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Comparative Study on Providing the Necessary Heating for a Renewable Air Treatment Plant

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Abstract: *This paper presents a comparative study of the different types of solar collectors regarding the provision of heating for an air treatment plant from renewable sources, namely, solar energy. An analysis of the area required for the use of photovoltaic panels and a calculation of the determination of thermal energy from the sun's rays when using solar collectors is provided. The study established that the production of own energy by capturing sunlight using these types of networks is advantageous in the long run. The possibility of faster amortization of the investment is obtained by putting to use the surplus energy to various consumers.*

Keywords: *Solar collectors, solar energy, photovoltaic panels*

1. Introduction

The sun is a sphere of very hot gaseous matter with a diameter of 1.39 x 109 m. It has an effective black body temperature of 5762 K [1]. In fact, the sun is a continuous fusion reactor in which hydrogen is converted to helium. The total energy production of the sun is 3.8 x 10^{20} MW which is equal to 63 MW / m^2 of the sun's surface. This energy radiates outward in all directions. Only a small fraction, 1.7 x 10^{14} kW, of the total radiation emitted is intercepted by the earth [1]. However, even with this small fraction it is estimated that 30 minutes of solar radiation falling to the earth is equal to the world's energy demand for a year.
Solar energy collectors are a special type of heat exchanger that converts the energy of solar radiation into the internal energy of the transport environment. The major component of any solar system is the solar collector. A large number of solar collectors are available on the market. A comprehensive list is presented in the paper [2].
The aim of this paper was to ensure the necessary heating of a space by adapting renewable energy sources. The following types of batteries were used to perform the heating process:
- Heating battery with electric resistance;
- Hot water heating battery.

Fig. 1. Heating battery with electric resistance [3]

Fig. 2. Hot water heating battery [4]

Photovoltaic panels aim to transform the sun's light energy into electricity. The main characteristic element of these panels are the photovoltaic cells. It can be used in connection with, or separately from, electricity storage batteries produced to power consumers.

To perform the calculation, a solar panel was chosen from the manufacturer WATTROM, with the WT 60-SM series [5].

Fig. 3. Photovoltaic panel [6]

The energy produced by the photovoltaic panels is used to provide the electricity needed for an air heater battery by means of an electrical resistor shown in Figure 1.
Compared to the photovoltaic panels (fig. 3), the flat solar collectors (fig. 4) through their constructive form capture the solar energy transforming it into thermal energy, used for heating the fluid that crosses the coil of the panel. Subsequently, the fluid is used to supply the heating battery (fig. 2).
To perform the calculation, a flat solar collector was chosen from the manufacturer SUNSYSTEM, with the PK SL / CL - 2.0 series [7].

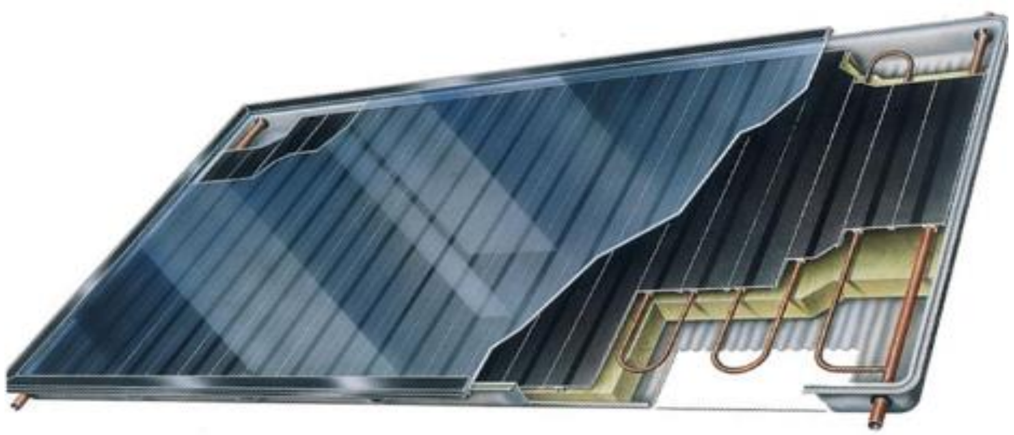

Fig. 4. Flat solar collector

The variability of electricity costs imposes uncertainties in the use of air conditioning systems in the future. For these reasons, the aim is to adapt to air conditioning the sources that produce the necessary electricity from renewable sources.
Today's air conditioning systems have become considerably more energy efficient, but these systems are usually the largest consumer of electricity in a residence, commercial or industrial space.
This paper was made for the climatic conditions on the territory of Bucharest. The aim was to find the collecting area required for a consumption of 4 kW.

