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PROVIDING HEAT ENERGY TO GREENHOUSES USING SOLAR AIR HEATER COLLECTORS

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Abstract

In this article, the issue of providing heat energy to greenhouses using solar air-heater collectors in the climatic conditions of Uzbekistan was considered. For a greenhouse with a total area of 400 m², a total of 20 rhombus-shaped solar air heater collectors accelerating heat processes, each with a working surface of 1 m², are installed. Economic analysis of heat energy obtained from solar air heater collectors.

Keywords: Solar air heater collector, greenhouse, energy efficiency, sunlight flow, energy saving.

Introduction

As a result of technological progress, the standard of living of people rises, the types of equipment and technologies increase. Taking into account the fact that all created equipment and technologies work at the expense of energy consumption, the need for energy is increasing day by day, and as a result of the reduction of primary energy reserves and the use of non-renewable energy sources, this causes production to emit a large amount of substances harmful to nature. In addition, as a result of a sharp rise in the cost of fuel, which is the basis of energy, the price of manufactured and grown products rises. The solution of such problems based on the use of devices operating on the basis of environmentally friendly and renewable energy sources has become one of the main tasks of scientific research in these areas. The use of a solar air heating collector in solving existing problems can reduce the problem. Receiving thermal energy is possible with the help of solar air-heating collector devices for greenhouses, buildings and structures, drying products, providing thermal energy in various industries [1-16].

Method

The greenhouse with solar air heating collector devices is located in the territory of Fergana region, Altiariq district, the cultivated area is 400 m². The total volume of the greenhouse is 1120 m³. In order to calculate the heat energy required for the

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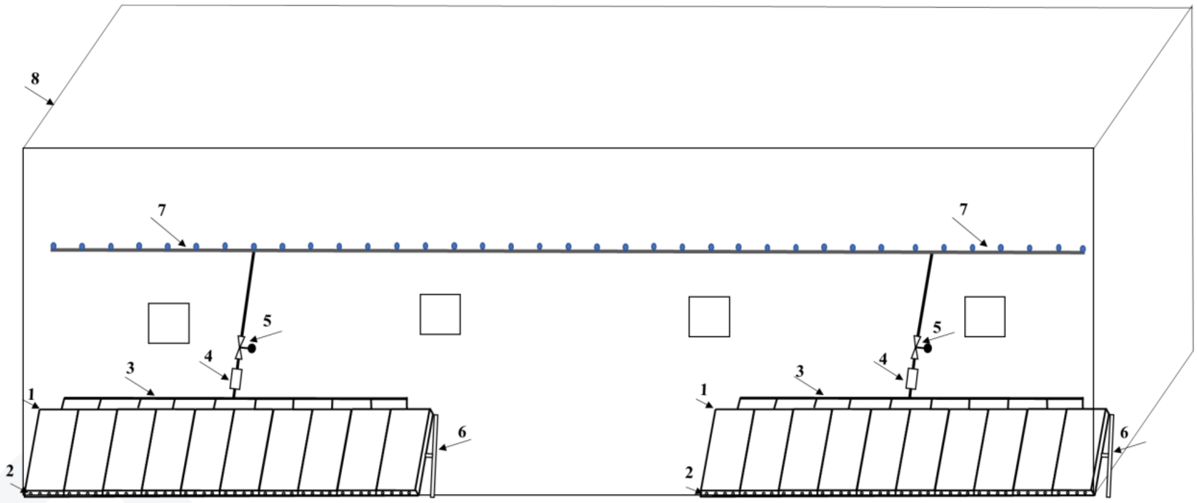
greenhouse, the heat balance of the greenhouse was drawn up. External wall dimensions of the greenhouse: entrance door 1.9 m^2, surface of air exchange windows 3.8 m^2, total external wall surface 144 m^2, external wall surface with selafan coating 550 m^2. Issykkhana is located in Altiariq district and the coordinates of the place where the device is installed are: Latitude - N = 40.35159°, Longitude - E = 71.49809°. Azimuth angle at 7^{34} hours of sunrise is 118.08 degrees.



1. solar air heating collectors with a working surface of 1 m2 (total surface 20 m2), 2- air intake pipes, 3- common outlet air pipe, 4- air suction pump, 5- air consumption changer, 6- base for installing solar air heater collectors, 7- air distribution tubes, 8- products grown greenhouse.

Figure 1. Schematic view of the application of solar air heating collectors to a greenhouse.

When drawing up the heat balance of the external walls, the temperature of the external and internal air and the thermal conductivity of the external walls, the thermal conductivity of the salafan forming an air gap to the inner part of the walls and the air gap were taken into account.

