Vol. 3, No. 2, 2021

https://doi.org/10.23939/jtbp2021.02.058

Volodymyr Labay , Bohdan Piznak, Bohdan Gulai, Iryna Sukholova

PROSPECTS OF USING POLYMERIC MATERIALS IN THE CONSTRUCTION OF SOLAR COLLECTORS

[1] Department of Heat and Gas Supply and Ventilation,
Lviv Polytechnic National University
piznak.b@gmail.com

The solar energy that reaches the Earth is free, but installations to convert solar energy into heat, as well as equipment for transporting and storage that heat, require some investment. A significant part of the components of these systems are metals. Pipelines in solar collectors and heat exchangers are made of copper, aluminum is used for the absorber and housing, and the steel is often used in heat storage tanks. One of the options to reduce the cost of solar collectors and increase their efficiency is to use polymeric materials instead of metals. The main advantages of using polymeric materials in solar thermal collectors are their cost, especially if you are taking into account the growth of the renewable energy market and rising prices for metal. The use of polymers also reduces the costs of production, transportation and installation for the user.

Keywords: solar thermal collectors, polymeric materials, renewable energy sources, solar radiation, thermal efficiency, absorber.

Introduction

Now on the market there are numerous examples of polymer solar thermal collectors. Most of them are used without glazing and insulation especially for pools heating in the warm season. Some of them are more advanced and are able to achieve better performance at higher operating temperatures, either as built-in storage collectors or as glazed flat collectors with absorbers made of highly efficient polymers.

Although there are a large number of solar thermal systems where polymers are already used, the number and variety of possible applications of polymer combinations is much greater. For greater integration of polymers into this industry, purposeful research of relevant materials and compounds is conducted, as well as a detailed consideration of their characteristics, special advantages and weaknesses (Köhl, 2015).

Systemic problems with the use of polymer materials are the limitation of the maximum temperature of the absorbers during stagnation (when heat is not used from the heliosystem) to a value of about 120 ° C and the increase in coolant pressure, which should be avoided. Another problem is the degradation of polymers during operation, if their service life is compared with conventional solar thermal collectors (Weiß, 2014).

When compared to other materials, polymeric materials are characterized by their versatility, extremely flexible ability to process complex components and low weight. Based on these and other benefits, the increased use of polymeric materials in solar thermal collectors leads to the following improvements (Reiter, 2014).

Components based on polymers in solar thermal collectors demonstrate improved functionality and significantly reduce the number of individual parts compared to conventional metal-based structures (Zhelykh, 2012).

Collectors and heat accumulators made of plastic lead to a significant reduction in installation costs due to their lower weight, as well as a result more innovative methods of connection and installation.

Using plastics in the components of solar thermal collectors gives much more freedom of design and better satisfaction of aesthetic needs. For example, colors and shapes can be varied so that future solar panels are not necessarily flat or cylindrical, but can also have a free shape according to the architecture of the roof surface and facade.

A feature of polymer processing technologies is the simplicity of production of a large number of complex parts. As in other areas, these technologies offer mass production opportunities combined with a high degree of integration. This, in turn, at the same time reduces costs by ensuring high market growth rates, which are needed to cover the significant needs of low-temperature heating systems.

One of the key innovative aspects is related to advanced technologies for processing polymers, which are less energy-intensive than metal processing.

Target of this article

This article discusses the current state of solar collector structures and methods of their manufacture. The main attention is focused on the study of the use of polymeric materials in the design of solar thermal collectors in order to reduce the cost of manufacturing and installation of solar thermal systems

Techniques used

The absorber is the main element of the solar collector and in most cases is made of copper. It absorbs solar radiation, which consists of direct and scattered radiation, and converts the energy of sunbeams into heat. The largest number of absorbers have a flat construction with tubes. The plate with a black surface receives solar radiation. On the reverse side of the plate, the liquid pipes absorb heat energy.

Glazing over the absorber reduces heat loss of the absorber plate by convection and radiation. Glazing is usually made of special impact-resistant glass with very good light-transmitting characteristics. Insulation, usually consisting of mineral wool, it reduces heat loss at the back of the collector and on the sides. The thickness of the insulation is 40–60 mm at the back and about 15 mm at the edges.

The absorber, glazing and insulation of the collector are built into the housing to protect against environmental influences.