2. Calculation of the area required for the use of photovoltaic panels

To perform the calculations of energy produced with the help of the sun, the Photovoltaic Geographical Information System program was used, in which the coordinates of the Municipality of Bucharest were introduced. These coordinates are shown in Table 1.

Table 1: The coordinates of the Municipality of Bucharest.

City	Latitude	Longitude
Bucharest	44.4267674	26.102538390000063

Figure 1 shows the workspace of the Photovoltaic Geographical Information System [8].

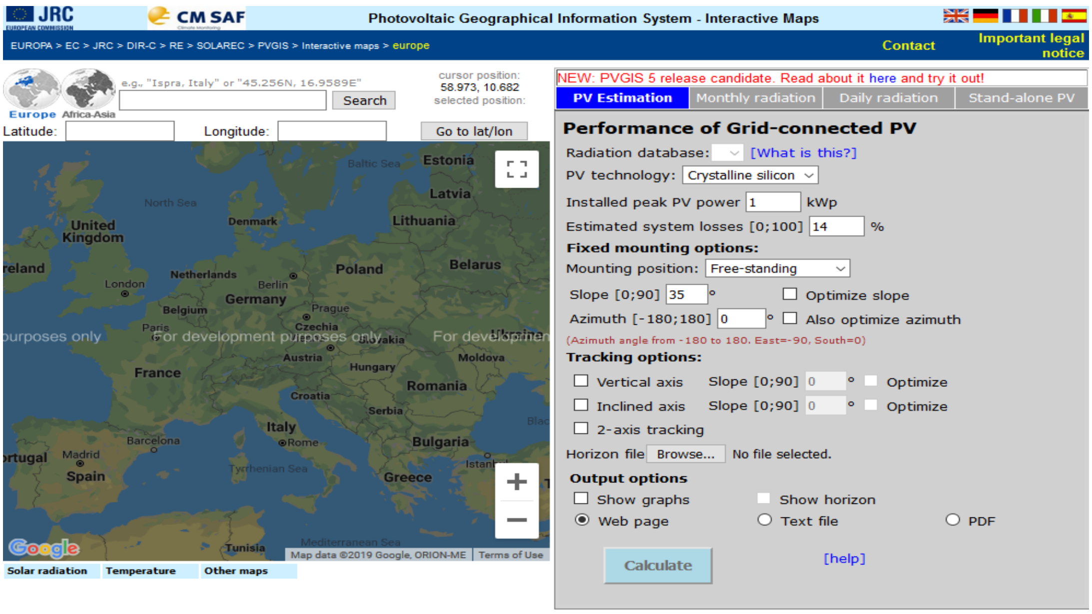

Fig. 5. Photovoltaic Geographical Information System

The results generated by the program shown in Figure 5 are presented in Table 2:

Table 2: Numerical simulation results.

	E_d [kWh]	E_m [kWh]	H_d[kWh/m^2]	H_m[kWh/m^2]
January	1.60	49.50	1.91	59.30
February	2.45	68.60	3.01	84.20
March	3.69	114.00	4.78	148.00
April	4.09	123.00	5.50	165.00
May	4.41	137.00	6.07	188.00
June	4.53	136.00	6.32	190.00
July	4.68	145.00	6.60	204.00
August	4.56	141.00	6.43	199.00
September	3.79	114.00	5.22	157.00
October	3.13	97.10	4.10	127.00
November	2.00	60.10	2.51	75.40
December	1.37	42.30	1.65	51.30

Where:
E_d - average daily electricity produced by the collecting area [kWh];
E_m - average annual electricity produced by the collecting area [kWh];
H_d - average daily solar radiation per m2 received by the collecting area [kWh /m^2];
H_m - average annual solar radiation per m^2 received by the collecting area [kWh/m^2].

To determine the optimal area, a study was performed based on an imposed energy requirement and several values of the solar energy collecting area.
The data sheet of the treatment plant [9] specifies that the air handling unit has a heating battery with an electrical resistance with two coils, each of 3 kW. Thus, a minimum value (3kW) and a maximum value (6 kW) were chosen, with the help of which the energy requirement (4kW) was determined, for which the module operates at a capacity of 67%.
Five values of the optimal area of the photovoltaic panels were chosen. These are shown in Table 3.

Table 3: Areas of photovoltaic panels.

