COMPARATIVE ANALYSIS FOR RENOVATION OF AN AIR HEATING AND COOLING SYSTEM FROM A ROMANIAN ADMINISTRATIVE BUILDING

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Abstract. In this paper, the authors determine the energy consumption for heating and air conditioning of an administrative building located in the second climatic area, in Romania. The heating and cooling system is provided with fan coils, and the fresh air is supplied by an AHU. The aim is to identify the best solution from 3 proposed heating and cooling systems that can be applied in order to improve the living conditions, namely: boiler with solid fuel (wood) or gas and chiller with mechanical vapor compression (VCM); reversible heat pump; boiler with solid fuel (wood) or gas and absorption chiller type LiBr-H₂O driven by solar energy. The goal of the study is to select one of the three solutions which involves minimum investment and exploitation costs.

1. Introduction

Currently, in the field of building installations, there are several systems available for space heating and cooling. The current trend is to use renewable energy wherever possible.

Choosing an appropriate air conditioning system which combines heating and cooling, is done considering next features:

- The users of the space and the type of the building;
- The occupancy duration of the building;
- The size of the heat load (heating / cooling) required;
- Primary energy sources available;
- The possibilities of using renewable energy resources;
- Energy performance of component parts;
- Investment and operating costs.

Until now, numerous studies have been realized on the following related subjects, such as: simultaneous heating and cooling [1], comparison between different systems for buildings heating and cooling [5], energy efficiency for achieving a sustainable development [2], [6] or promoting the usage of renewable energy sources for buildings heating and cooling [3].

Besides these aspects, account must also be taken of the financial part directly related to the investors in the rehabilitation of the cooling and heating installations and the buildings in general [4], [7], [8].

In the building that is the subject of the present work, the present heating system which must be updated consists of a boiler that operates with solid fuel (wood), with 40 kW installed capacity, and the hot water temperatures of 80/60°C. The cooling system consists of split air conditioners mounted in a small number of rooms. In this paper the authors analyse, by economically and technically point of view, 3 alternatives which can improve indoor comfort.

These are:

Table 1. The proposed solutions

No.	Indoor installation	Heating	Cooling
1.	4-pipe fan coil (fresh air introduced separated by an AHU)	Gas Boiler	Chiller with mechanical vapor compression
2.	4-pipe fan coil (fresh air introduced separated by an AHU)	Reversible heat pump	Reversible heat pump
3.	4-pipe fan coil (fresh air introduced separated by an AHU)	Wood Boiler	Absorption Chiller with Li-Br solution

The study is made on an Administrative Building, Figure 1, (Town Hall) from Ialomita County, Romania and includes It includes office spaces and an Annex that serves as a garage and as technical space for the thermal plant, with a masonry structure.

Fig. 1a. Analysed building (Town Hall)

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Fig. 1b. Exterior façade in front of the building with existing outdoor cooling unit

Fig. 1c. The mayor's office with the existing heating radiator

Fig. 1d. Building's lobby with the existing heating radiator

2. Characteristics of the building

2.1. Geometric characteristics of the building

The analysis was carried out for an administrative building, built of brick masonry, with one level above ground. The heated surface is 323 m², the height is 3 m and the total heated volume is 969 m³.

2.2. Characteristics of the building envelope

The buildings envelope consists of the following materials:

- Exterior walls of brick masonry, with the thickness of 37.5 cm and external thermal insulation made of expanded polystyrene with 5 cm thickness;

- Wooden frame roof covered with sheet of 0.5 mm thickness;
- 12 mm thick plasterboard under the roof, thermally insulated with 10 cm basalt mineral wool;
- PVC Windows and exterior doors with windows and thermal insulating glass.

2.3. Outdoor climatic parameters

Outdoor climatic parameters for the hot and cold season have been established in accordance with Romanian regulations (Norms I.5/2010 and SR 1907-1/2014).

Thus, the parameters are:

- For the hot season: the indoor air temperature 25°C and the relative humidity 40%; the outdoor air temperature 33°C and the relative humidity 41%;
- For the cold season: the indoor air temperature 20°C and the relative humidity 50%; the outdoor air temperature -15°C and the relative humidity 80%.

2.4. The energy requirement for heating /cooling the building

The fresh air flow, determined according to Norm I.5/2010, is 1365 m³/h.

The fresh air required is treated up to the indoor temperature in an AHU equipped with a 60% recovery system.

The thermal load for fresh air is 14 kW in summer and 26,7 kW in the winter. Using a 60% recovery system, the thermal load to be insured is reduced to 5,6 kW in the summer season and 10,7 kW in the winter season.

The energy requirement for space heating /cooling and hot water consumption was determined according to Romanian regulations (SR 1907-1/2014).

The cooling needs of the building were determined by summing up the heat inputs through opaque envelope elements, glazed building elements, neighboring rooms with different indoor temperatures, heat releases from humans, electric lighting and electrical equipment from the offices. The cold load for the warmest day of the year is 18,4 kW.

Considering the fresh air required, a total cooling load of **24 kW** results.

The heating demand of the building was determined by taking into account the heat releases from: people, electric lighting, office electrical equipment. These were subtracted from the total thermal demand obtained using the standard method [13].

The heating load obtained is 7,8 kW.

By taking into account the fresh air and domestic hot water results in a total heating load of **18,5 kW**.