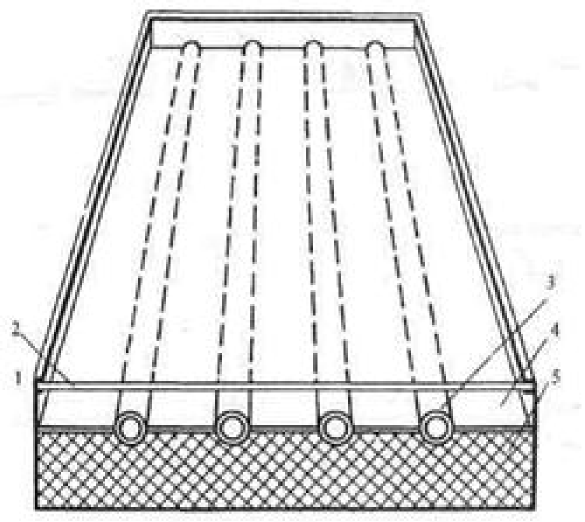

Fig. 1. Flat solar collector: 1 – housing; 2 – transparent protection; 3 – channels for the heat carrier; 4 – absorbing panel; 5 – thermal insulation

The operation of the solar collector is based on the greenhouse effect: the sun's rays of the visible part of the spectrum (short waves) pass freely through the glass and heat the coolant inside the solar collector, and infrared radiation of the heated body (long waves) does not come out through the glass.

In recent years, numerous development projects have been implemented in the field of flat solar collectors, which have mainly focused on improving the efficiency of the collector: improving the transparency of glass, the use of highly selective absorbent coating (Reiter, 2014). This has led to an increase in production costs and eventually to an increase in the price of collectors. Figure 2 illustrates the mass percentage of materials of the modern collector.

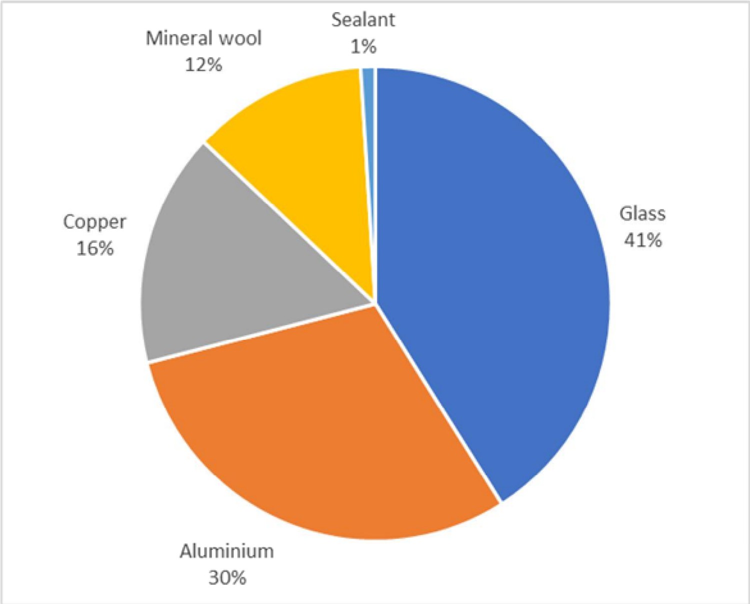

Fig. 2. The percentage of mass of materials of a modern flat collector

In addition, the cost of commonly used raw materials is growing, mainly copper and aluminum. The flat solar thermal collector has a very high mass percentage of copper, aluminum and glass. Figure 3 shows the distribution of the cost of the elements of solar collector (Reiter, 2014).

