AIR HEATED SOLAR COLLECTORS AND THEIR APPLICABILITY

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Abstract
This paper describes the results of the investigation, the aim of which was to find new air heating solar collector constructions and easily accessible materials which may be used as absorbers. We tested the inflatable air heating solar collector construction. An inflatable solar collector gives good correlation with the air heating degree and radiation (r=0.93). This type of collectors is very sensitive to radiation changes, a response time is only about 1 minute. The given type of air heating solar collectors has a good efficiency, the efficiency coefficient is η =0.63. Absorber materials (seed boxes made of polypropylene, black colored energy drink cans situated on a steel-tinplate) are tested for room heating. Stationary air heating solar collectors for room heating are used when sun radiation exceeds 300 W/m^2, otherwise it is not effective or ambient air temperature is cooling room air. These collectors should be well insulated, especially if they are to be used in early spring, when ambient temperatures are low. These researches show the applicability of air heated collectors in drying agricultural production and in room heating at Latvia weather conditions.
Key words: solar collector, air, temperature, absorber.

Introduction

The Sun as an alternative energy source more and more widely is used in the national economy. The greatest advantage of solar energy as compared with other forms of energy is that it is clean and can be supplied without environmental pollution. So if more people used solar energy to heat the air and water in their homes, our environment would be cleaner. Over the past century, fossil fuels provided most of our energy, because they were much cheaper and more convenient than energy from alternative energy sources. The limited reserves of fossil fuels cause situation in which the price of fuels will increase as the reserves are decreased.

The Sun is the most powerful heat generator, which neither of the heat sources created by mankind can compete with. Yearly the earth is reached by the solar energy 15000 times more than the power industry of the whole world can produce. It means that only a tiny part of solar energy is being used for the sake of mankind.

We can use solar energy to heat and cool buildings (both actively and passively), drying production, heat water for domestic and industry use, heat swimming pools, generate electricity, for chemistry applications and many more operations.

The application of solar energy is completely dependent on solar radiation. An intrinsic difficulty in using solar energy is given by the wide variation in the solar radiation intensity. The availability of solar radiation depends not only on the location, but also on the season. Extreme differences are experienced between summer and winter, and from day to day.

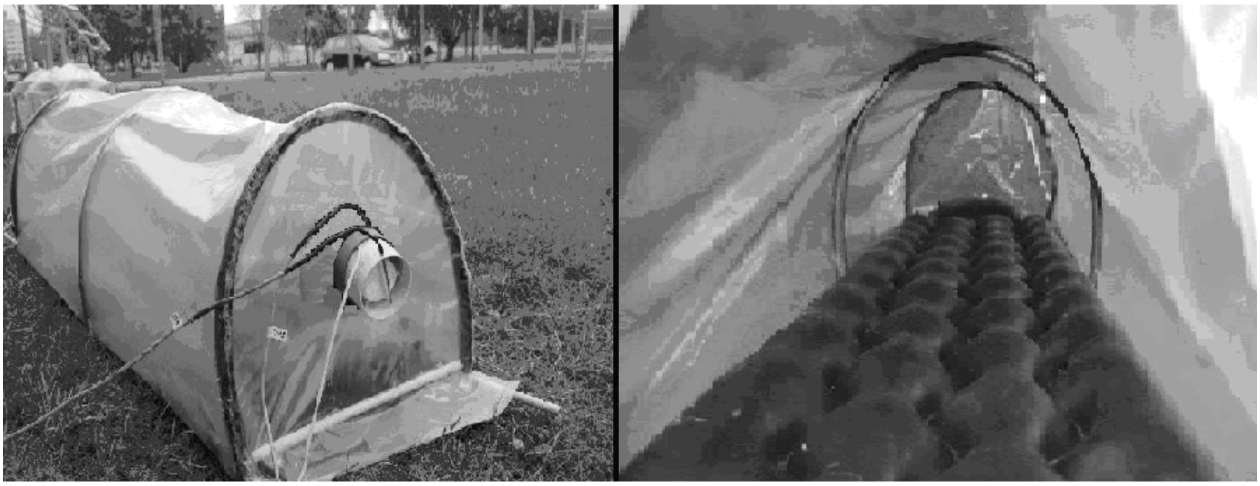
In general, solar air heaters are flat-plate collectors (FPCs), consisting of an absorber, a transparent cover, and backward insulation. The performance of solar air heaters is mainly influenced by meteorological parameters (direct and diffuse radiation, ambient temperature and wind speed), design parameters (type of collector, collector materials) and flow parameters (air flow rate, mode of flow). The principal requirements of these designs are a large contact area between the absorbing surface and air 'Kalogirou, S (2009)'.

