

ENERGETIC AND ECONOMICAL ANALYSIS FOR CHOOSING A HEAT PUMP PLANT FOR DOMESTIC NEEDS

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Abstract: This paper presents the implementation of a heat pump plant in a small house for heating and producing warm water for domestic needs. After analyzing the weather conditions correlated with the heat power consumption, the final decision was for implementing a heat pump water/water. According to the international environmental laws, another analysis was done for choosing the right refrigerant.

The paper also includes a study for choosing the suitable heat pump type: reversible system (heating pump / cooling system) or simple system (just heating). An economic calculus will be included, presenting comparison with other heating systems and their recovery rate.

Key words: *Heat pump, Energetic analysis, Household energy consumptions, Domestic heat needs*

1 INTRODUCTION

Even if today the classic installations for heating and hot-tap water represent a still economically attractive investment in comparison with unconventional heating systems ("heat pump") the number of those interested in such a system is still increasing.

Conventional (classic) heating systems on fossil fuel (natural gas, coal, liquid fuel) provide for the use of maximum 90% of actual energy capacity. Moreover, the burning process results in toxic discharges which pollute the environment. In response to the classic system, we have the "heat pumps" which are equipment or installation which use the heat in the air, soil or water, being quasi-unlimited or recoverable resources due to the sun or earth heat. In other words, the primary heat power (ecologic energy) is taken and amplified through the "heat pump" up to an energy level usable for domestic consumption. Therefore, the heat pumps are the only equipment which, to produce a heat power of 1 kW (useful energy) requires the introduction of a smaller energy quantity (consumed energy). As well, the CO₂ emissions are relatively high in the classic systems while the heat pump accounts for up to 1/20 discharges of its own.

In the household field, the most part of the consumed energy is oriented toward heating and hot-tap water. This energy accounts for about 2/3 of the total energy consumed. One can notice a distribution of household energy consumption in figure 1.

If to these reasons related to the consumption reduction and environmental preservation we add the bivalent functioning of the installation in both heat pump mode and cooling installation mode, then a remote location of a household recommends this system as a viable alternative to classic systems.

The implementation of these systems leads to a reduction of CO₂ emissions from households while such emissions are harder to monitor when resulted from industrial consumptions.

The design team, with an expertise of more than 10 years in solution analysis studies, determination of actual performance (measurements, tests) of such systems and even implementation in various locations, hereby wishes to go through the design stages for the construction of a low-power heat pump for the household domain which has a very large potential and relatively low impact of CO₂ on the atmosphere (between 6 and 9.5 t CO₂/year/person – Europe, and 18 t CO₂/year/person – USA).

