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Energy efficiency of educational buildings using photovoltaic panels and air-water heat pumps. Case Study

Eficientizarea energetică a clădirilor de învățământ utilizând panouri fotovoltaice și pompe de căldură aer-apa. Studiu de caz

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Abstract. *Considering the current energy context, with the increase in the price of natural gas and electricity, the use of renewable energy has recently had an increasing trend. In this sense, the article presents a case study for the energy efficiency of educational buildings, through the installation of photovoltaic systems and air-water heat pumps. The simulation was carried out with the help of the Polysun calculation program, analyzing the energy consumption of the ASPC building of the Faculty of Construction in Timișoara, in the existing situation and in the proposed efficiency stages. The results show that in the first stage of efficiency in which the photovoltaic PV system and the air-water heat pump are installed, a decrease in costs for the necessary thermal and electrical energy is achieved, by 42.36%. In the second stage, in which it is proposed to decrease the return/return temperature regime of the indoor installation from 60/40 ℃ to 40/30 ℃, the result is a decrease in the electricity consumption from the national network by 7.94%.*

Key words: *energy efficiency, photovoltaic panel, heat pump*

1. Introduction

Energy, regardless of its form, represents an indispensable resource for contemporary life. Currently, approximately 40% of the energy demand in the European Union (EU) is used in buildings, of which 80% represents the energy required for thermal needs (heating and water preparation in the building), and the energy demand for cooling increases every year. Taking into account the requirements related to energy economy through the sustainable use of human resources, the energy efficiency of buildings represents an increasingly current problem and of increased interest [1,2].

Another important aspect that must be taken into account is the increase in the price of natural gas, something that pushes us more and more towards the use of renewable energy sources, as evidenced by the measures taken by the EU, regarding the increase in energy efficiency from 9 to 13% and at the same time to reduce gas demand by 15% until the end of March 2023 [3-6].

A safe and sustainable source of energy is the solar one, which together with improving the energy efficiency of buildings, can contribute both to achieving the measures taken by the EU and to the reduction of greenhouse gas emissions and to the prevention of dangerous climate changes.

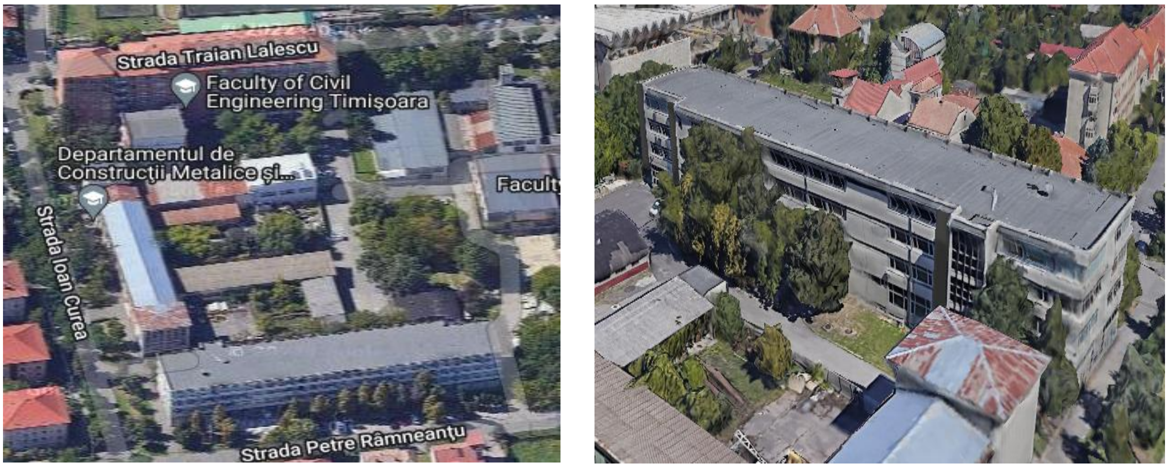
On the other hand, the agglomeration of buildings with different heights in urban areas, generates partial shading or uneven distribution of light intensity on the photovoltaic modules, causing considerable negative effects on the efficiency and integrity of the photovoltaic systems [3,7].

The article proposes, on the one hand, a study related to the shading of photovoltaic panels (PV) that affects the output power of the PV system and, on the other hand, the use of the energy produced to meet the thermal needs of the studied building, using an air-water heat pump.