The efficiency of air heating solar collector depending on collector covered materials (polyvinylchloride film, cell polycarbonate PC, translucent roofing slate), absorber (black colored wood, steel-thin plate etc.) and insulation of collector body with different air velocities in a collector was investigated '(A.Aboltins[a] et al., 2011; G. Ruskis et al., 2011; A. Aboltins[a], et al., 2011; A. Aboltiņs[b], et al., 2011; A. Aboltins, et al., 2009)'.

The air heating collectors can be used in two main directions for production drying and room heating (ventilation). Production issues through drying in the sun-warmed air are discussed a lot in works '(H.Y. Andoh et al., 2011; A. Aboltins[b], et al., 2011)'. We are exploring a variety of coating and absorbent materials to increase the air warm-up stage.

In case if you are using FPCs for room air heating, then they are mostly stationary, their efficiency is not only dependent on sun radiation, but also on a sun rays angle against collector surface. The sun rays fall under an angle to the collector plane (it means they fall under an angle to covered material) and they give more reflection.

We want to describe and to study some usages of created inflatable solar air heating collector in production drying and room heating using stationary air-heating solar collectors of different material absorbents.



Source: author's photo.

Figure 1. **Inflatable air heating solar collector (overview, inside).**

Source: author's photo.

Figure 2. ***View of the solar collector with cylinders of black coloured energy drink cans situated on the steel-tinplate absorber***

Source: author's photo.

Figure 3. **View of the solar collector with black polypropylene seed boxes absorber**

Materials and Methods

An aim of the experiment was to make an inflatable solar collector. The inflatable solar collector had simple constructions, easily usable and transportable. This type of collector is based on the inflated carcass with a good insulator of absorbent. As a coating material, polyethylene film has been used. For experiments, we used an inflatable air heating solar collector with dimensions: length 1.5 m, width 0.7 m and height 0.6 m (Fig.1). We used a fan with power 100 m^3/h for air ventilation in the collector.

Another part of our investigations devoted to the flat-plate collectors situated at wall in southward direction. The aim of our investigations was to compare different absorber materials and to make out their usability in air heating solar collectors for room heating and ventilation.

The *0.1x0.5x1.0* meters long experimental solar collector was constructed for research. As an absorber, there was used: a steel tinplate with cylinders of black coloured energy drink cans (Fig.2) and black seed boxes which were made of polypropylene (Fig.3). Air velocity in the experiments in the collector was v=0.9 m/s. In the collector, we used a fan with power 100 m^3/h and room space was approximately 80 m^3.

In the experiments, the collector cover material was polystyrol plate. This material has gained immense popularity due to such properties as safety, mechanical crashworthiness, translucence and high UV radiation stability. The cover material – a polystyrol plate reduced sun radiation by 12-15 %. The pyranometer was a solar radiation measuring instrument, which is used to measure total radiation.