Collecting area 1	10	m^2
Collecting area 2	25	m^2
Collecting area 3	50	m^2
Collecting area 4	**75**	$\mathbf{m^2}$
Collecting area 5	105	m^2

With the help of the Photovoltaic Geographical Information System program, depending on each chosen value, the total electricity produced for each month of the year was calculated. The results are presented in Table 4

Table 4: Annually produced electricity.

	E_d Area 1	E_d Area 2	E_d Area 3	E_d Area 4	E_d Area 5
January	0.67	1.67	3.33	**5.00**	7.07
February	1.02	2.55	5.10	**7.66**	10.82
March	1.54	3.84	7.69	**11.53**	16.30
April	1.70	4.26	8.52	**12.78**	18.06
May	1.84	4.59	9.19	**13.78**	19.48
June	1.89	4.72	9.44	**14.16**	20.01
July	1.95	4.88	9.75	**14.63**	20.67
August	1.90	4.75	9.50	**14.25**	20.14
September	1.58	3.95	7.90	**11.84**	16.74
October	1.30	3.26	6.52	**9.78**	13.82
November	0.83	2.08	4.17	**6.25**	8.83
December	0.57	1.43	2.85	**4.28**	6.05
Total [kW]	16.79	41.98	83.96	**125.94**	177.99

Based on the data presented in Table 4, the graph in Figure 6 was plotted.

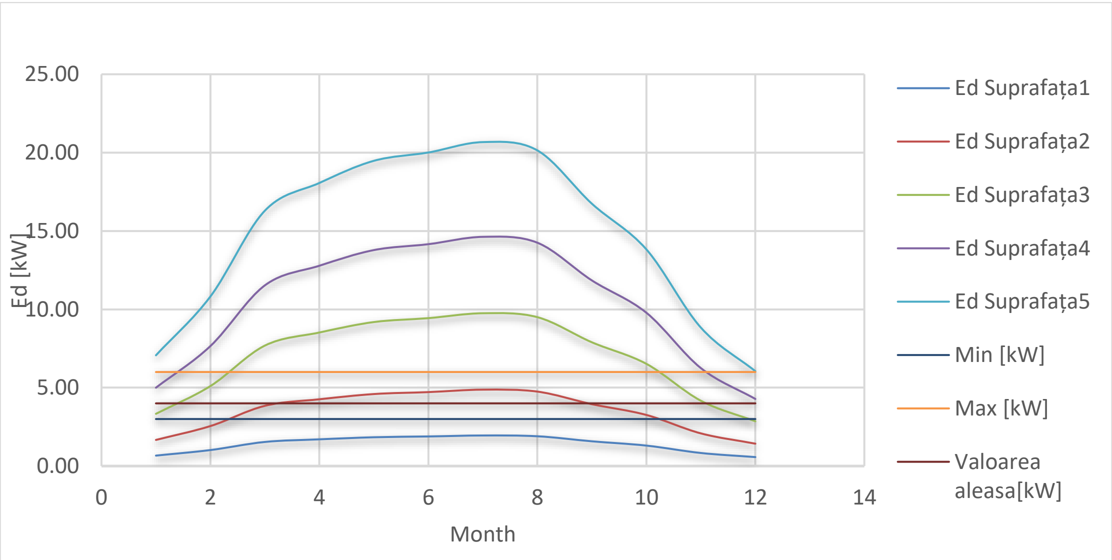

Fig. 6. Study of the energy produced by the sun's rays for several areas

The aim was to obtain a power requirement greater than or at least equal to 4 kW (previously established value). As can be seen, for the value of area 4, the energy requirement has a minimum value of 4.28 kW in December. Thus, the value of the optimal area will be 7575 m^2.

3. Calculation of heat flux when using the solar collector

For the use of thermal energy calculations from the sun's rays, the Photovoltaic Geographical Information System program was used, in which the coordinates of the Municipality of Bucharest were introduced, presented in table 1.
Figure 7 shows the Photovoltaic Geographical Information System program interface.

