DOI: 10.17512/bozpe.2018.2.08

**Stepan SHAPOVAL** (orcid id: 0000-0003-4985-0930), **Vasyl ZHELYKH** (orcid id: 0000- 0002-5063-5077)
**Bogdan GULAI** (orcid id: 0000-0001-6951-6994), **Iryna VENHRYN** (orcid id: 0000-0002-2317-0913)
**Volodymir SHEPITCHAK** (orcid id: 0000-0001-5883-548X)
**Lviv Polytechnic National University, Ukraine**

# ENERGY EFFICIENCY OF HEATING SYSTEMS USING SOLAR WINDOWS

**The era of technological progress provides people with many opportunities to install in a building various systems such as heating, gas supply and ventilation that will help to improve the microclimate and comfort of use of the room. The environmental and economic side of these systems remain the main issues in selecting the type of installation. The article considers the energy efficiency of a heating system using a solar window. The data describes changes in the solar window heat carrier temperature and the nature of the change in thermal power over time. It was found that the proposed solar window model is quite effective and can be used in the design of of solar heating systems. The results of the study can be used in the design and choice of location of solar energy installations in Ukraine.**

**Keywords:** solar window, heating system, heat carrier temperature, energy efficiency

## INTRODUCTION

The exploitation of solar energy, bioenergy, and wind power is sufficiently promising to improve the environmental situation, to decrease the consumption of fossil fuels, as well as to meet household and technological needs. Solar installations often have different design complexities and require complex electromechanical systems and guidance mechanisms.

The importance of finding and using alternative energy sources are to reduce the dependence on non-renewable energy resources and at the same time, reduce the environmental impact of eco-damaging effects on the environment, which leads to the search for the best ways for effective development of renewable energy in general. Alternative energy is designed to help solve first of all two important issues - environmental safety and energy efficiency.

Furthermore, in the future, the amount of organic fossil fuels will be limited. Accordingly, implementing new ideas which concern changes in the alternative energy sector through the prism of environmental education is important for present and future generations.

From historical sources it is known that the year 1883 is considered to be the beginning of the era of solar energy in electricity. This is a topical issue for the

Ukraine because it is located on a territory with a sufficient surface area of solar insolation [1].

The formation of solar energy design took place in 1891 by well-known scientists and engineers, when the first patent for a solar installation was issued to Clarence M. Kemp from Baltimore, and a market model was proposed in 1902 by Frank Walker.

## 1. OBJECTIVES - PROBLEM FORMULATION

In the Ukraine the solar electricity sector significantly began to develop in 2004, and the solar heating industry since 2011. The slow development of solar energy systems has a number of causes, which are the main stages in the development of solar heating systems for the Ukraine [1].

In addition to finding alternative energy sources, as opposed to traditional fuel, it is important to integrate existing solar installations in simpler constructions as well as improve wind and bioenergy constructions. It should be done without losing the existing efficiency, but rather raise it.

## 2. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

A great deal of research is being undertaken to address environmental problems through, e.g. using renewable energy to reduce greenhouse gas emissions and using energy resources intelligently.

For instance, Robins (2010) describes various practical approaches to reduce GHG emissions, while Rosen (2009) describes methods to combat global warming through non-fossil fuel energy alternatives [2]. Work [3] discusses the needs of the solar industry with its fundamental concepts, the world's energy scenario, highlights of research done to upgrade the solar industry, its potential applications and the obstacles for a better solar industry in future in order to resolve the energy crisis. Article [4] presents an overview of the different techniques that are employed to enhance the efficiency of flat plate collectors. For example, the effect of using nanofluids as heat transfer fluid, the effect of altering the absorber plate design to better capture radiation, methods to reduce heat loss, the use of polymers, employing mini channels for fluid flow, using PCM (phase changing materials) to provide heat during the night without a tank and the effect of using enhancement devices like inserts and a reflector were discussed in this paper.The range of constructive and technological solutions for solar systems is very wide [5-7].

However, for the Ukraine, the topical issue is cheaper solar collectors for the market, but without loss of efficiency.

