HEAT PUMPS, HEATING SYSTEMS FOR INTELLIGENS BUILDINGS

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Abstract. *One of the most important research directions in the building sector is reducing the energy consumption. In Hungary the residential sector is the biggest energy consumer with 32% from the total energy consumption of the country. One possibility to decrease the energy consumption for heating is using renewable energy sources. In this paper a short description of the heat pump technology is presented. Also the results of some measurements are shown which were done at the autonomous house build.*

1. INTRODUCTION

The Earth's energy consumption is continuously growing and according to some researchers the fossil fuel reserves of the world are diminished. The environmental pollution is the other important problem. Most the used today's energy sources are not really environmentally friendly, and it is said the Earth is not ours, we borrowed it from our grandchildren only.

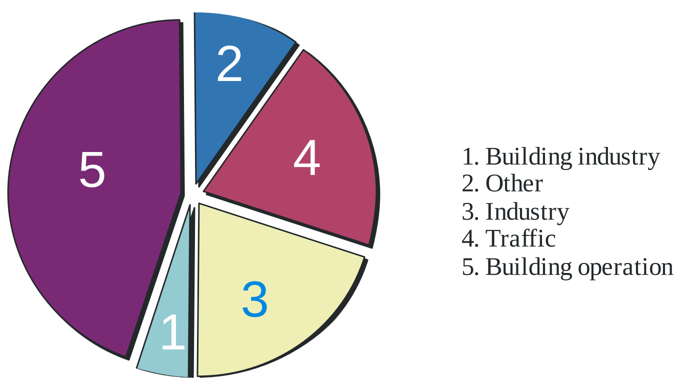

Figure 1. Structure of world energy consumption

As it is shown in Figure 1 we use a huge amount of energy for the buildings operation [8]. This is caused on the one hand by the low thermal properties of our buildings envelope and the other hand by our comfort needs which leads to high energy consumption for heating and cooling.
The number of heating (180) and cooling (45 – t_i =22 ^oC) days in Hungary based on the specific degree-day curve is presented in Figure 2. [5]

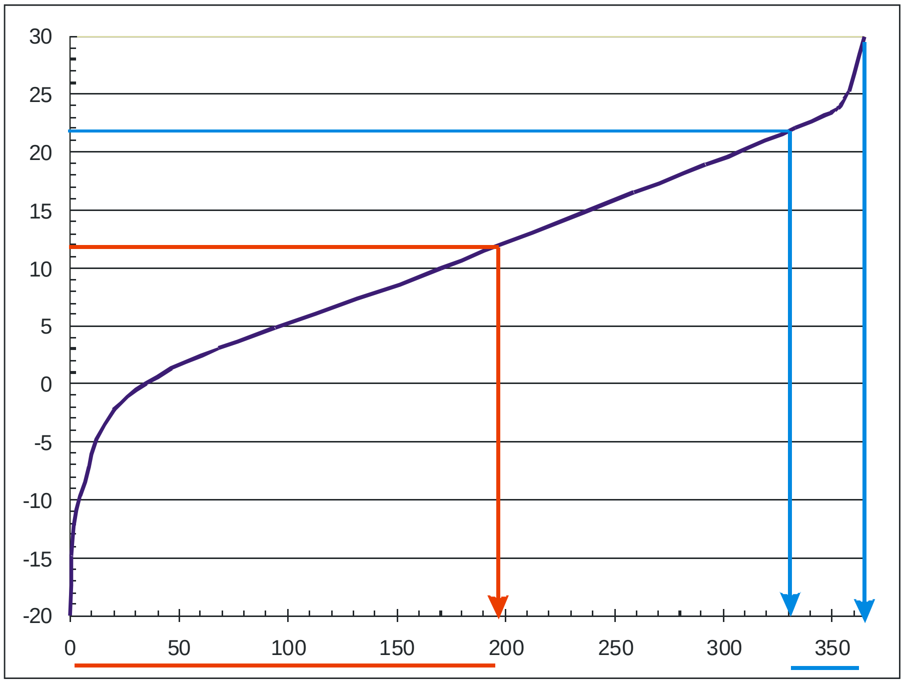

Figure 2. The number of the heating and cooling days in Hungary

A four person family uses about 4500 l fuel oil for heating per year in a single family house which is not insulated properly. The energy consumption of this kind of houses may be reduced with up to 85% after an appropriate refurbishment. The energy obtained from the Earth and the Sun used for buildings energy supply will lead to reduction of greenhouse gas emissions and at the same time our fossil energetic dependency will decrease too. From this reason nowadays is very important that the engineers pay more attention to renewable energy use.