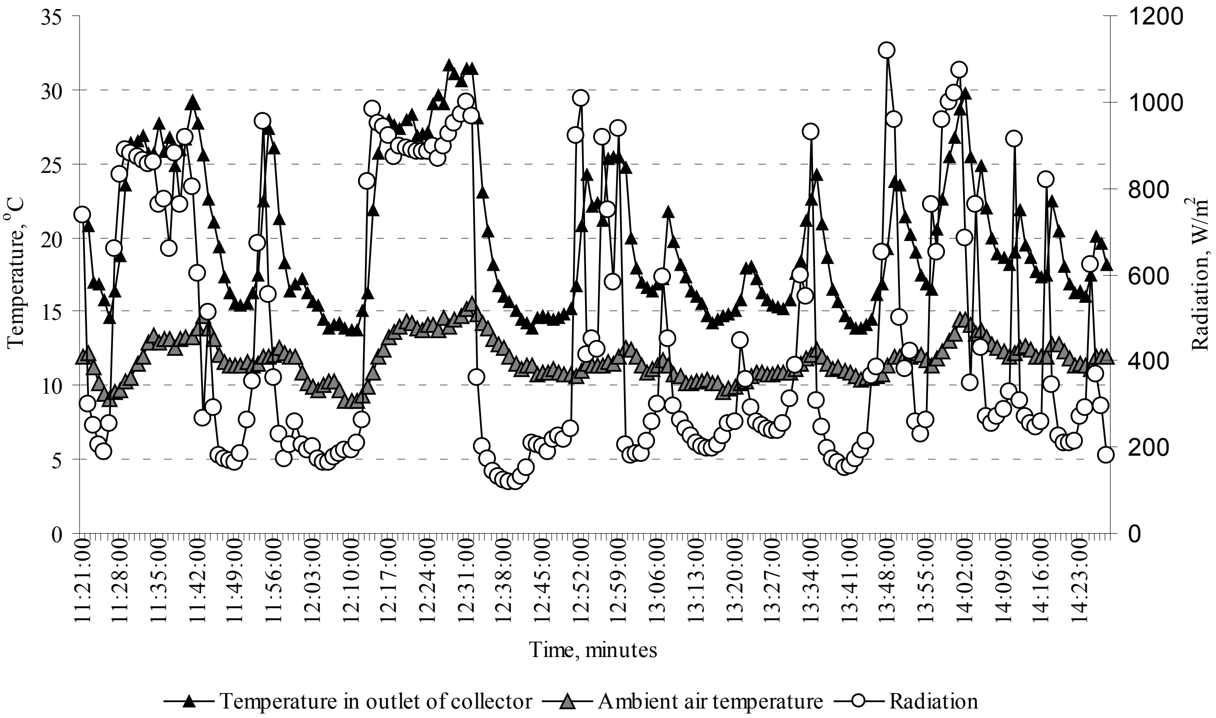


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Figure 4. **Inflatable solar collector's heated and ambient air temperatures comparing with sun irradiance in time**

Our task was to investigate a possibility to use the air heating solar collector for room heating. For this task, we used the collector built-in window. Through this collector window we ventilated room air. We measured room air, ambient air, and ventilated air temperature in the inlet and outlet of collector.

Experimental data are recorded by means of an electronic metering and recording equipment for temperature, radiation and lighting REG 'REG (2004)'. The pyranometer was the solar radiation measuring instrument.

The aim of our experiment was to compare and analyze the use of air heating solar collectors of different types for Latvian climatic conditions.

Experiments were made in the year 2011 from spring to autumn in different weather conditions at different ambient air temperatures and wind speed.

Results and Discussion

The data on the inflatable solar collector are shown in Figure 4. The experiment took place on 6 May 2011. Results show a very strong correlation between the solar radiation and the air warm-up stage. It should be noted that the air warm up in the collector quickly react to changes in radiation (clouds, shadows). Response delay time for the inflatable collector is approximately 1 minute, compared with the classical one it accounted for 5-7 minutes '(A.Aboltins[a] et al., 2011; G. Ruskis et al., 2011)'.

Using the obtained data and taking into account the warm-up delay time (1 minute), the relationship is obtained, which is characterized by the atmospheric air warm-up degree in the inflatable air heating solar collector, depending on solar radiation (Fig.5).

It should be noted the correlation coefficient (r = 0.93) is high under such rapidly changing sun radiation conditions.

We determined the efficiency of the solar collector, as prescribed in ASHRAE Standard 93 2003. The efficiency of the solar collector can be calculated by the following equation 'Clearinghouse (1994)':

$$\eta = \frac{m \cdot c_p \cdot (T_{fo} - T_{fi})}{S \cdot R_T} \tag{1}$$

where

η - efficiency coefficient of solar radiation converted into heat;

m - mass flow rate of air, kg·s¹;

c_p - specific heat, J·kg°C¹;

S - area of solar collector, m²;

R_T - global solar irradiance incident upon the aperture plane of collector, W·m²;

T_{fo}, T_{fi} - outlet and inlet working air temperatures, °C.