## 3. MAIN MATERIAL

To introduce solar thermal installations, it is necessary to optimize energy-efficient external fencing through the proper installation and design of these facilities.

The proposed model of a solar energy system was combined with a window of a house. The general principle of operation is as follows: the heat carrier feeds into the storage tank; when opening and setting regulating valves, water enters the solar window, is heated by the solar energy and under the principle of natural convection and with the help of a circulation pump, moves back into the storage tank in a circulation mode (Fig. 1).

Before every experiment, the system was filled with a fresh portion of water. Air was removed from the system. The system was checked for leaks at working pressure. The accuracy of the measuring devices was also checked.

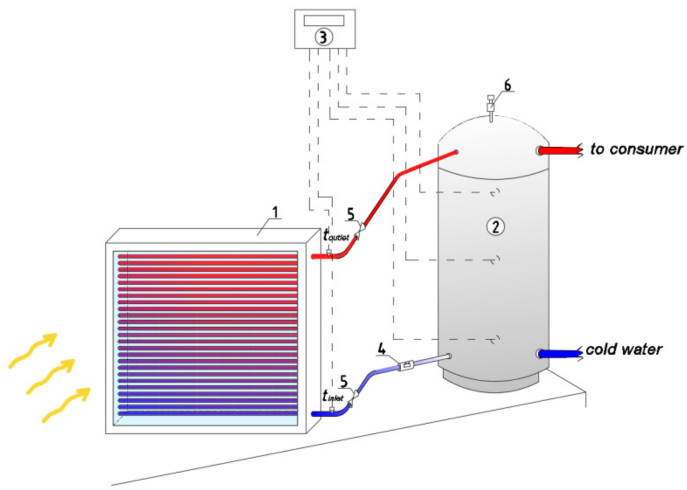


Fig. 1. Combined solar window system, where: 1 - solar window; 2 - storage tank; 3 - temperature sensor; 4 - circulation pump; 5 - regulating valves; 6 - air release valve

The specific heat capacity of the solar window (as a solar collector SC), [W/m$^2$] is determined by formula (1):

$$Q_{SC} = \frac{m \cdot c \cdot (T_{outlet} - T_{inlet})}{F_{SC}} \quad (1)$$

where:

$m$ - mass of the heat carrier in the tank battery [kg],

$c$ - the average specific heat capacity (at constant pressure) at the arithmetic mean temperature of heat carriers [J/(kg·K)],

$T_{inlet}$, $T_{outlet}$ - the heat carrier temperature at the SC inlet and outlet respectively [K],

$F_{SC}$ - SC surface area [m$^2$].

Figure 2 shows the results of experimental studies of the temperature of the heating system heat medium in circulation mode at the radiation intensity of 300 W/m$^2$. It was found that the increase in the temperature of the heat carrier of the solar system $\Delta t_{outlet}$ [°C] in the circulation mode reached 3.16°C, which is 36% more than the inlet temperature of the heat carrier $t_{inlet}$ [°C].

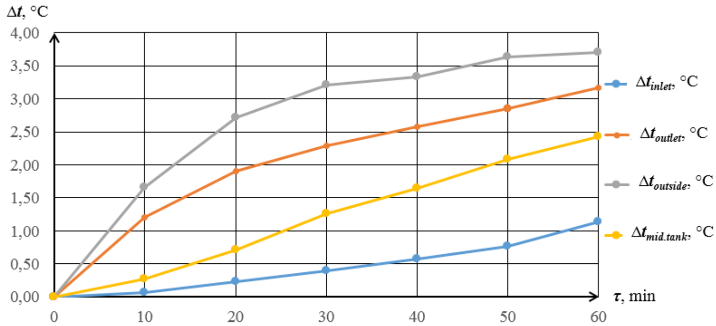


Fig. 2. Increase in temperature Δ of heat carrier according to research of solar window in circulation mode at solar collector inlet $\Delta t_{inlet}$ [°C], outlet $\Delta t_{outlet}$ [°C], ambient temperature $\Delta t_{outside}$ [°C] and middle temperature in storage tank $\Delta t_{mid.\ tank}$ [°C] during experiment

The amount of thermal energy that was received with the radiation intensity of 300 W/m$^2$ shown in Figure 3.