An air gap of 100 mm was created for the side walls, and 300 mm for the roof.

Calculation work was carried out on 17.01.2023 at $13{:}^{00}$ hours.

Solar radiation for this time was 400 W, outdoor air temperature was -1 °C, indoor air temperature was 19 °C.

Heat transfer coefficients of the materials used in the wall construction are required to calculate the heat losses in the external walls.

Heat losses were calculated by the following formula:

$$Q = S\frac{1}{R_0}(T_1 - T_2) \quad 1)$$

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here: Q – heat loss through the outer wall, W; S - the external wall surface to be calculated, m²; R_0 – coefficient of resistance to heat transfer, $m^2\,°C/W$; T_1 – the temperature of the interior of the greenhouse, °C; T_2 is the temperature of the outer part of the greenhouse, °C.

The coefficient of resistance to heat transfer is determined as follows:

$$R_o = \frac{\delta}{\lambda} \qquad 2)$$

here: δ – layer thickness, m; λ - is the thermal conductivity coefficient of the material, W/(m·°C).

The thermal conductivity of the materials used in the outer wall of the greenhouse is equal to the following.

$\lambda_1 = 1,51$ W/(m·°C) - thermal conductivity of concrete;
$\lambda_2 = 0,0259$ W/(m·°C) - thermal conductivity of air;
$\lambda_3 = 0,8$ W/(m·°C) - thermal conductivity of salafan;
$\lambda_4 = 0,18$ W/(m·°C) - thermal conductivity of the plastic door;
$\lambda_5 = 0,84$ W/(m·°C) - thermal conductivity of transparent glass;
$\lambda_6 = 0,8$ W/(m·°C) - thermal conductivity of clay putty.

The thickness of the materials used in the outer wall of the greenhouse is as follows.

$\delta_1 = 0,2$ m, concrete wall thickness;
$\delta_2 = 0,1$ m, air gap;
$\delta_3 = 0,9$ Mkm, selafan thickness;
$\delta_4 = 0,5$ m, plastic door thickness;
$\delta_5 = 0,003$ m, glass thickness;
$\delta_6 = 0,02$ m, clay putty thickness.

The coefficient of resistance to heat transfer of the materials used in the outer walls was determined as follows.

$R_1 = \frac{\delta}{\lambda} = \frac{0,2}{1,51} = 0,132$ m² °C/W;

$R_2 = \frac{\delta}{\lambda} = \frac{0,1}{0,0259} = 3,861$ m² °C/W;

$R_3 = \frac{\delta}{\lambda} = \frac{0,9\cdot 10^{-6}}{0,8} = 1,125 \cdot 10^{-6}$ m² °C/W;

$R_4 = \frac{\delta}{\lambda} = \frac{0,05}{0,18} = 0,277$ m² °C/W;

$R_5 = \frac{\delta}{\lambda} = \frac{0,003}{0,84} = 0,004$ m² °C/W;

$R_6 = \frac{\delta}{\lambda} = \frac{0,02}{0,8} = 0,025$ m² °C/W.

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Discussion of Results

The coefficient of resistance to general heat transfer of external walls was determined as follows.

For an exterior wall with slats:

$$R_{s.com} = R_2 + 2R_3 = 3861000 + 2{,}25 = 3861002{,}25 \cdot 10^{-6}\ \text{m}^2\ {}^{o}\text{C/W}$$

For concrete exterior wall:

$$R_{c.com} = R_6 + R_1 = 0{,}025 + 0{,}132 = 0{,}157\ \text{m}^2\ {}^{o}\text{C/W}$$

For air exchange windows:

$$R_{a.com} = R_2 + R_5 = 3{,}861 + 0{,}004 = 3{,}865\ \text{m}^2\ {}^{o}\text{C/W}$$

The amount of heat lost from the outer wall was determined as follows.

The amount of heat lost from the concrete wall:

$$Q_c = S\frac{1}{R_{c.com}}(T_1 - T_2) = 144\frac{1}{0{,}157}(19 - (-1)) = 18343\ \text{W}$$

The amount of heat lost from the insulated outer wall:

$$Q_s = S\frac{1}{R_{s.com}}(T_1 - T_2) = 550\frac{1}{3{,}861}(19 - (-1)) = 2849\ \text{W}$$

The amount of heat lost through the plastic door:

$$Q_p = S\frac{1}{R_4}(T_1 - T_2) = 1{,}9\frac{1}{0{,}277}(19 - (-1)) = 137\ \text{W}$$

Amount of heat lost in air exchange windows:

$$Q_a = S\frac{1}{R_{a.com}}(T_1 - T_2) = 3{,}8\frac{1}{3{,}865}(19 - (-1)) = 19{,}66\ \text{W}$$

