Radovanovic, M. Lambic, Some aspects of the use of solar energy in Serbia. *Energy Sources, Part B: Economics, Planning, and Policy*, 13(4), 2018: 237-245. https://doi.org/10.1080/15567249.2012.714842

[15] J.-F. Ituna-Yudonago, Y.-R. Galindo-Luna, O. García-Valladares, R. Best y Brown, R. Shankar, J. Ibarra-Bahena, Review of solar-thermal collectors powered autoclave for the sterilization of medical equipment. *Alexandria Engineering Journal*, 60(6), 2021: 5401-5417. https://doi.org/10.1016/j.aej.2021.04.007

[16] A. Ašonja, V. Vuković, The potentials of solar energy in the republic of serbia: current situation, possibilities and barriers. *Applied Engineering Letters*, 3(3), 2018: 90-97. https://doi.org/10.18485/aeletters.2018.3.3.2

[17] J. Pekez, Lj. Radovanovc, E. Desnica, M. Lambic, The increase of exploitability of renewable energy sources, *Energy Sources, Part B: Economics, Planning, and Policy*, 11(1), 2016: 51-57. https://doi.org/10.1080/15567249.2011.580318

[18] D. Dihovični, A. Ašonja, N. Radivojević, D. Cvijanovic, S. Škrbić, Stability issues and program support for time delay systems in state over finite time interval. *Physica A: Statistical Mechanics and Its Applications*, 538, 2020: 122815. https://doi.org/10.1016/j.physa.2019.122815

[19] D. Veselica, The main mechanical project of the installation for heating sanitary hot water using solar energy. *Termoprojekt*, Subotica, 2012.

[20] Technical documentation of energy facilities of the "General Hospital Subotica", Subotica, 2012-2020.