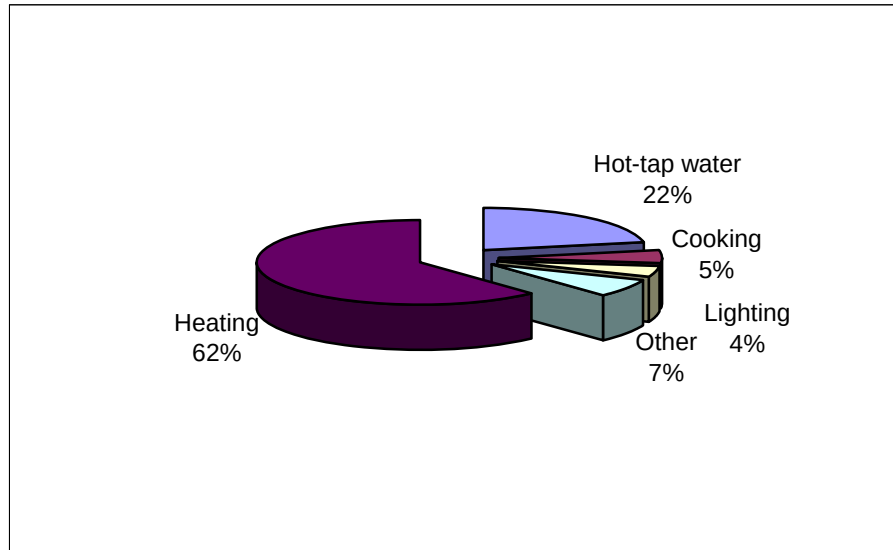


Figure 1: Household energy consumptions

When implementing such a system, the ideal is to have the architectural solution and construction system correlated with it. The designing and selection of such a system must begin with an analysis of the geographical location, climate and available energy resources (potential). After having selected the construction type of the heat pump based on the climate analysis, one must analyze the correlation between the installation type and heat carrier to be used. After having solved these two aspects, one can pass to the construction of the system, with the possible allocation of some underground room for the “water-water” or “soil-water” heat and continuing with the reduction of the outward heat losses through proper insulation of the dwelling rooms, creation of a moderate indoor temperature level, installation of certain door and window types and proper positioning and orientation of building on the land. As well, the arrangement of outside room may contribute the reduction of the building’s heat transfer through the creation of a natural barrier between the two interacting systems (environment – building). In the case of already existing buildings, the above mentioned stages are not all possible and one can look for an enhancement of the energy efficiency to improve the heat transfer between the building and the environment.

We will continue to present the actual implementation of a heat pump in a one-family building alongside the elements that had to be corrected for the success of this project of our design team [2].

2 INITIAL DATA

The house to be modernized from the viewpoint of both the construction and the in-house installations is located at about 50 km away from the capital city, in the village of Frumusani. The village is located in a remote area, with a limited number of houses and population and therefore there is no gas supply in the area. The building features a basement, ground floor, story and attic, with an overall useful ground-floor area of about 150 sq m. Although built

recently, the insulation from the outside was not very good. According to the local climate, the heat potential is only needed for the heating of that building, being 30 kW, without any intervention on the building's insulation system. If we add the determined heat charge with the hot-tap water needs for four persons who will dwell in that house, the heat needs would reach 38 kW. The heating can be provided through any classic or modern solution, but the initial and especially the operational costs are very high. The environmental impact of this heating and hot-tap water solution is very high. Therefore, the first decision made was to rehabilitate energetically the building in order to minimize the consumptions.

To implement a heat pump, we had to carry out an analysis of the climate and environmental factors in that area in order to know the energy needs and availability, such as:

- Outside temperatures: night, daytime, minimum, and maximum;
- Wind speed;
- Geothermal potentials: soil temperature, underground water temperature, flow rate and depth.

Following the survey and analysis, we found that the heat potential of the underground water is relatively high and the flow rate is more than sufficient for our application. As the distance down to that energy source was 50m, the water temperature was 12°C, a value being constant throughout the year. A thermal spring with such a yearlong potential is enough to ensure the heat needs almost completely during the entire cold season, even in the very low temperature days, when the heat needs practically reach a peak [3].

To select the heat charge of the heat pump, we carried out a project for the energy rehabilitation of the building [4]. The first stage was to insulate the slab between the story and the attic using a layer of polystyrene and wood. We also replaced the access doors of the house. Then we insulated the building on the outside, while replacing the windows to improve inside tightness. These two project stages lasted for 9 months. The building's heating system was constructed between the two stages. The advantage of the thermal rehabilitation in two stages can be seen from figure 2, which shows the reduction of the heat needs according to the outside temperature.

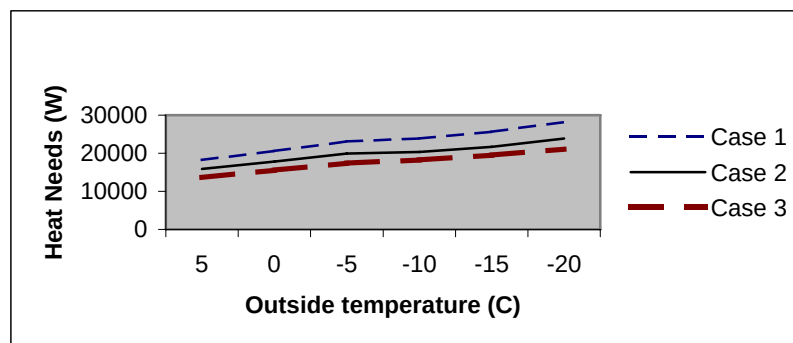


Figure 2: Heat needs according to outside temperature

After having found the heat needs, we proposed a heat pump which can develop a heat power of 18 kW with heat agent R404A using Scroll-type compressors. The heat agent in the installation amounts to 2.5 kg.