The total amount of heat lost in the greenhouse:

$$\sum Q = Q_b + Q_s + Q_p + Q_h = 18343 + 2849 + 137 + 19{,}66 = 21349\ \text{W}$$

As a result of the structure of the heat energy balance of the greenhouse, the power lost by the greenhouse in one hour (for $13{:}^{00}$ hours on 17.01.2023) is 21,349 kW (in the calculation process, air humidity and external wind speed were not taken into account). This value is constantly changing due to changes in external factors. In addition, the amount of water formed between the greenhouses, the open parts of the greenhouse, and the heat energy lost through the soil were not taken into account. Table 1 shows the daily heat energy consumption of the greenhouse and the cost of electricity.

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Table 1. Daily heat energy consumption for a greenhouse

№	Hour	Internal temperature (°C)	Outside temperature (°C)	Total heat loss (W)	Electricity price (Soum)
1.	00:00	19	-12	33092,19	14891,5
2.	01:00	19	-12	33092,19	14891,5
3.	02:00	19	-11	32024,7	14411,1
4.	03:00	19	-11	32024,7	14411,1
5.	04:00	19	-11	32024,7	14411,1
6.	05:00	19	-10	30957,21	13930,7
7.	06:00	19	-9	29889,72	13450,4
8.	07:00	19	-8	28822,23	12970,0
9.	08:00	19	-7	27754,74	12489,6
10.	09:00	19	-6	26687,25	12009,3
11.	10:00	19	-4	24552,27	11048,5
12.	11:00	19	-3	23484,78	10568,2
13.	12:00	19	-2	22417,29	10087,8
14.	13:00	19	-1	21349,8	9607,4
15.	14:00	19	-2	22417,29	10087,8
16.	15:00	19	-3	23484,78	10568,2
17.	16:00	19	-4	24552,27	11048,5
18.	17:00	19	-5	25619,76	11528,9
19.	18:00	19	-5	25619,76	11528,9
20.	19:00	19	-6	26687,25	12009,3
21.	20:00	19	-6	26687,25	12009,3
22.	21:00	19	-7	27754,74	12489,6
23.	22:00	19	-7	27754,74	12489,6
24.	23:00	19	-8	28822,23	12970,0
Total					**295908,2**

The main problem is the constant non-availability of electricity, although the total value of the results obtained based on the results of the calculations presented in the above table does not constitute a large amount as the actual cost of electricity. In addition, during the calculation, heat losses were taken for a perfect greenhouse. In many cases, the values of heat loss are 2÷3 times higher in practice.

Figure 2. Shows the amount of total heat and consumption for lost electricity.

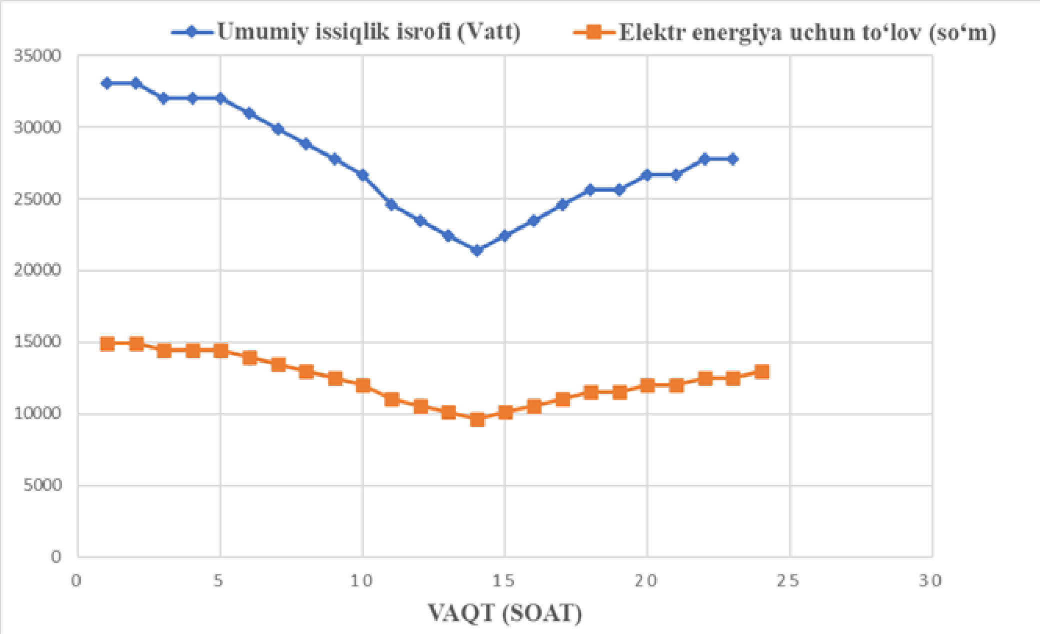

Figure 2. The cost of daily heat loss for electricity supply.