2. HEAT PUMP

The operation principle of the heat pump is practically the same to fridge's, just we used it inversely. A special liquid circulates in the fridge, which takes heat out from the inside and this heat is transmitted to outdoor environment through a heat exchanger placed on the fridge's back.

It is known that the changes of the physical properties of a fluid are described by the following equation:

$$P_1 \times V_1 \times (T_1)^{-1} = P_2 \times V_2 \times (T_2)^{-1} \qquad (1)$$

in which: P – pressure, [Pa]; V – volume, [m^3]; T – temperature, [K].
It can be seen that if we reduce the pressure and/or the volume the temperature will be reduce too in order to keep the ratio constant.
As an example when the pressure decreases suddenly in the siphon cartridge („to whip around") freezes our finger, meanwhile we touch it.

This phenomenon takes place inversely in a heat pump. The water in a pipe which is placed in the soil in a drilled hole will be heated up taking the heat out from the ground and this heat is used to evaporate the special liquid. Then changing the pressure of the obtained gas, this will condensate, giving the heat to the heat carrier used in the heating system.

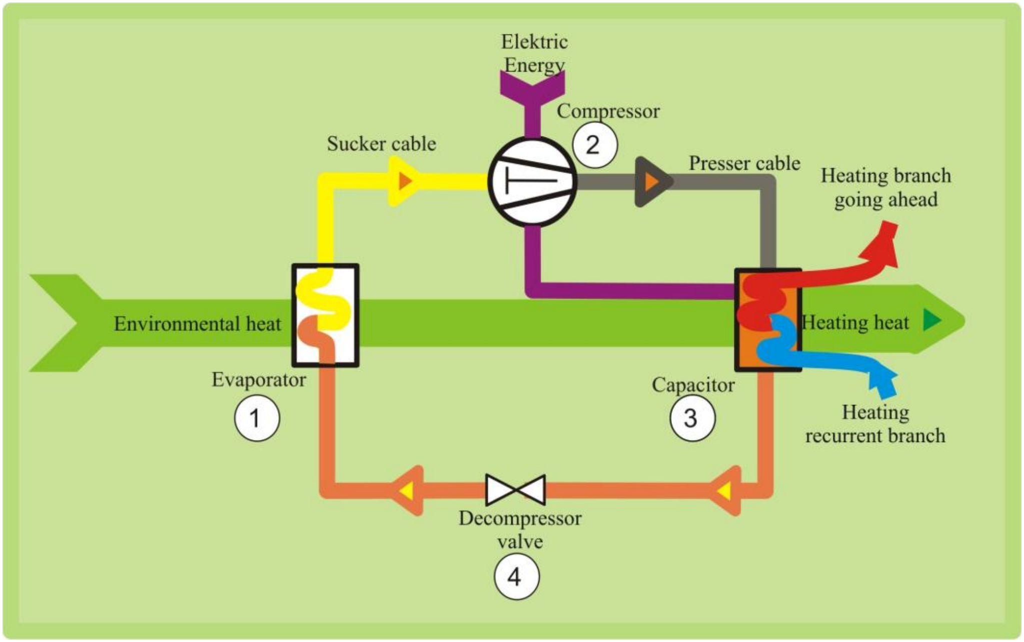

Figure 3. The operation principle of the heat pump

The process can be inversed. During the hot summer days the liquid takes out the heat from the building and transmitted it to the ground. Compared with heat pumps systems the absorption cooling is less known, which can be operated with waste heat.
Heat source can be the air, the ground and water. The advantage of the air source is that the investment costs are lower, however because of the low heat capacity of the air high air flows are needed and at the same time due to the variation of the air temperature the heat output is not constant. Nowadays using the known refrigeration medium we can obtain heat from air having -15 ^oC.
If the heat source is the ground water the investment costs are higher but system operation will be better because the temperature of the water is independent on the seasons. Using this solution we can obtain heat carrier at 55 ^oC temperature.
Based on this temperature limits it can be said that low temperature heating systems have to be used, as [6]:

- floor and wall heating;
- fan-coil heating;
- higher radiator surfaces.

The efficiency of the system may be characterized by the COP (coefficient of performance), which show as the ratio between the heat delivered by the heat pump and the power consumption of the heat pump. For example of COP=4.4 than for a heat demand of 10 kW the consumed power will be 10/4.4=2.27 kW. The value of COP varies depending on the environmental conditions.

The SPF (seasonal performance factor) is the annual corrected value of COP. The COP gives the ideal value of heat pump's performance, while SPF is a little bit critical value which contains:

- the effects of temperature variation of the soil caused by seasons;
- seasonal variation of the heating and cooling demand;
- melting phases.