The effectiveness of the solar heating system (SHS) in total, with the accumulation of heat energy in the storage tank at the intensity of 300 W/m$^2$ is shown in Figure 4. It was determined that efficiency $\eta_{SHS}$ reached more 70% after 30 min of the experiment.

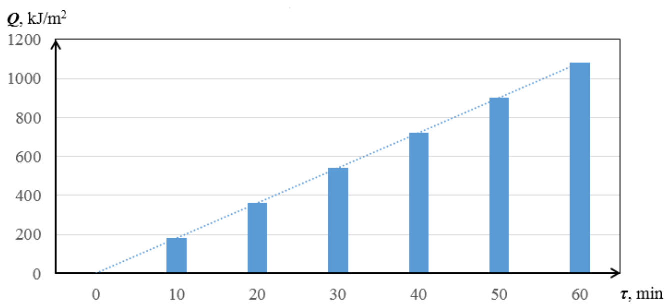


Fig. 3. Amount of thermal energy accumulated in storage tank $Q$ [kJ/m$^2$] at 300 W/m$^2$ in circulation mode during experiment

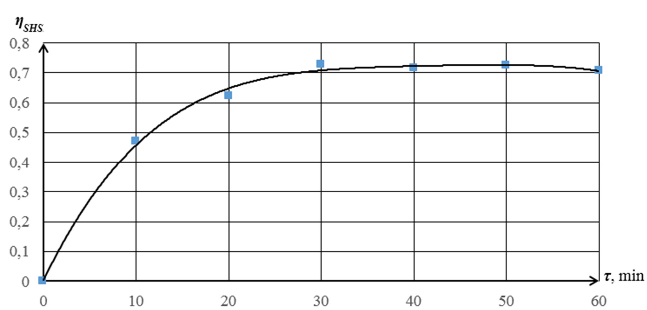


Fig. 4. Effectiveness of solar heating system in total $\eta_{SHS}$, with accumulation of heat energy in storage tank at intensity of 300 W/m$^2$ in circulation mode during experiment

The heating system using the solar window at the intensity of 900 W/m$^2$ in the circulation mode was also analyzed. The results of the experimental measurements of temperature are presented in graph form at the intensity of heat flow 900 W/m$^2$ (Fig. 5).

An important issue in the circulation mode was to investigate the instantaneous values of specific heat capacity for the solar heating system, which is shown in Figure 6.

An important point in the study of the solar window was to examine the change in the coefficient of performance of the solar collector in circulation mode, which is shown in the Figure 7.

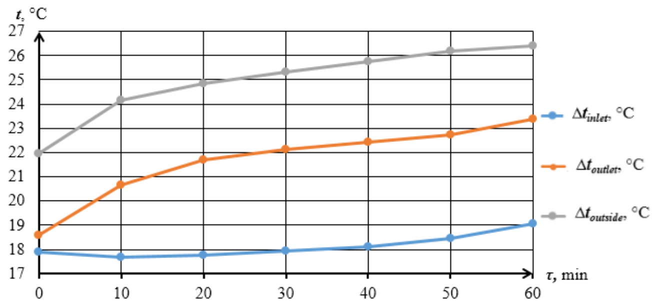


Fig. 5. Temperature of heat carrier according to research of solar window in circulation mode at solar collector inlet $t_{inlet}$ [°C] and outlet $t_{outlet}$ [°C], ambient temperature $t_{outside}$ [°C] at intensity of 900 W/m$^2$ during experiment