As we can see from the graph above, the accompanying heat energy is increasing depending on the temperature. In winter, the heating system of greenhouses with electricity is usually not used in our country. One of the main reasons for this is the increase in costs and interruptions in the supply of electricity.

We analyze the change in the cost of electricity using a solar air heater collector.

The calculation was made for 17.01.2023.

Table 2. Economic indicator of the use of a solar air heater collector

№	Hour	Outside temperature (°C)	Total heat loss (W)	The angle of the sun falling on the area degree	Azimuth angle degrees	The flow of sunlight is energy (W)	Electricity price (Soum)	Price of electricity in case of installation of SAH (Soum)
	08:00	-7	27754,74	3,65	121,21	120	12970	12721,6
	09:00	-6	26687,25	12,7	131,91	210	12489,6	11884,83
	10:00	-4	24552,27	20,32	144,16	280	12009,3	11001,26
	11:00	-3	23484,78	25,81	158,17	300	11048,5	9806,522
	12:00	-2	22417,29	28,64	173,62	350	10568,2	9008,901
	13:00	-1	21349,8	28,33	189,57	360	10087,8	8500,181
	14:00	-2	22417,29	24,96	204,8	270	9607,4	8513,91
	15:00	-3	23484,78	18,97	218,47	210	10087,8	9360,131
	16:00	-4	24552,27	11,01	230,4	150	10568,2	10156,4

The information given in Table 2 is relevant for the date 17.01.2023, and calculations were made for the case where the energy of the solar radiation is available.

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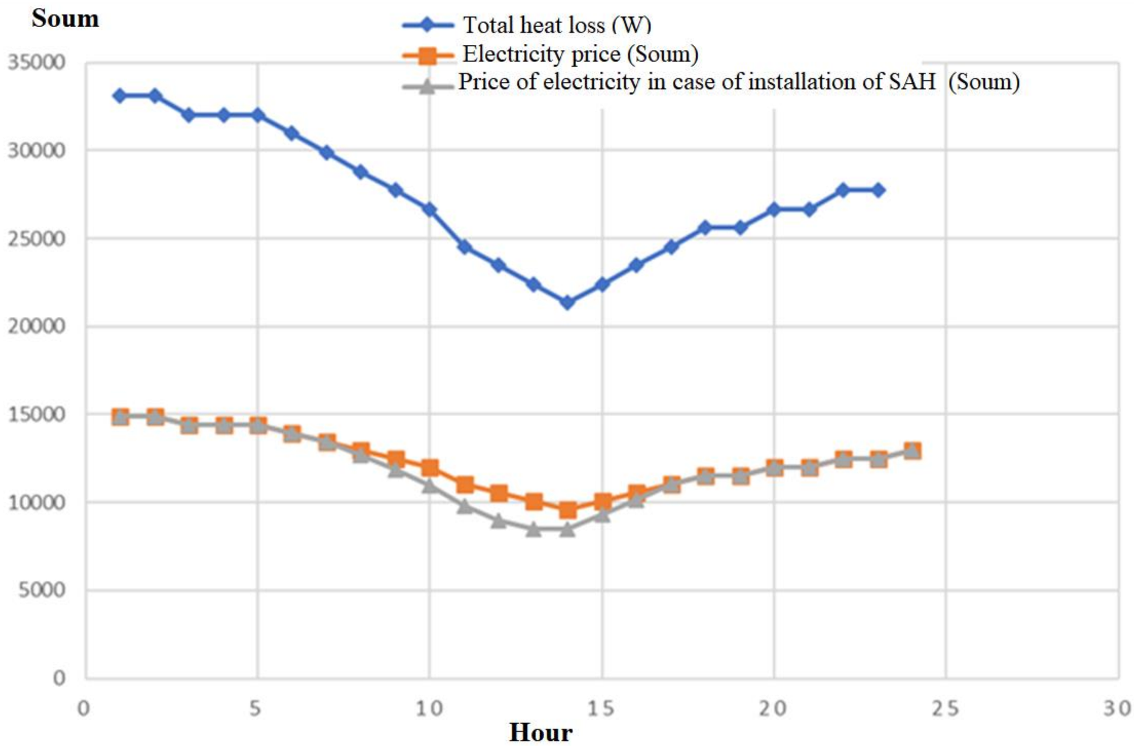

Figure 3. The cost of daily heat loss for the supply of electricity for the case where the solar air heater collector is installed.