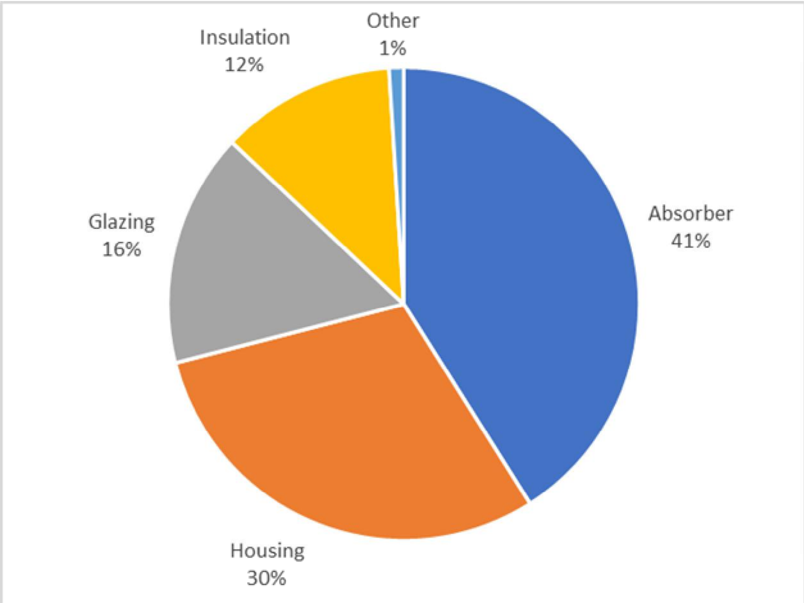

Fig. 3. The cost of production costs for flat solar panels

One way out of this dilemma is to use polymeric materials instead of metals. Good energy performance is achieved by using solar collectors made of polymeric materials in appropriate systems. These favorable systems have low or medium temperature, low pressure, optimized coolant flow, protection against overheating, appropriate surface coverage of collectors. Examples of such systems are pool heating systems, combined hot water and space heating systems, systems with high consumption of hot water (sports centers, hotels, hospitals, apartment buildings, etc.) and air heating systems in commercial or educational buildings.

Various production technologies such as extrusion, thermoforming, vacuum forming and injection molding can be used to manufacture solar collectors. Polymeric materials give freedom for the production of collectors with large geometric dimensions, flexibility in the integration of such structures in the external protection of buildings with greater aesthetics.

Solar absorbers for outdoor pool heating have been made of polymeric materials since the early 1970s. This technology is simple and ideal for the use of plastics in solar systems with low material costs and high production volumes. Solar collectors for swimming pools exist in different designs and are produced using different polymer processing technologies. These polymer collectors without glazing are currently being promoted for domestic hot water supply systems in the sunny regions of the world.

Such unglazed solar absorbers can supply the system with low temperature (30–40 °C). Therefore, high thermal and mechanical stability is not required for such absorbers. In addition, water from the pool circulates directly through the heat absorber of the collector, and therefore, resistance to glycol is not required. Inexpensive polymers such as polyethylene (PE), polypropylene (PP) and EPDM are mainly used. These inefficient unglazed and uninsulated pool heat absorbers cannot be used for hot water and space heating in the European climate (Reiter, 2014).

There are two types of absorbers available on the market - absorbers of volume construction and absorbers with parallel channels.

Volume absorbers are made of black polyethylene by extrusion blow molding. Figure 4 shows the products of OKU Obermaier GmbH.

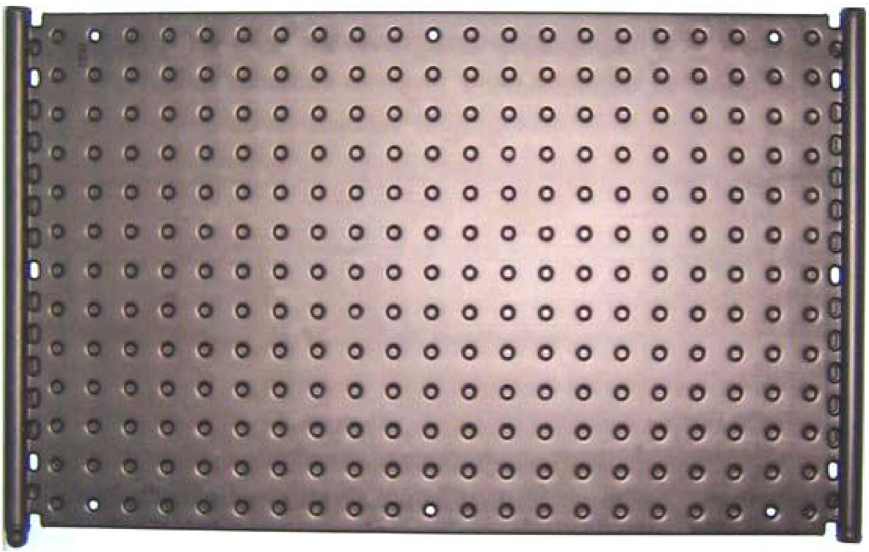

Fig. 4. Unglazed and uninsulated solar collector for pool heating

The Heliocol pool heater is a bundle of parallel PP pipes joined together. Fig. 5 shows a solar collector for pool heating.