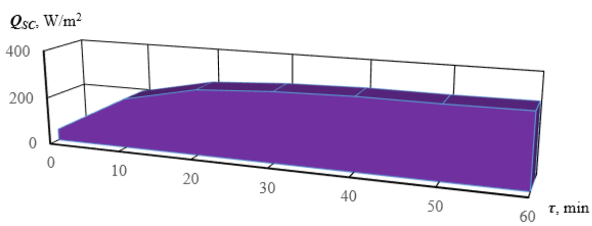


Fig. 6. Instantaneous values of specific heat capacity for solar collector $Q_{SC}$ [W/m$^2$] at intensity of 900 W/m$^2$ in circulation mode during experiment

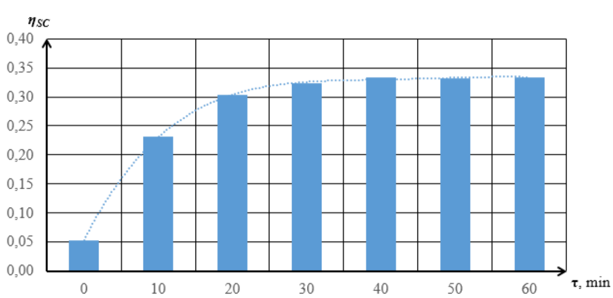


Fig. 7. Coefficient of performance of solar collector at intensity of 900 W/m$^2$ in circulation mode during experiment

## CONCLUSIONS

Summarizing the above-mentioned data it could be argued that the model of the of solar heating system allows one to predict during the design and production stages what the temperature of the heat carrier in the solar system will be. This gives the opportunity to choose the best conditions at the design stage for the solar heat system to achieve the maximum temperatures.

Such a solution would enable engineers to calculate such systems for practical use with the assumption of the practical efficiency of such a system. The maximum achieved average efficiency of a heating system with a solar window in circulation mode was approximately 62%.

## REFERENCES

[1] Shapoval S., The efficiency of the combined solar collector in the gravity mode in the southern orientation, 5th International Youth Science Forum 'Literis et artibus', 2015, 5, 124-126.

[2] Behnaz Rezaie, Seasonal Stratified Thermal Energy Storage Energy Analysis, Proceedings of eSim 2012, The Canadian Conference on Building Simulation, 2012, 352-365.

[3] Kannan N., Solar energy for future world, Renewable and Sustainable Energy Reviews 2016, 62, 1092-1105.

[4] Krishna M.P., A review on analysis and development of solar flat plate collector, Renewable and Sustainable Energy Reviews 2017, 67, 641-650.

[5] Features of designs of solar collectors for hot water, Scientific Bulletin NLTU Ukraine 2012, 22, 96-99.

[6] User's handbook on solar water heaters, 2015, Access: http://www.undp.org/.

[7] Soteris A. Kalogirou, Solar thermal collectors and applications, Progress in Energy and Combustion Science 2004, 30, 1-65.

## EFEKTYWNOŚĆ ENERGETYCZNA SYSTEMÓW CIEPŁOWNICZYCH WYKORZYSTUJĄCYCH OKNA SŁONECZNE

**Postęp techniczny stwarza możliwości i warunki do zastosowania w budynkach różnych systemów grzewczych i wentylacji, co pozwala kształtować odpowiedni mikroklimat i komfort użytkowania pomieszczeń. Jednak jednym z głównych aspektów wyboru rodzaju instalacji pozostają względy ekologiczne i ekonomiczne funkcjonowania tych systemów. W artykule omówiono efektywność energetyczną systemów grzewczych wykorzystujących tzw. okna słoneczne. Dane przytoczone w artykule zawierają informacje o temperaturze nośnika ciepła okna słonecznego i charakterze zmiany mocy cieplnej w czasie. Stwierdzono, że zaproponowany model okna słonecznego dobrze oddaje warunki jego funkcjonowania i może być stosowany w projektowaniu systemów opartych na wykorzystaniu energii promieniowania słonecznego. Wyniki badań mogą być przydatne przy planowaniu i wyborze miejsca lokalizacji instalacji wykorzystującej energię promieniowania słonecznego na terenie Ukrainy.**

**Słowa kluczowe:** **okno słoneczne, system ogrzewania, temperatura nośnika ciepła, wydajność energetyczna**