In order to determine the daily amount of heat obtained from the solar air heater, we need to determine the installation angles of the solar air heater. We will determine the optimal location point for the device.

Solar energy reaches its maximum value between $12{:}^{00}$ and $13{:}^{00}$ hours. It is advisable to set the installation angle of the device in accordance with the Azimuth and the maximum angle of sunlight in this range.

Installation angles of the solar air heater collector:

We set the azimuth angle to 90°;

The installation angle of the solar air heater collector with respect to the ground was set at 61.1°.

We can determine the amount of heat received from the device, taking into account the angle of incidence of solar energy on the surface of the solar air heater collector.

If the flow of sunlight falls on the device at an angle other than 90°, the working surface of the device will be reduced in relation to the sun, and the amount of energy corresponding to 1 m2 of the surface of the sun will decrease. To take this into account, we calculate the change of the surface using the Pythagorean theorem.

$$a^2 + b^2 = c^2 \quad 3)$$

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The change of the surface of the device in relation to the flow of sunlight and the amount of heat energy received from the device

Table 3. The amount of heat energy received from the solar air heater collector

№	hour	The angle of the sun falling on the area (degree)	Azimuth angle degrees	General working surface of SAH (m²)	Total working surface of SAHs in relation to solar energy (m²)	The amount of heat energy produced (W)
1.	08:00	3,65	121,21	20	9,2	552
2.	09:00	12,7	131,91	20	12,8	1344
3.	10:00	20,32	144,16	20	16	2240
4.	11:00	25,81	158,17	20	18,4	2760
5.	12:00	28,64	173,62	20	19,8	3465
6.	13:00	28,33	189,57	20	19,6	3528
7.	14:00	24,96	204,8	20	18	2430
8.	15:00	18,97	218,47	20	15,4	1617
9.	16:00	11,01	230,4	20	12,2	915
Total						**18851**

We can conclude from the information presented in the above table that it is possible to save 18851 watts of energy for a cold winter day, which is the basis for saving a large amount of energy reserves as a result of using the solar air heater collector device in greenhouses.

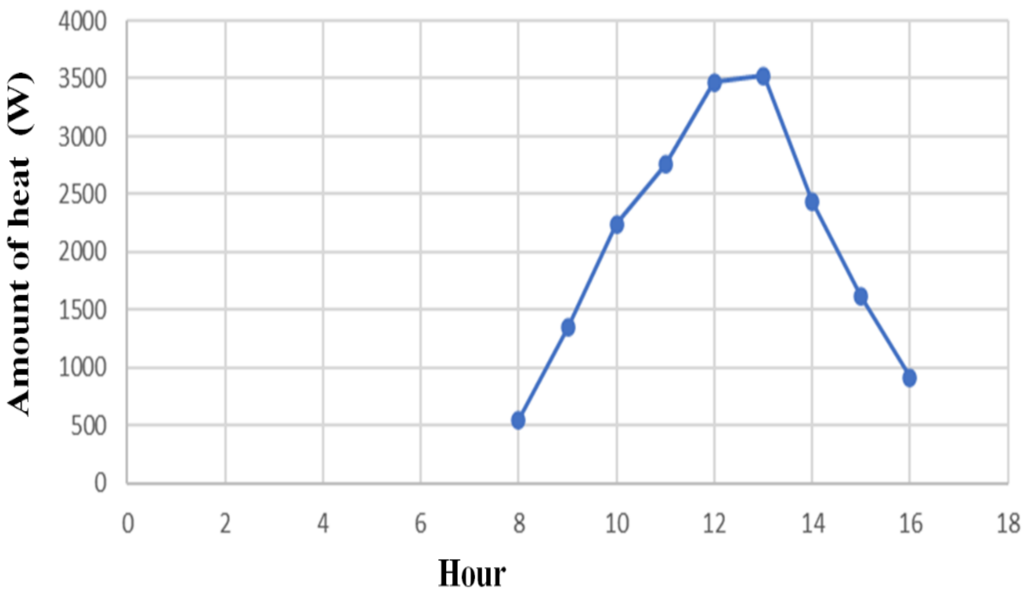

Figure 4. The amount of heat energy received from the solar air heater collector.

Conclusion

As we can see from the graph above, solar air heater collectors are one of the most effective devices for our country.

The use of solar air heater collectors for heating greenhouses is not only economical but also ecologically efficient. Because a large amount of coal or natural gas is used to provide heat energy to greenhouses, and as a result, along with economic costs, it causes a large amount of harmful substances to be released into the environment. Reduction of environmental damage caused by the use of the device is achieved.

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