2. Simulation of the photovoltaic system for the ASPC building. Case Study

To carry out the simulations, the simulation programs Polysun SPTX Constructor [8] and Polysun Designer [9] were used, a comparative study was carried out regarding the performance of the building's heating system, between the current situation and the proposed modernization solution.

The studied ASPC building, where teaching activities are carried out, is part of the building complex of the Faculty of Construction in Timișoara, has a height of 13m (P+3E), and the roof is of the terrace type with a perimeter attic of 50 cm high and 30 cm wide (Fig. 1).



a) b)

Fig. 1 ASPC building of the Faculty of Construction in Timișoara [9]

In the existing situation, the building is supplied with thermal agent for heating and preparing hot water for consumption from the public heating network of the city of

Timisoara. The basic diagram of the power supply system of the studied building is presented in Fig. 2.

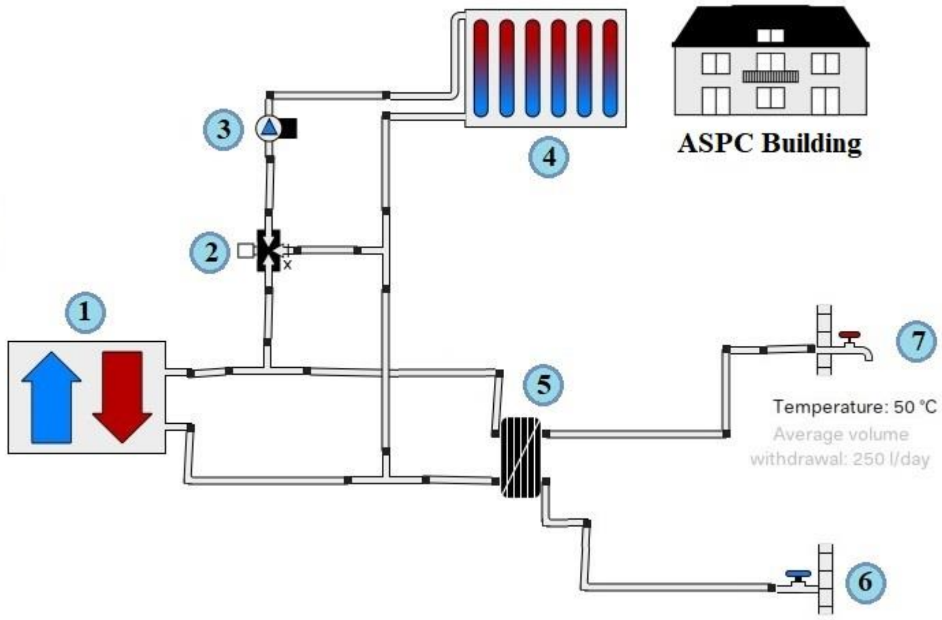


Fig. 2. Diagram of the heating and ACC installation in the existing situation [9]
1 – Heating network, 2 – Mixing valve, 3 - Circulation pump,
4 – Internal heating system, 5 – Heat exchanger,
6 - Cold water supply, 7 - Hot water consumers

The proposed modernization solution for the studied educational building involves, in the first phase, the installation of a PV system on the terrace of the building, designed to produce the electricity needed for its own consumption, following which the surplus energy produced will be transferred to the national energy system (NES).

Considering the previous studies carried out, we found that the ASPC building, from the point of view of the energy production of the PV system, its optimal orientation is East-West, the production compared to the orientation of the system on the South, being 5.58% bigger. We also found that of the total of 72.5 MWh of electricity produced by the PV system, 59.85% is transferred to NES [3].

For this reason, we proposed that the first stage of energy efficiency of the building should also include the installation of an air-water heat pump, which, using part of the surplus energy produced by the PV system, would ensure the thermal energy required for heating and water production hot housekeeper The basic diagram of the power supply system of the studied building is presented in Fig. 3.