3. Proposed Systems Analysis (Heating /Cooling)

In the present paper for all three proposed technical variants was chose an indoor unit, respectively a 4-pipe fan coil.

This solution has been chosen for several reasons:

- The use of the same equipment for both seasons which reduces the investment cost, the payback period and the space;
- The system has a low inertia, that is very useful for buildings with a reduced working program (when compared to the residential area) and high variability intakes;
- Can easily integrate into existing building, without any modifications to the construction;
- Individual temperature adjustment;
- Hot water and chilled water circuits are separate and do not require a new hydraulic balancing at every season change;
- Saves the space which was initially occupied by radiators.

3.1. Heating agent production equipment

- *Solution 1: Gaseous fuel boiler*

In this variant a boiler with gaseous fuel (methane) was considered with an installed capacity of 30 kW;

- *Solution 2: Reversible heat pump*

In this variant, a heat pump with a heating load of 24 kW, operating at 45/40°C heating parameters.

- *Solution 3: Solid fuel boiler (wood)*

A boiler with an installed capacity of 30 kW was used in the study (the thermal capacity corresponds to a $\Delta T=20$ K).

These solutions were chosen after a preliminary consultation of the beneficiary.

We must take into consideration that the medium hot water temperature from the fan coil circuit is 50/45°C.

3.2. Cooling agent production equipment

For the preparation of chilled water, the equipment selection was made depending on the thermal load, respectively:

- *Solution 1: Chiller with mechanical vapor compression*

In this variant it was chosen a chiller with mechanical compression of vapor, with a cooling capacity of 27 kW, which prepares 7/12°C cold water.

- *Solution 2: Reversible heat pump*

A heat pump with a cooling output of 27 kW which prepares 7/12°C cold water.

- *Solution 3: Absorption chiller with Li-Br solution*

The Lithium Bromide solution chiller which produces 7/12°C cooled water, was selected with a maximum installed refrigeration power of 27 kW.

To make this solution environmentally friendly, a number of 40 solar panels were considered in order to ensure the heat necessary in the plant heat generator. The

determination of the solar panels number is made in accordance with the plant's heat generator heat flux required to achieve the 27 kW cooling load, with the COP of 0.7. This can be covered by 40 solar panels with 1 kW thermal power each.

4. Technical and economic analysis

The investment and exploitation costs for the three solutions proposed for the administrative building were analysed.

Electricity consumed annually is calculated for 8 hours of operation, according to the program of the institution; It was also considered the electricity consumed by the pumps, which is taken from the pump data sheet provided by the producer's selection software.

The absorbed power by the fan coil units is in accordance with the technical data sheet for the maximum fan speed.

The total electrical power required to power the boiler is the sum of the electrical power and the equivalent electrical power obtained from the conversion in [W] of the gas / wood consumption.

4.1. Investment costs

A study has been conducted to determine the total investment cost. In this study were considered all the equipment listed above- fan coils, boilers, reversible heat pump, chiller, solar panels, and auxiliary elements involved in the realization of the installations such as pumps, taps, pipes, pipe joints and the workmanship.

The considered prices represent average values for the components of each air-conditioning solution and were obtained after a rigorous market research, considering at least five offers from different producers.

The results are synthesized in the graph shown in Figure 1.

At first sight, it can be noticed the clear difference between the first and second solution on the one hand, and the costs for the third solution on the other hand.

This is the result of the high cost of the solar panels.

So, even if the trend in our day is to use more and more energy from renewable sources, the investment cost is still very high in Romania and it does not pay.

Fig. 1. Investment costs

4.2. Energy costs for operation

The calculation was made considering the following particularities:

- Electricity consumed annually is calculated for 8 hours of operation/ day, according to the institution program;
- The electrical energy consumed by the pumps is taken from the pump data sheet;
- The fan output power is taken for the maximum fan speed;
- The energy consumed by the boiler is dependent on the gas / wood consumption.

The conclusions on energy consumption for the three solutions are presented in Figure 2.

Fig. 2. Energy costs for operation

5. Discussions and Conclusions

As a result of the technical and economic analysis, the values of the investment and exploitation costs (for 1 year) corresponding to each solution presented are shown in Figure 3.

Fig. 3 Total cost after first year of operation

From Figures 1 and 2 we can conclude that:

- Solution 3 shows the highest investment values, about 55% higher than Solution 1 and about 58% higher than Solution 2;

At the same time, Solution 3 has the lowest exploitation values, about 57% smaller when compared to Solution 1 and about 71% smaller in comparison to Solution 2. Because of the very high investment costs, the City Hall cannot assume the implementation of this solution although there is a possibility of a rapid recovery of the investment over time.

The first two proposed solutions are analyzed in parallel in the following in order to take a decision.

It results that Solution 1 shows higher investment values, 8% higher compared to Solution 2, but it has 33% lower values for exploitation.

Considering that the reversible heat pump has a life span of 10 years, we can extend the analyze for 10 years of operation.

The resulted values are shown the operating and investment costs, shown in Figure 4.

Fig. 4 Total cost after ten years

From Figure 4, it results that the solution accepted for implementation is the Solution 1 which uses the chiller with mechanical compression for cooling, and for heating it uses gas-fired boilers.

Finally, even if Solution 3 presented the most environmentally friendly option, the fact that the Romanian state only subsidizes the costs of photovoltaic panels and not the thermal panels, resulted in a very high investment price which ultimately led to the selection of Solution 1.

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