Analysis of engineering solutions implemented for a hotel

Analiza soluţiilor inginereşti implementate pentru un hotel

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Abstract. *The purpose of this paper is to analyses the solutions for the heating and domestic hot water supply system for a modernized hotel in the city of Chisinau for the climatic conditions of the Republic of Moldova. In the paper, the implemented solutions were analyses, the investment recovery term was determined. The Republic of Moldova does not have its own energy sources, and the need to implement alternative sources is obvious. In this sense, the use of heat pumps, photovoltaic panels form an energy efficient, economical and more ecological system than any thermal energy generating installation.*

Key words: heating, domestic hot water, heat demand, heat pumps, photovoltaic panels

1. Introduction

The construction sector is one of the largest energy consumers in the Republic of Moldova. The objectives of the state policy in the field of energy are established in the Energy Strategy of Moldova until the year 2030 [1]. The document provides for the increase of security in the energy field, because the Republic of Moldova is affected by such factors as: the politicization of trade in energy resources, the increase in electricity and natural gas prices.

Lower energy consumption and a higher degree of energy and ecological efficiency [2] can be advanced by introducing new technologies (more efficient engineering installations and equipment, buildings with reduced energy consumption, buildings with intelligent heating/cooling systems ...).

Features of heating of hotels, hotels or guest houses up to 500 m^2 are determined by the nature of their operation. As a commercial enterprise, a mini-hotel must bring profit to its owners without compromising the comfort and satisfaction of hotel guests.

- Residential and non-residential premises will have to be heated;
- Warming up should be as fast as possible (the room was empty - you did not heat it, the guest checked in - the room was immediately warmed up);
- Washing dishes in hotels with their own restaurants requires a lot of hot water;

- The maximum consumption of hot liquid will be in the evening and morning, when the majority of guests take a shower; The standard for calculating the rate of hot water consumption among guests is 50 liters per person;
- Room occupancy usually has seasonal fluctuations. In winter you will need a lot of heat, and in summer you will need hot water. Also, in summer it is mandatory to use the air conditioning system.

Operating costs directly affect financial results. Therefore, reducing heating and hot water supply costs in the hotel business is of significant importance. Heat pumps are the optimal heat generators for mini-hotels.

2. Requirements for engineering installations in hotels of engineering installations in hotels and the analysis of the solutions implemented in a Hotel in Chisinau

Heating, ventilation, air conditioning should be designed in accordance with [3, 4, 10]. In hotels of categories “four stars” and above, it is necessary to ensure the operation of engineering systems from at least two separate sources. All heat exchangers and pumping equipment must have a reserve of at least 100%. For hotel premises, a ventilation system with natural and (or) mechanical impulse should be provided. For hotels of categories “four stars” and above, mechanical ventilation should be provided in additional service areas.

Ventilation systems for conference rooms, catering establishments, halls for physical education and recreation, swimming pools, cinema rooms, battery rooms located in hotels must be separate from the ventilation systems of other rooms in these buildings. Air conditioning of hotel rooms should be equipped with local control devices or with programming of heat and humidity parameters. Heating for hotels involves supplying coolants heated to 60 degrees to radiators. For water floors, use liquid up to 35 degrees. Hot water is heated up to 50 degrees. The total liquid consumption will depend on the size of the restaurant and kitchen. Usually this is at least 3000 litters daily. Air heating of a hotel involves a complete refusal of gas or the use of a boiler as a backup energy source. Air-to-water heat pumps operate in frosts down to -15 degrees and are used as primary or additional heating equipment. The system can cool buildings in the summer, that is, it is multifunctional. Hot water supply is available. The heated air is distributed throughout the rooms in the building through ventilation ducts.

In order to analyses the efficiency of the implemented engineering solutions, a hotel located on Ciuflea street, Chisinau municipality was examined. The recently modernized building, in 2020, has: 16 hotel rooms, restaurant for 80 people, breakfast room, bar, offices, dental office, conference room for 150 people, technical and storage spaces in the basement. Height regime: S + P + 2E + M, with the surface - 700 m^2.

During the modernization of the building, the following measures were implemented: thermal insulation of the external wall, of the ceiling of the building and the windows were changed. The calculation of the heat requirement for the building

was made for two boundary conditions of outdoor air temperature -16°C and 0.6°C at a constant indoor air temperature of 20°C. The -16°C/20°C module was selected to determine the required power of the thermal plant; and the 0.6°C/20°C mode was selected to estimate the amount of heat needed throughout the entire heating season to maintain the set indoor temperature. The outside air temperature of -16°C is the temperature of the coldest 5 days, and 0.6°C corresponds to the average temperature of the heating season for Chisinau, the duration of the heating period being 166 days. The heat requirement for the entire building surface during the cold period of the year is 42 kW for the -16°C/20°C module, and 22.5 kW for the 0.6°C/20°C module, respectively. The heat requirement for the heating season, according to calculations, is: 89640 kW.