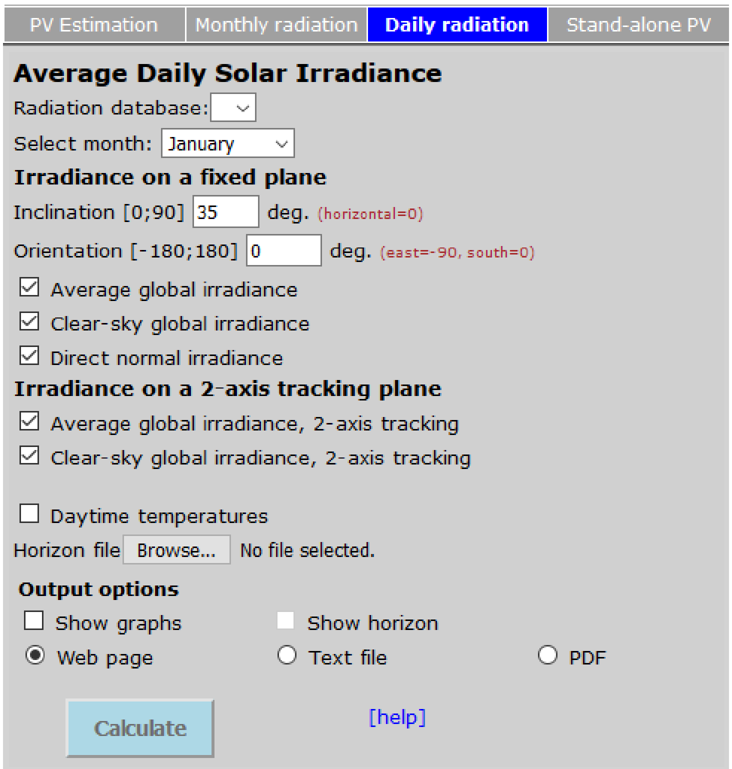

Fig. 7. Solar radiation section within the Photovoltaic Geographical Information System program

The heat flow rate can be determined with the following relation:

$$\dot{Q}_{cs} = \frac{m_w \cdot c_w \cdot \left(t_{final} - t_{initial}\right)}{\Delta\tau} \left[kW\right] \qquad (1)$$

Where:
m_w = 700 kg – the mass of water in the installation tank;
c_w = 4,186 kJ/kgK – specific heat of water;
t_{final} – the final temperature of the water in the tank after 15 min;
$t_{initial}$ – the initial temperature of the water in the tank at the beginning of a new measurement;
$\Delta\tau$ = 15 min – the time interval at which a new measurement is made.
The determination of the value for t_{final} after every 15 minutes can be done by means of an iterative calculation.
From relation (1) it is possible to determine t_{final}, as:

$$t_{final_I} = \frac{\dot{Q}_{cs_I} \cdot \Delta\tau_I}{m_w \cdot c_w} + t_{initial_I} \left[{}^{\circ}C\right] \qquad (2)$$

For the next iteration, the condition that the value of t_{final} from the previous calculation becomes the new value for $t_{initial}$.

$$t_{final_{II}} = t_{initial_{I}} \left[{}^{\circ}C\right]$$

$$t_{final_{II}} = \frac{\dot{Q}_{cs_{II}} \cdot \Delta\tau_{II}}{m_w \cdot c_w} + t_{final_{I}} \left[{}^{\circ}C\right] \qquad (3)$$

Is possible to determine the iterative computational relation:

$$t_{final_{i}} = \frac{\dot{Q}_{cs_{i}} \cdot \Delta\tau_{i}}{m_w \cdot c_w} + t_{final_{i-1}} \left[{}^{\circ}C\right] \qquad (4)$$

In relation (4) the determination of the final temperature in the tank of the installation at the end of a unit of time ($\Delta\tau$ = 15 min) was performed. The installation was designed to power the heating battery of an air treatment plant. The treatment plant module needs a water temperature between 50 - 60 °C according to the technical data sheet of the installation [9].
To determine the t_{final} temperature, the relation (4) is resumed:

$$t_{final_{i}} = \frac{\left(\dot{Q}_{cs_{i}} - \dot{Q}_{CTA_{i}}\right) \cdot \Delta\tau_{i}}{m_w \cdot c_w} + t_{final_{i-1}} \left[{}^{\circ}C\right] \qquad (5)$$

Where:
$\dot{Q}_{CTA_{i}}$ - heat flow rate consumed by the air treatment plant [kW].
The graph presented in figure 8 was made based on the values determined for a whole year.