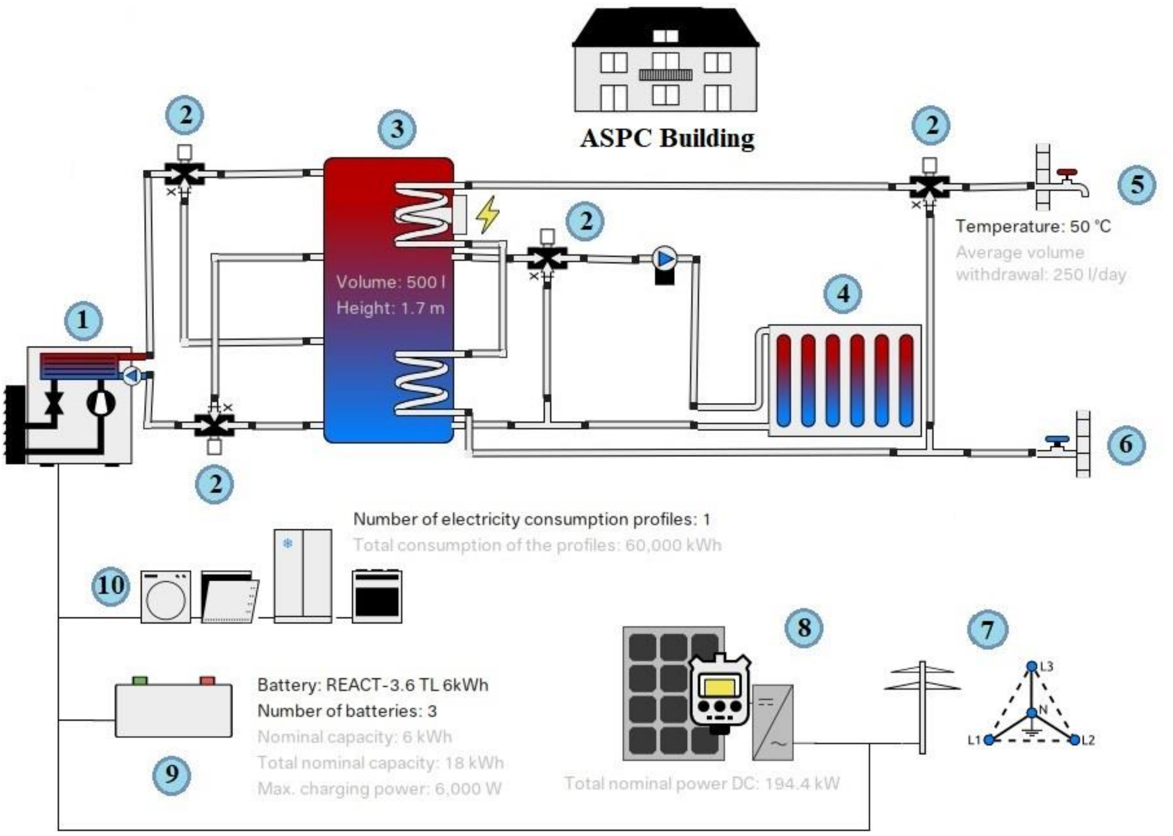


Fig. 3. Basic diagram of the installation after the proposed modernization [9]
1 – Heat pump, 2 – Mixing valve, 3 - Accumulation tank,
4 – Internal heating installation, 5 – Hot water consumers,
6 - Cold water supply, 7 - NES, 8 - PV system, 9 - Storage batteries, 10 - Electricity consumers

The PV system is composed of 486 EvoCells 400 MIB modules with a maximum production power of 400 Wp, with a total installed power of 194.4 MWp. The distance between the rows is 18.3 cm and a passageway of 40 cm is provided for a group of 10-12 rows, positioning distances determined by the shading of the PV modules by the attic of the building (Fig. 4) The PV system is also provided with 3 energy storage batteries, each of 6 kWh [3].

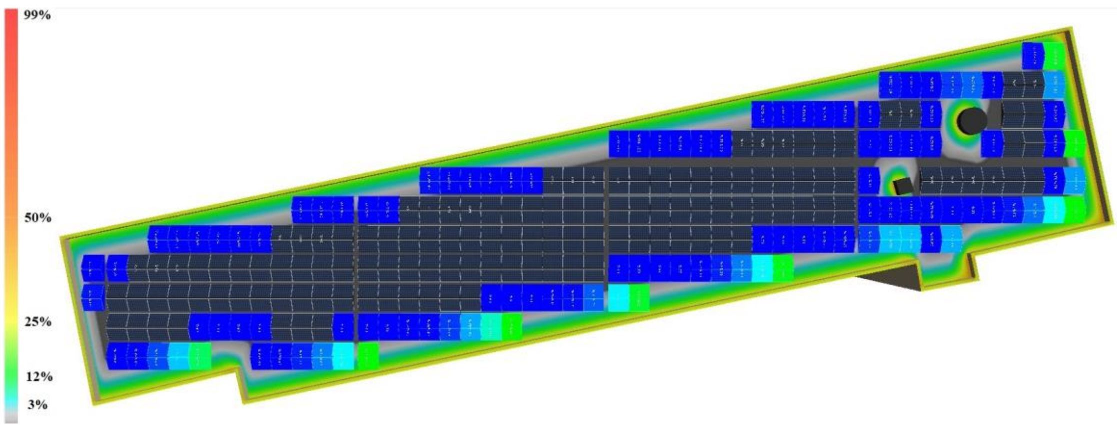


Fig. 4 Placement of PV modules on the ASPC building [1]