Until the modernization works are carried out, there was a problem with achieving and maintaining comfortable temperature in the offices and living spaces in the building. The thermal plant could not cope, and the gas consumption was very high. In 2021, two Split type heat pumps, manufacturer NIBE, model AMS 10-16 + HBS 05-16, each of 16 kW - were connected to the existing heating plant, equipped with a 49 kW gas boiler, which is used only for the winter season, for heating (Fig. 1). An amount of 157 thousand lei was invested for a set, including installation and accessories. The pumps worked very economically, quietly. Invoice amounts have decreased considerably compared to previous years. The owners made the decision, in 2023, to install the third heat pump in the existing system, fully providing the heat required.

The heat pumps are connected in cascade/parallel and controlled by NIBE KVR 10-30 control panels.

a) b)

Fig. 1. a) NIBE heat pumps connected to the existing heating plant;
b) External blocks of the NIBE heat pump

Fig. 2 shows the dependence of the heating power and COP of these pump models according to the outside air temperature for different temperatures of the heating agent.

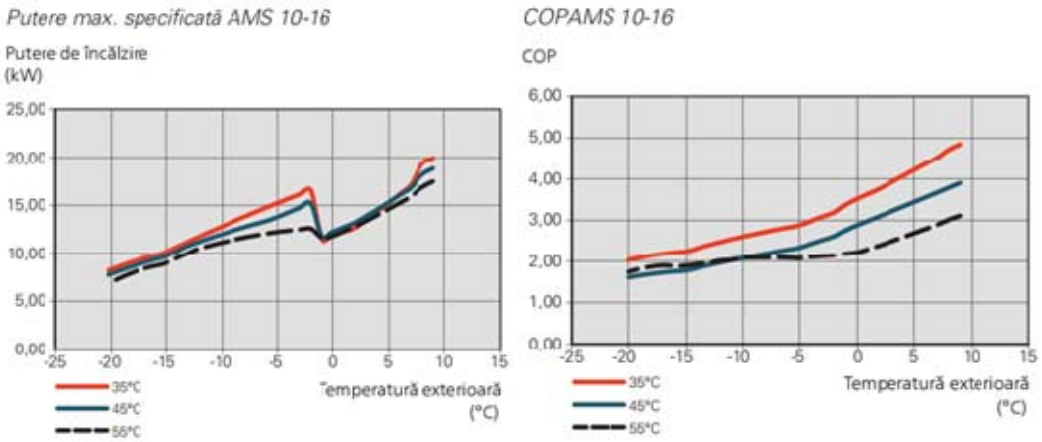

Fig. 2. Dependence of the heating power and COP depending on the outside air temperature for different temperatures of the heating agent [5]

From Fig. 2, it can be seen that with the decrease in the temperature of the outside air, the thermal power of the heat pump also decreases. At the same time, the electricity consumption increases, respectively the COP decreases. At temperatures lower than - 5 ℃, the COP coefficient decreases.

Panel-type steel radiators are used as heating elements. The pipes are made of polypropylene insulated pipe.

a) b)

Fig. 3**.** a) Solar panels with vacuum tubes for the preparation of DHW
b) Boilers with 2 coils for DHW preparation

When modernizing the building, it was invested in solar panels for the preparation of domestic hot water (DHW), 3 solar panels of 15 vacuum tubes, which prepare DHW in 3 boilers of 200 liters with 2 coils (Fig. 3 b). The amount of the investment reached 140 thousand lei. Showing a good result on the electricity consumption bill for the preparation of domestic hot water, in 2023, another solar

panel of 30 vacuum tubes with a 300-liter boiler was invested and mounted for 60 thousand lei (Fig. 3. a).

Taking into account the high consumption of electricity, approximately 95% compared to gas consumption, for heating and other needs, in the year 2023, the owner invested in the photovoltaic panel system which includes: 40 panels x 415 W, Inverter 25 kW, accessories for installation, design, installation and commissioning services, in the amount of 190 thousand lei. The installed panels have a total power of 16.6 kW of the 30 kW allowed by the Inverter. Since the electricity consumption is not fully covered by the photovoltaic system, the owner plans to add 30 more solar panels to the system [9].

3. Calculation of the recovery period of implemented solutions

Considering that a heat pump can be used both for heating the building and for cooling it, in the given paper a comparative analysis of the efficiency of heat pumps for heating systems only was made. To perform the calculations, the following initial data are required: initial investments and operating expenses.

When comparing the heating system between the heat pumps and the gas boiler, the prices set by the National Agency for Energy Regulation of the Republic of Moldova for the 2023-2024 heating season were used.

In the calculations, the following parameters were used:

- Calorific value of natural gas: 33.5 MJ/m^3 (9.3 kWh/m^3);
- The price for 1 m^3 of gas is 18.07 lei [6];
- The price for 1 kWh of electricity: 2.39 lei [7].