As the client wanted to condition the rooms during the hot season, we provided for certain convectors for alternative air conditioning. Special heating elements (towel holders) have been installed in the restrooms, along with standard elements correlated with the temperature provided by the heat pump. Because the installation featured two types of heating elements (convectors and static elements), the installation was fitted with a double circuit, one for each type.

Figure 3 shows the functional scheme of the heat pump. The underground water is taken from well P1 at a temperature of 12°C, runs through the plate heat exchanger SCP and is returned in the ground through well P2 at a temperature of 9°C. The heat pump vaporizer is supplied from a glycol water circuit of 7/10°C which takes over a heat rate Φ_0 . Inside the de-overheater and condenser, Freon R404A is releasing a thermal rate $\Phi_c = 18$ kW and makes hot-tap water at 40/50°C [2].

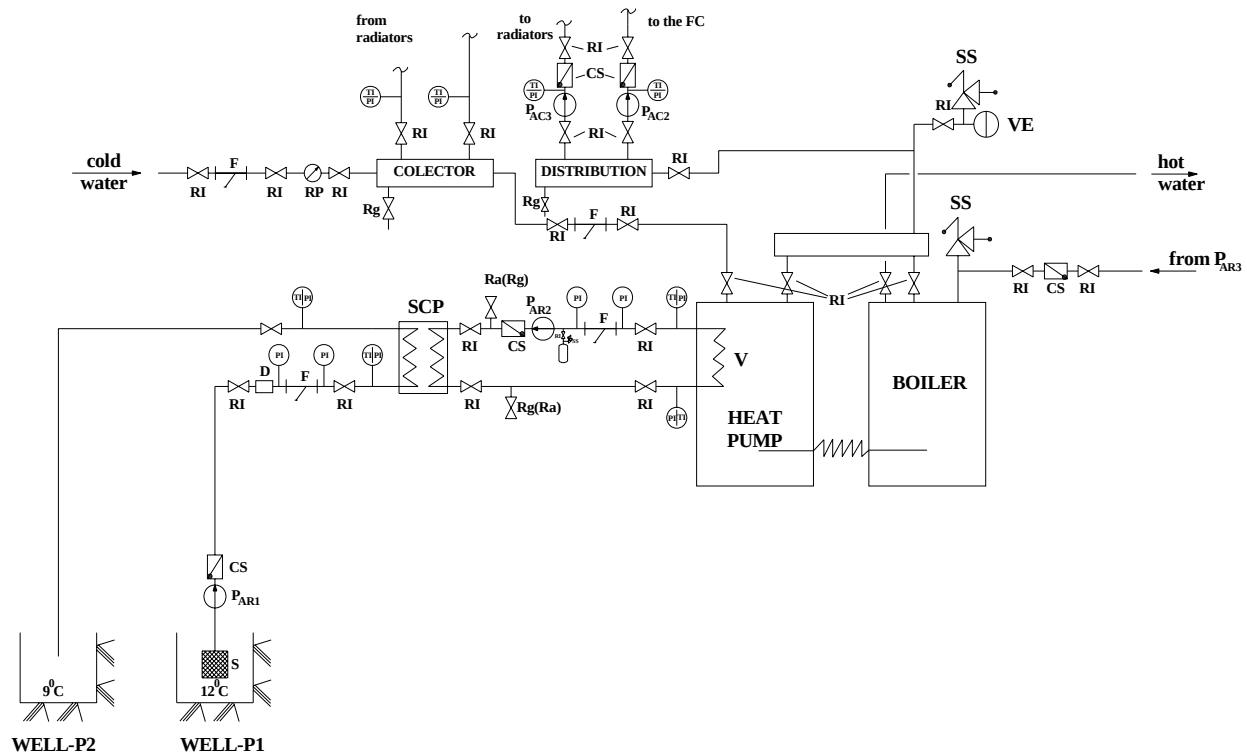


Figure 3: Operational scheme of the heat pump

This circuit supplies the heating elements or the boiler which prepares the hot-tap water (10/45°C). The peak charge appears when the outside temperatures are very low; the heat power of the pump is increased through three electric resistances (3 x 2 kW).