The SPF gives the possibility to compare the traditional heating systems with those heating systems where the heat source is the heat pump.
In Hungary the geothermal energy is used mostly in thermal swimming pools (SPA), thus we have high potential of geothermal energy (around 30,000 MW).

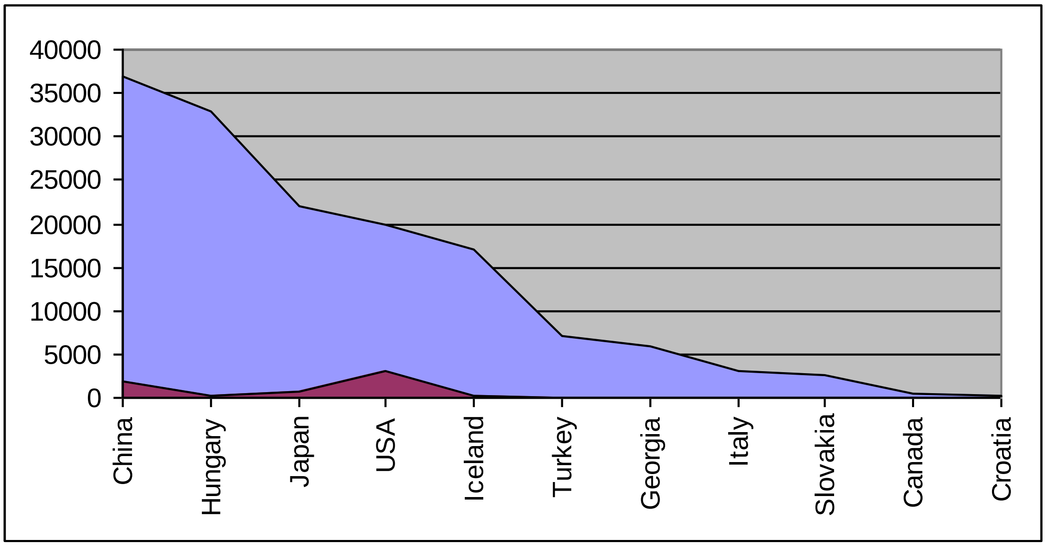

Figure 4. The geothermal capacity in different countries

The low curve shows the exploited heat quantity in which the balneology and energy are both included. Taking into account the exploited geothermal energy Hungary is on the 7th place in the world. If we use 1/10 of the capacity (3,000 MW), the yearly energy produced covers 26.28 TWh energy demand. The power consumption of Hungary in 1998 was 35.3 TWh.
Obvious and applied procedure, that it is possible to use the different alternative energies collectively, for example, solar collector and heat pump. In this case until the solar collector can deliver enough heat the heat pump will be stand by operation mode. Than the stored heat decreases under the demanded value the heat pump switched on and delivers the difference.

3. VERTICAL CLOSED LOOP

A vertical closed loop field is composed of pipes that run vertically in the ground. A hole is bored in the ground, typically, 30-150 m deep. Pipe pairs in the hole are joined with a U-shaped cross connector at the bottom of the hole. The borehole is commonly filled with a bentonite grout surrounding the pipe to provide a good thermal connection to the surrounding soil or rock to maximize the heat transfer. Vertical loop fields are typically used when there is a limited square footage of land available. Bore holes are spaced 5–6 m apart and are generally 15 m deep per kW of cooling. During the cooling season, the local temperature rise

in the bore field is influenced most by the moisture travel in the soil. Reliable heat transfer models have been developed through sample bore holes as well as other tests.
Having a drilling well this can be used efficiently as geothermal energy source, especially in the case the water temperature is up to 7 ^{o}C. In this case a heat pump must be inter-connected between the heating system and the heat source. Other possibility is to store the heat during the summer in the ground and take it out in the winter. The obtained energy quantity depends mainly on the soil type:

The soil	Obtained energy
Dry, sandy subsoil	: 20 W/m
Stony or wet-sandy subsoil	: 50 W/m
Stony, rocky, good thermal conductor subsoil	: 70 W/m

4. THE ING-REORG AUTONOMOUS HOUSE

An autonomous house was built up in Debrecen. The aim was, to heat the rooms with environmental friendly solutions. Having this goal solar collectors, vertical closed loops, heat pumps and ventilation with heat recovery was built-in.

Naturally the conception of the building leads to minimal heat losses. They made use of the best building materials, insulating materials of our days and the most modern fenestrations are found in building. The hot water is prepared with solar collectors and the supplementary energy is stored in storage tanks.