Fig. 5. Solar collector for the pool from Heliocol

About 50 % of final energy consumption is used for low-temperature heating systems, therefore this energy market has the greatest potential to replace fossil fuels with renewable energy, especially solar thermal energy. The need for greater use of solar thermal energy is also becoming increasingly apparent due to rising prices for traditional fuels and the threat of future shortages.

Many existing collectors use a protective coating made of transparent polymers. The following types of polymer glazing are mainly used: flat plates, bent plates and multilayer plates. The simplest option consists of flat sheets similar to standard tempered glass. When it is necessary to achieve higher mechanical stability, the bent plate is an alternative to single-layer glazing. In particular, it is possible to make collectors of the big sizes without losing durability of a covering. British company Imagination Solar Ltd. uses this type of polycarbonate plates for collectors. Thermosyphon solar collectors manufactured by Stibetherm S.A., as well as ICS collectors manufactured by Solarpower GmbH consist of bent polymer glazing. Figure 6 shows the glazing with a curved structure.

Fig. 6. Flat collector from Solarpower GmbH (Meir, 2008)
with dome-shaped glazing

Polycarbonate cellular sheets, a huge selection of which is available on the market, are also used as polymer glazing of solar collectors. Most of these plates are found in carports or on the roofs of terraces. Transparent plates are extruded from polycarbonate, which combines both light weight and high stability, and therefore have excellent potential for lightweight structures.

For example, Solar Twin, a solar collector equipped with a double-walled polycarbonate sheet 10 mm thick (Fig. 7). Polymeric solar collector from the Solar Twin company can be integrated into an existing heating system.

The protective coating is an extruded double-walled polycarbonate profile, flexible absorption pipes are made of silicone rubber. This absorber is resistant to temperatures in the range from -60 °C to 200 °C. Expansion of the liquid volume when freezing inside the absorber can't break the elastic tubes. Therefore, thanks to the flexible absorber, the system is also frost-resistant.

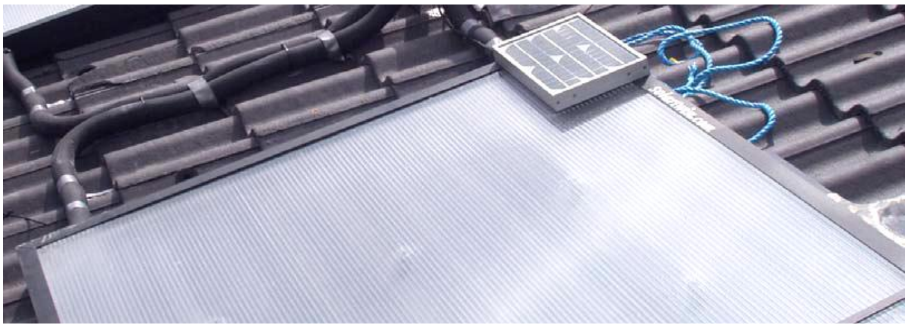

Fig. 7. Solar collector with polycarbonate double-walled sheet

Solar collectors which are made entirely of polymeric materials, with high performance, are the most technologically complex and the most interesting because of the potential market size. Components made of polymeric materials have already been implemented for use in solar thermal collectors, where the unique advantages of polymers exceed the properties of conventional materials and their cost.

The extrusion process can provide significant benefits for the production of heat absorber. The design of flow channels can be improved in order to achieve high efficiency, despite the low conductivity of polymeric materials. This process also allows you to produce absorbers of any length that can be adjusted to the required size to integrate them into the structure of buildings.

Most of the previous examples of the use of polymers were limited to individual parts of the collectors. Currently, there are researches on how to apply polymeric materials not only for individual parts, but also in integrated polymer collectors. The Norwegian manufacturer Aventasolar AS proposed the design of a solar collector almost entirely made of polymers (Fig. 8).

Fig. 8. Sectional view of a polymer solar collector (Aventasolar n.d.)

The transparent protection of the collector is an extruded double-walled polycarbonate sheet with an additional protective layer against ultraviolet light. The absorber consists of an extruded sheet with double walls with fixed end caps made of high quality polyphenylene sulfide.