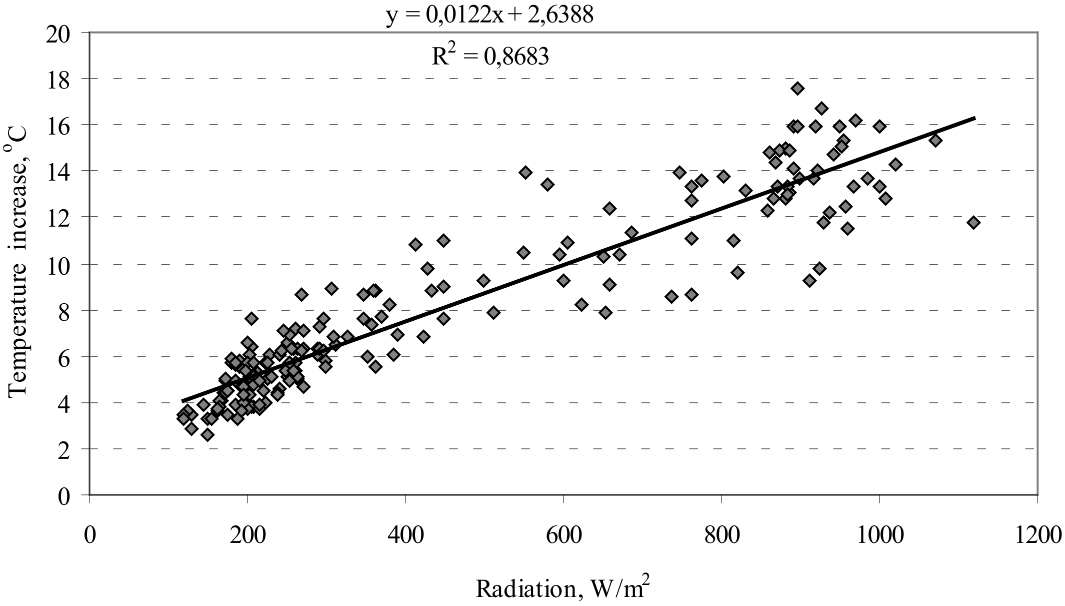

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Figure 5. **Temperature increase in the outlet of the inflatable air heating solar collector comparing with sun radiation.**

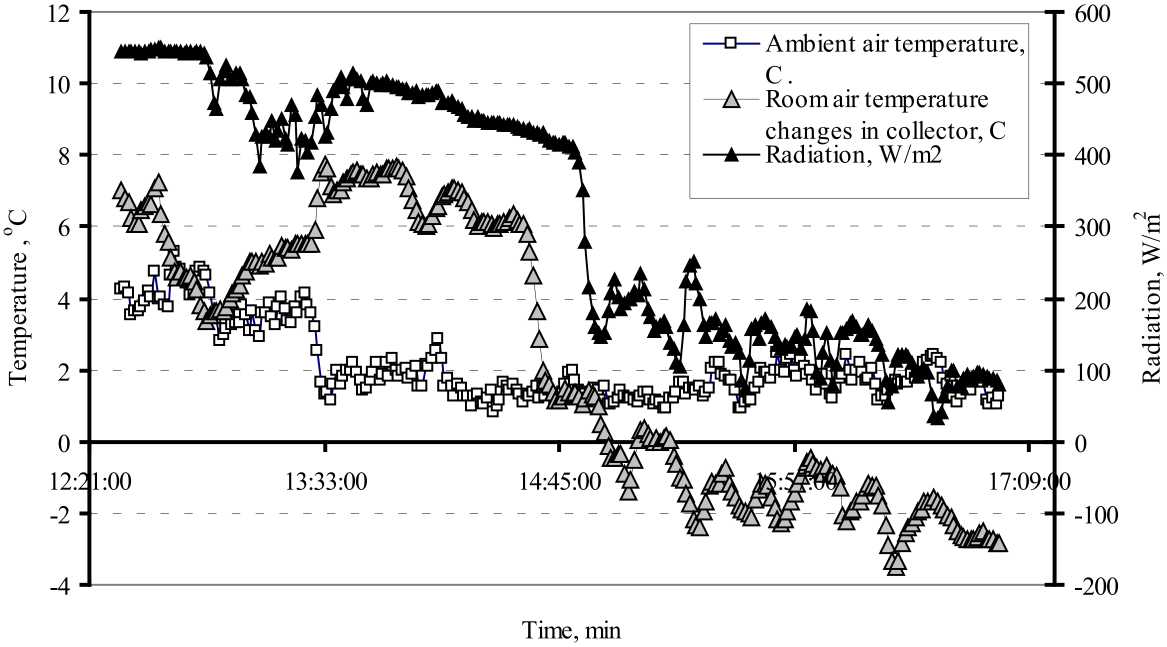

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Figure 6. **Room air temperature changes in the outlet of the collector (cylinders of black colored cans) and ambient air temperatures comparing with sun radiation in time**