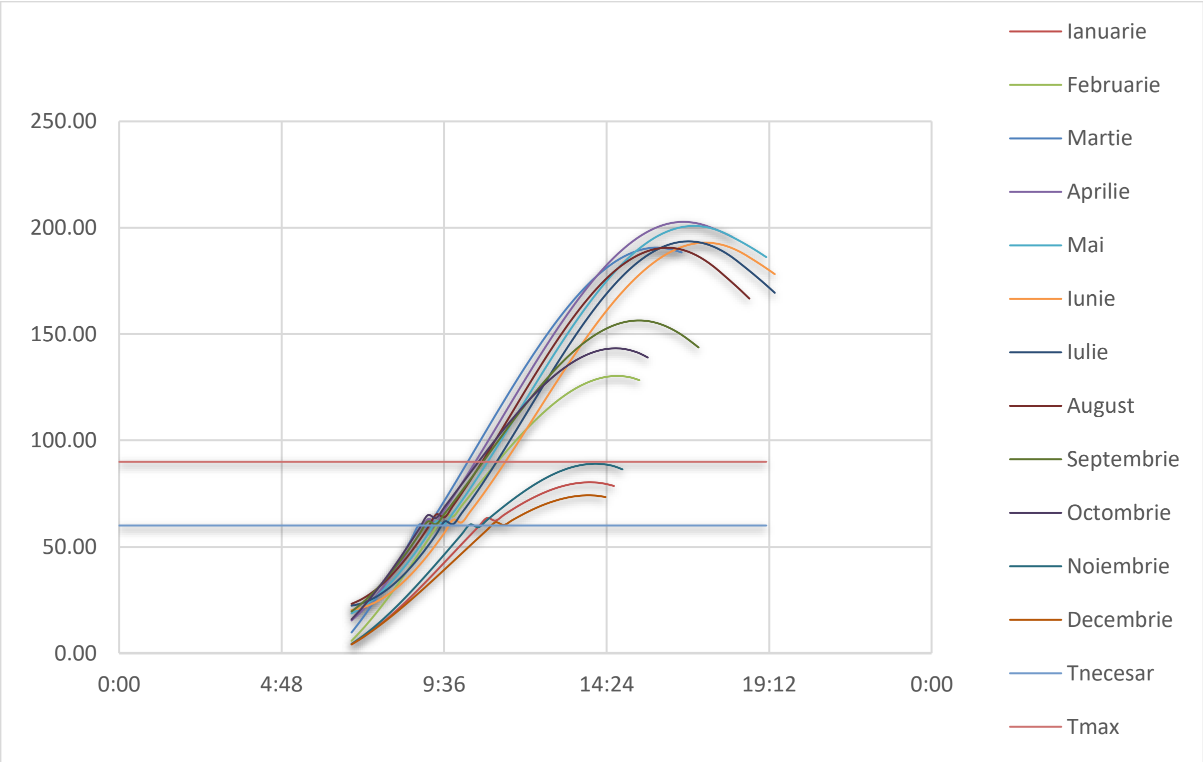

Fig. 8. Temperature variation in the installation tank

It can be seen that the temperatures reach values approximately equal to 210 °C.
To avoid overheating, the network of solar collectors must be equipped with an automatic shading system. This system has a trigger temperature of 90 °C.

4. Comparative study on the prices of the two installations

A comparative study was carried out on the approximate costs of achieving the desired installation.

Table 5: The price of the elements when using photovoltaic panels

Elements	Price
Complete set of photovoltaic panels x 12 (75 m^2)	41000 RON
Invertor x 1	1700 RON
Total (approximative)	**42700 RON**

Table 6: The price of the elements when using solar collectors

Elements	Price
Solar collectors x 24 pieces (60 m^2)	42000 RON
Tank	2600 RON
Circular water pump x 2	800 RON
Piping	70 RON/4 m
Water temperature sensor	40 RON
Total (approximative)	**45510 RON**

The difference in cost between the two types of solar collectors is acceptable, either of which can be used in an air treatment plant depending on the beneficiary requirements.

5. Conclusions

In the present paper, a theoretical study was carried out on the adaptation of photovoltaic panels and flat solar collectors to the air treatment plant (ATP), located in room CG126 within the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment's of the Faculty of Mechanical and Mechatronics Engineering, University Politehnica of Bucharest.
The fields of application described in this paper show the possibility of using solar collectors in a wide variety of systems. It can provide significant benefits to the environment and should be used whenever possible.
The useful collecting area to ensure a need of 4kW is large, and the investment price for an installation of photovoltaic panels or flat solar collectors is quite high.
The efficiency of solar energy capture installations (photovoltaic panels, flat solar collectors) is closely related to the geographical region in which it is to be located. Both the angle of inclination and the altitude at which it is located must be calculated so that the exposure to the sun's rays is as high as possible throughout the day.
Due to the complexity and lower investment costs, the use of photovoltaic panels is more advantageous than that of flat solar collectors.

Acknowledgments

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