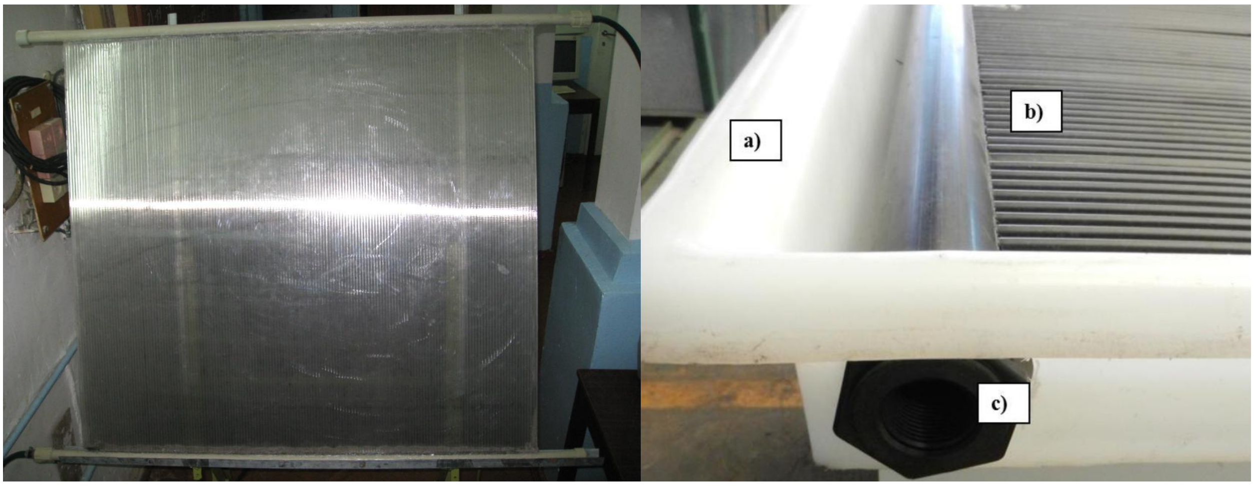

Fig. 9. The design of the solar collector:
a – pipelines for supply and removal of heat transfer fluid;
b – polycarbonate absorber; c – pipeline connectors.

One of the options for the construction of solar collectors, which would reduce the cost of their manufacture, installation and maintenance, increase the service life is a solar collector made of three-layer honeycomb polycarbonate plate, the upper layer of which acts as a transparent protective coating, the middle layer is an absorber of solar energy, through which the coolant circulates, the lower layer serves as thermal insulation (Zhelykh, 2011). To ensure even circulation of the coolant in the individual cells of the polycarbonate plate, the solar energy absorber is connected to the pipes for supply and discharge of coolant. The solar absorber is made of polycarbonate by extrusion.

Conclusions

The potential of polymeric materials for use in solar thermal collectors mainly consists of two aspects: the production process and the technical properties of materials.

The processes of production of polymeric materials are significantly different from most known production processes in the solar thermal industry, where mainly metals are used. These production processes allow to apply an innovative approach to the design of products and components, which can lead to significant benefits.

Components with a complex shape can be easily manufactured based on injection molding processes. This can be a major advantage for the production of most of the required components (and a significant reduction in fittings and components as well as weight minimization.

References

Weiß R. (2014). Life cycle analysis of extruded polymeric solar thermal collectors, Gleisdorf SOLAR 2014, Gleisdorf, Austria. https://task39.iea-shc.org/data/sites/1/publications/Task39-A3--Life-Cycle-Analysis--Weiss.pdf

Peca, J., & Aguilar, R. (2014). Polymer solar collectors, a better alternative to heat water in mexican homes. Solar World Congress. DOI: 10.1016/j.egypro.2014.10.187

Köhl M. (2015) Polymeric Materials for Solar Thermal Applications. IEA, For the 58th ExCo-meeting in Sydney, Australia. https://task39.iea-shc.org/Data/Sites/1/publications/IEA-SHC-Polymeric-Materials-Position-Paper.pdf

Duffie, J. A., & Beckman, W. A. (1974). Solar Energy Thermal Processes. Wiley, New York. https://books.google.com.ua/books/about/Solar_Energy_Thermal_Processes.html?id=iKoGAAAAMAAJ&redir_esc=y.