With equation (1) were defined the effectiveness coefficient over the all experimental time using average working air temperatures and radiation. In our case, the inflatable air heating solar collector's efficiency coefficient η =0.63

An issue is how to use the air heating solar collectors for room heating at Latvian climatic conditions. Experiments were performed with two types of absorbent materials (cylinders of black colored energy drink cans and with black polypropylene seed boxes).

As can be seen from the experimental 1 March 2011, solar radiation significantly affected the passing room air temperature warm-up stage (Fig 6). Experimental data show that due to little sun radiation constitutive air heating is not visible,

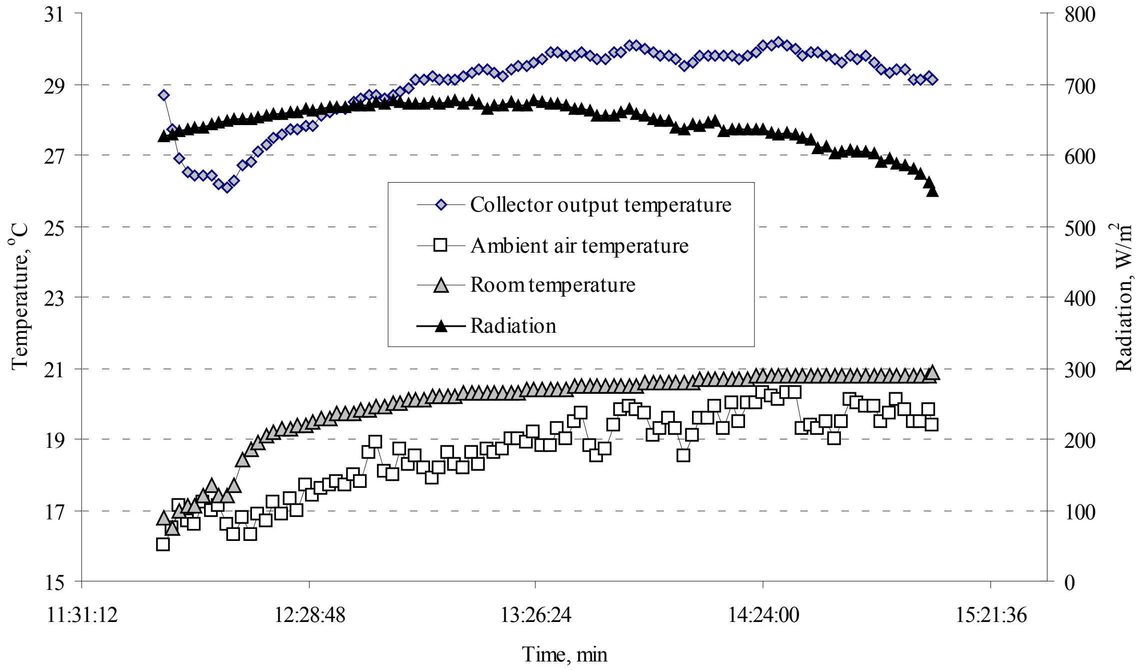

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Figure 7. **Room air, ambient air and collector outlet air temperatures (absorber material - black polypropylene seed boxes) comparing with sun radiation in time.**