Considering the fact that the existing installation of the building contains radiators as well, the temperature regime chosen for the round and return is 60/40 ℃. It is well known that the efficiency of air-water heat pumps is related both to the temperature the outside air as well as the temperature of the thermal agent that it must achieve. In order to increase the efficiency of the heat pump, we must lower the temperature of the heating agent, which leads us to the need to intervene on the existing heating bodies.

Thus, the second stage of efficiency proposed involves the replacement of radiators with fan coil units and thus reducing the temperature regime of the thermal agent to 40/30 ℃.

3. Results and discussion

Following the simulations carried out, it can be seen in Table 1, in comparison, the annual consumption of electricity from the national energy system (SEN), and the consumption of thermal energy from the centralized heating network, both for the existing situation and for the two stages of efficiency proposed .

A calculation of the necessary costs for the energy consumed from the network was also made, at the currently estimated prices of 205.85 EUR/MWh for thermal energy and 306.12 EUR/MWh for electricity.

Table 1

Annual energy consumption

<table>
<tr><th>The type of energy</th><th>Stage</th><th>Consumption MWh</th><th>Price EUR</th><th>Total costs EUR</th></tr>
<tr><td>District heating consumption</td><td>Existing situation</td><td>58.58</td><td>12,059.13</td><td rowspan="2">30,442.40</td></tr>
<tr><td>Electricity from NES</td><td>Existing situation</td><td>60.05</td><td>18,383.27</td></tr>
<tr><td>District heating consumption</td><td>Stage 1</td><td>0</td><td>0.00</td><td rowspan="2">17,546.94</td></tr>
<tr><td>Electricity from NES</td><td>Stage 1</td><td>57.32</td><td>17,546.94</td></tr>
<tr><td>District heating consumption</td><td>Stage 2</td><td>0</td><td>0.00</td><td rowspan="2">16,154.08</td></tr>
<tr><td>Electricity from NES</td><td>Stage 2</td><td>52.77</td><td>16,154.08</td></tr>
</table>

In Fig. 5, the monthly electricity consumption from the national network for the two proposed efficiency stages is presented and a decrease in energy consumption is observed due to the reduction of the temperature regime of the indoor installation from 60/40 ℃ to 40/30 ℃.

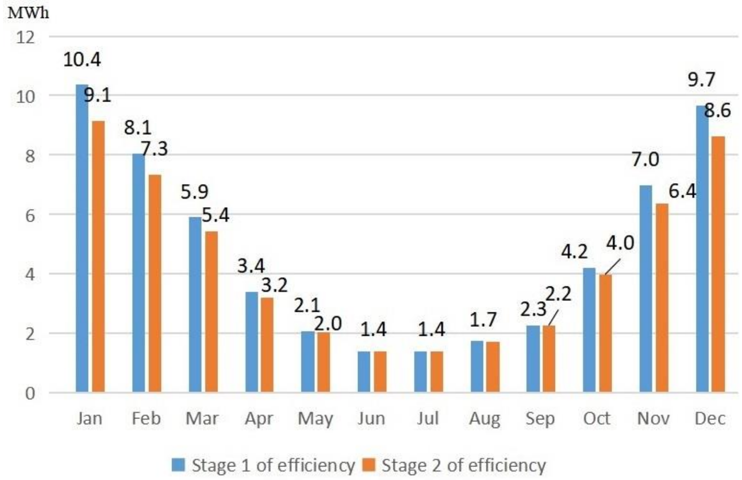


Fig. 5. Electricity consumption from NES for the 2 stages of efficiency

4. Conclusions

In conclusion, through the efficiency proposed for the studied educational building, it is observed for the first stage in which the photovoltaic PV system and the air-water heat pump are installed, a decrease in the costs for the purchased energy by 42.36% compared to the existing situation in which the building is supplied with thermal energy from the city's heating network.

Also, for an even greater increase in the efficiency of the air-water heat pump, a decrease in the temperature regime of the indoor installation is proposed, thus resulting in a decrease in the consumption of electricity from the national network by 7.94%.

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