Reiter C. N. (2014) Polymeric Solar-Thermal Flat-Plate Collectors. PhD thesis, Institute of Energy and Sustainable Development De Montfort University Leicester. https://core.ac.uk/download/pdf/228200038.pdf

Zhelykh, V., Piznak, B., Lesik, C. (2012). The analysis of exergy efficiency evaluation of low-temperature solar collectors. MOTROL, Lublin – Rzeszów. https://agro.icm.edu.pl/agro/element/bwmeta1.element.agro-87b13cf2-67f5-4d12-9b01-8ac3da0c4ec1

Venhryn, I., Shapoval, S., Furdas, Y., Piznak, B., Kasynets, M. (2020). Thermal efficiency analysis of solar heat supply unit combined with glass facade of building. Energy Engineering and Control Systems, 2020, Vol. 6, No. 1, pp. 1 – 6. DOI:10.23939/jeecs2020.01.001

Zhelykh, V., & Piznak, B. (2011). Polymeric solar energy collectors in heat supply systems. XIIIth International scientific conference current issues of civil and environmental engineering in košice, Lviv – Rzeszów. http://ena.lp.edu.ua:8080/bitstream/ntb/19390/1/58-Piznak-160-161.pdf

Aventasolar (n.d.) A new generation of energy technology Aventa AS. http://www.aventa.no/index.php?/eng.

Duffie, J. A., & Beckman, W. A. (2013). Solar engineering of thermal processes. Fourth Edition. New Jersey: John Wiley & Sons. https://www.sku.ac.ir/Datafiles/BookLibrary/45/John%20A.%20Duffie,%20William%20A.%20Beckman(auth.)-solar%20Engineering%20of%20Thermal%20Processes,%20Fourth%20Edition%20 (2013).pdf

Heliocol (n.d.) Residential Pools. http://www.heliocol.com/residential/ easy1.html.

Reiter, C., Hanby, V., Trinkl, C., Zörner, W. (2010). Thermal Load Analysis of a Solar-Thermal Flat-Plate Collector in a Domestic Heating System. In: EUROSUN 2010 International Conference on Solar Heating, Cooling and Buildings – Book of Abstracts, Graz (AT), September 2010. Graz: AEE INTEC, pp. 113. DOI: 10.18086/eurosun.2010.09.22/

В. Й. Лабай, Б. І. Пізнак, Б. І. Гулай, І. Є. Сухолова
Національний університет Львівська політехніка,
кафедра теплогазопостачання та вентиляції

ПЕРСПЕКТИВИ ВИКОРИСТАННЯ ПОЛІМЕРНИХ МАТЕРІАЛІВ В КОНСТРУКЦІЇ СОНЯЧНИХ КОЛЕКТОРІВ

Хоча сонячна енергія, яка потрапляє на Землю, є безкоштовною, установки для перетворення енергії сонячного випромінювання на тепло, а також для транспортування та зберігання цього тепла потребують певних інвестицій. Значну частину компонентів цих системи становлять метали. Трубопроводи в сонячних колекторах і теплообмінниках виготовлені з міді, алюміній використовується для поглинача та корпусу, а сталь часто використовується у ємностях для зберігання теплоти. Одним із варіантів зменшення вартості сонячних колекторів та підвищення їх ефективності є використання полімерних матеріалів замість металів. Сонячні колектори виготовлені повністю з полімерних матеріалів, які б мали високу продуктивність, найскладніші у виготовленні з технологічного погляду і найцікавіші для виробництва через потенційний обсяг ринку. Основними перевагами використання полімерних матеріалів у сонячних теплових колекторах є їхня вартість, особливо з урахуванням зростанням ринку відновлювальної енергетики та зростання цін на метали. З використанням полімерів знижуються також витрати на виробництво, транспортування та монтаж для кінцевого споживача. Різноманітні технології виробництва, такі як екструзія, термоформування, вакуум-формування та лиття під тиском можна застосовувати для виготовлення сонячних колекторів. Процеси виробництва полімерних матеріалів істотно відрізняються від більшості відомих виробничих процесів у сонячній тепловій промисловості, де переважно використовують метали. Ці виробничі процеси дають можливість застосовувати інноваційний підхід до проектування продукції та компонентів. Полімерні матеріали дають свободу для виробництва колекторів з великими геометричними розмірами, гнучкість у інтеграції таких конструкцій у зовнішні захищення будівель з більшою естетичністю. Порівняно з іншими матеріалами, полімерні матеріали характеризуються своєю багатофункціональністю, надзвичайно гнучкою здатністю до опрацювання складних компонентів та малою вагою.

Ключові слова: сонячні теплові колектори, полімерні матеріали, відновлювальні джерела енергії, сонячна радіація, теплова ефективність, абсорбер.