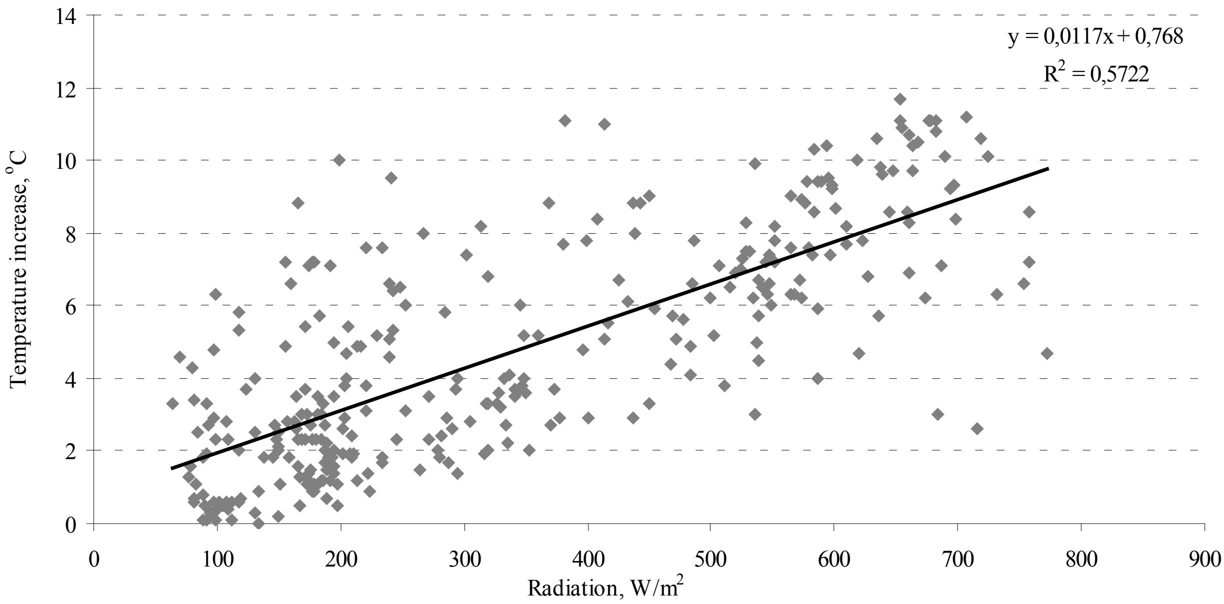

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Figure 8. **Temperature increase in the outlet of the collector (absorber steel-tinplate with cylinders of black colored cans) comparing with sun radiation.**

but increasing sun radiation is raising the air heating level (Fig. 6).

When radiation is smaller than 300 W/m^2, the collector is not heating room air, because the absorbent cannot compensate heat loses influenced by atmospheric temperature. The air heating level is not highly dependent on ambient temperature, much more it is influenced by solar radiation and a horizontal irradiance angle of sunlight to the collector's surface.

We can see that the solar radiation changes significantly affect the passing air temperature. This effect does not happen instantly, but with a delay of 4-7 minutes. It should be noted that the un-insulated collector efficiency is highly influenced by wind speed, which cools the surface of the collector body.

Experimental data, which took place on 14 April 2011, with the black polypropylene seed boxes absorber are shown in Fig. 7. The room air passing through the collector heats up to 10 degrees up if the radiation greater than $600\ W/m^2$.

We are interested in room air temperature increasing in the outlet of the collector. We would like to know how sun radiation influences the air heating level for a stationary collector. Experimental data from 14 September 2010 show sun radiation and air temperature increase dependence in Fig. 8 (collector with an absorber steel tinplate with cylinders of black colored cans). Large data dispersion shows that the horizontal irradiance angle of sunlight to the collector's surface influences temperature increase which we ignored. The Sun's rays angle influence on the collector's effectiveness is shown at '(A.Aboltins[c] et al., 2011)'.

Conclusions

The inflatable solar collector is giving good results, an average ambient air temperature increase in experiments is 10.2C° and the max increase is up to 16 C°. This collector gives good correlation with the air heating degree and radiation (r=0.93). This type of collectors are very sensitive to radiation changes, response time is only about 1 minute. The given type of air heating solar collectors has a good efficiency, the efficiency coefficient is η =0.63.

The inflatable solar air heating collector is easy to make, operate and to derange its construction. It works well in Latvian climatic conditions.

Stationary air heating solar collectors for room heating are used when sun radiation exceeds 300 W/m^2 , otherwise it is not effective or ambient air temperature is cooling room air. It should be noted that the collectors should be well insulated, especially if they are to be used in early spring, when ambient temperatures are low.

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