As an initial investment, the cost of the entire system was taken into account, which includes:

- 3 heat pumps, auxiliary equipment, accessories for heat pump connection, installation and commissioning;
- gas condensing boiler.

Knowing the required heat produced by the thermal power plant for a year and the capacity of the heat pump given by the manufacturer [5] will determine the amount of electricity required by the heat pump to produce the same amount of heat. Natural gas consumption will be determined based on the condition that 1 m^3 of natural gas produces 9.3 kWh/m^3 of heat.

The results of the calculations are presented in Tables 1 and 2.

Exchange rate: 1 Euro=19.30 lei, according to the National Bank of Moldova data on the day of the calculation [8].

Table 1

Electricity consumption emerging from the data producers and heat demand

The analyzed object	The heat requirement for the cold period (0.6°C/20°C), kWh	COP heat pump to t_e =0,6 °C	Electricity consumption in the cold period for heating, kWh
hotel	89640	2,95	30386

Tablel 2

The investment recovery period for the heat pump

Expenses for the heating system	Air-water heat pump	Thermal power plant 49 kW
1.Initial investments, lei	A=471000	B=0, existence
The amount of thermal energy required for the cold period of the year, kWh	89640	89640
The amount of electricity/gas required for the cold period of the year	30386 kWh electricity	10953 m^3 natural gas
2. Operating expenses, lei	X=72622	Y=197920
Investment recovery period, years T=(A-B)/(Y-X)	The investment recovery period for the heat pump is 3 years 274 days	

From Table 2 it can be seen that the recovery period is very small. This is due to high natural gas prices. Until the price increase in 2021, this investment would recover in 7-8 years, which is still a good result.

Part of the electricity consumed would be recovered with the help of the purchased photovoltaic system. The authors made a simulation of the production of electric current by the photovoltaic system for the examined hotel with the help of software ver.5.2, PVGIS [9], the results are presented in Fig. 4.

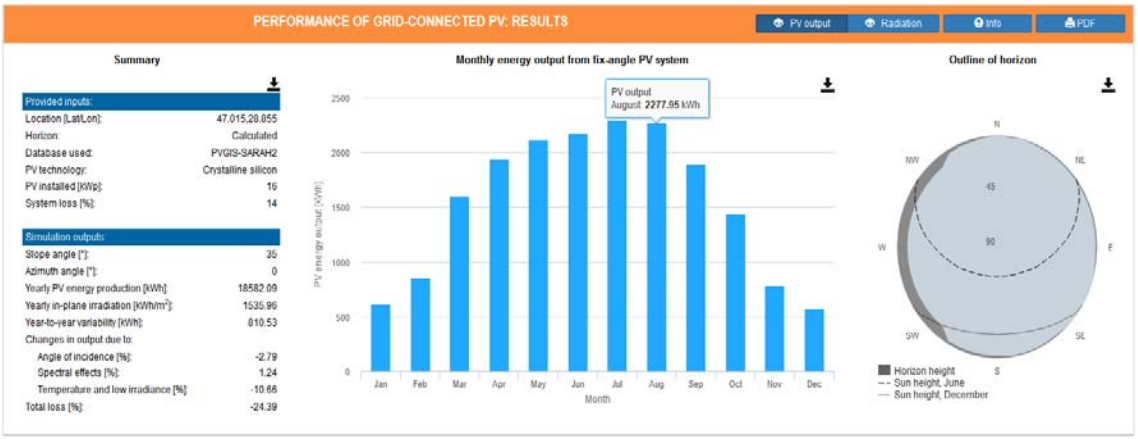

Fig. 4. Simulation of the production of electric current of the photovoltaic system for the hotel [9]

From the results obtained in Fig. 4 it can be seen that with the photovoltaic system it would produce approx. 5 thousand kWh of electricity consumed in the heating season, which is 12.7 thousand lei at current prices, the recovery period being - approx. 15 years. But which is not correct, because in the cold season, photovoltaics has a low production, and in the warm season, the production increases considerably. During the warm period of the year, electricity is consumed for air conditioning, ventilation, lighting, office equipment, etc. Based on the knowledge and experience gained, an investment for such a photovoltaic panel system is recouped in 7-8 years.

4. Conclusions

Following the study, the following conclusions can be made:

- heat pumps are good solutions for hotels, only on the condition that these buildings are new and were built according to the norms in force, or energy efficiency works are planned for the building;
- if the heat pump is used only for heating a building, the investment recovery period is 3-4 years. Considering the unstable gas prices, the increasingly warm climate during the cold period of the year, the choice in favor of heat pumps is obvious;
- air-water heat pumps are able to provide heating/cooling of buildings ensuring comfortable conditions throughout the year, have a long lifespan and require minimal maintenance;
- it is beneficial to use heat pumps connected to photovoltaic panels, especially for the summer period when operating in cooling mode.

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