3 ECONOMIC ANALYSIS

A comparison between the investment and 10-year operational costs for various heating systems that would have been installed in our building is shown below.

We considered the following options for calculation:

- Heating system with a boiler on gas fuel (methane);
- Heating system with a boiler on gas fuel (LPG);
- Heating system with a boiler on liquid fuel (gasoil);
- Heating system with heat pump (compressor on electric energy);

The results and the economy achieved over ten years in comparison with the heat pump system are shown in tables 1 and 2.

Table 1: Savings achieved through the introduction of a heat pump (10 years)

Characteristics	System on methane	System on LPG	System on gasoil	Heat pump
Heat power (kW)	24	24	24	18
Fuel calorific power (kW/l)	9,44	6,3	10	1
Boiler / heat pump efficiency	0,9	0,9	0,85	2,33
Hourly consumption (fuel/energy)	2,84	4,23	3,018	9
Operation hours (hours/year)	1700	1700	1700	1870
Fuel price (Euro/year)	0,3	0,5	0,9	0,085
Annual fuel consumption (l/year)	4828	7191	5130,6	16830
Annual fuel cost (Euro/year)	1448,4	3595,5	4617,54	1430,25
Estimated price increase	2,9	1,5	1,5	1,4
10-year costs (Euro)	42003,6	53932,5	69263,1	20023,5
10-year savings with heat pump instead of other heating system (Euro)	21980,1	33909	49239,6	-

As well, if we also want to check the investment return we see that the heat pump provides for the most efficient heat recovery system. The initial additional investment is returned in 2 to 7 years in comparison with the other systems analyzed, as shown in table 3.

Table 2: Investments for various heating systems

Equipment	Amount (heat pump system)	Amount (boiler on methane)	Amount (boiler on LPG/gasoil)
Heat pump	7700	3000	3000
Wells	4900		
Plate heat exchanger	1344		
Pumps	1600		
Gas connection		4300	
Fuel tank			3500
Total	15544	7300	6500
Difference between heat pump and other system	-	8244	9044

Table 3: Is this the pay back time of the heat pump compared with the conventional systems

System	Calculation	Recovery time (years)
Boiler on natural gas	$N = (I_{pc} - I_{cz}) / E_{e_NG}$	5,67 - 3,75
Boiler on LPG	$N = (I_{pc} - I_{cz}) / E_{e_LPG}$	2,5 - 1,67
Boiler on gasoil	$N = (I_{pc} - I_{cz}) / E_{e_L}$	1,95 - 1.30

4 CONCLUSIONS

After comparing the heat pump system with a conventional heating system, analyzing not only the values for energy savings for a 10 years running time but also the values for the pay back time it was concluded that the heat pump system is obviously a better solution. Even if this system has the disadvantage of an initial high investment, the long term advantage is obviously: low impact on the environment and a lower quantity of CO₂ discharged on the atmosphere.

NOMENCLATURE

N – recovery years;

I_{pc} – investment in heat pump;

I_{pb} – investment in boiler;

E_{e_GN} – energy saving between system on methane and heat pump;

E_{e_GPL} – energy saving between LPG system and heat pump;

E_{e_L} – energy saving between gasoil system and heat pump.

REFERENCES

1. Eckert M. – Le nouveau Pholmann – Manuel technique du froid, Pyc Edition, 1991.
2. Drughean L, Hera Dr. – Tehnical project for implementing a heat pump system in a residential house, 2006.
3. Hera Dr. – Heat Pumps for residential use, Instalatorul review, nr 9/2006, ISSN 1223 – 7418, 8 – 14.
4. Le Recknagel – Manuel pratique du genie climatique, PYC Edition.