Around the building several vertical closed lopps were placed, temperature sensors can be found on these pipes in differing depth. These vertical closed lopps cover the heating of the building. The operation of the system in summer and winter time is oresented in Figures 6-7.

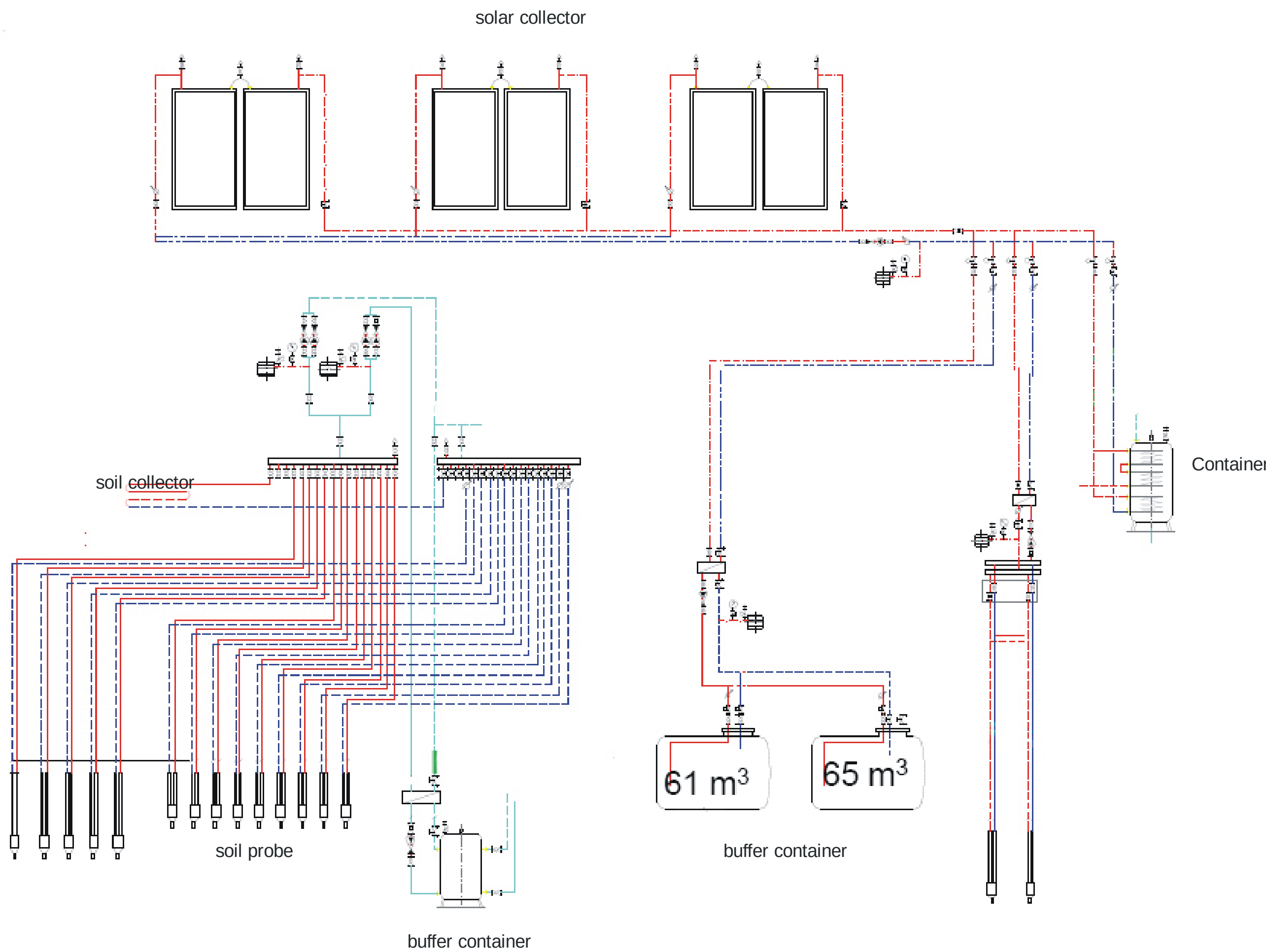

Figure 5. Summer operation mode

Inside the system several sensors (temperature, quantity of heat, pressure) were placed. These sensors at given time intervals send signs to the central computer, which register these data all day continously. We have an opportunity to study the system.

The main goal of the project is the accomplishment of detailed measurements and after the assessment of collected data the COP of the system has to be determined. My interest was to analyse the temperature gradient in the ground around the vertical closed lopps.

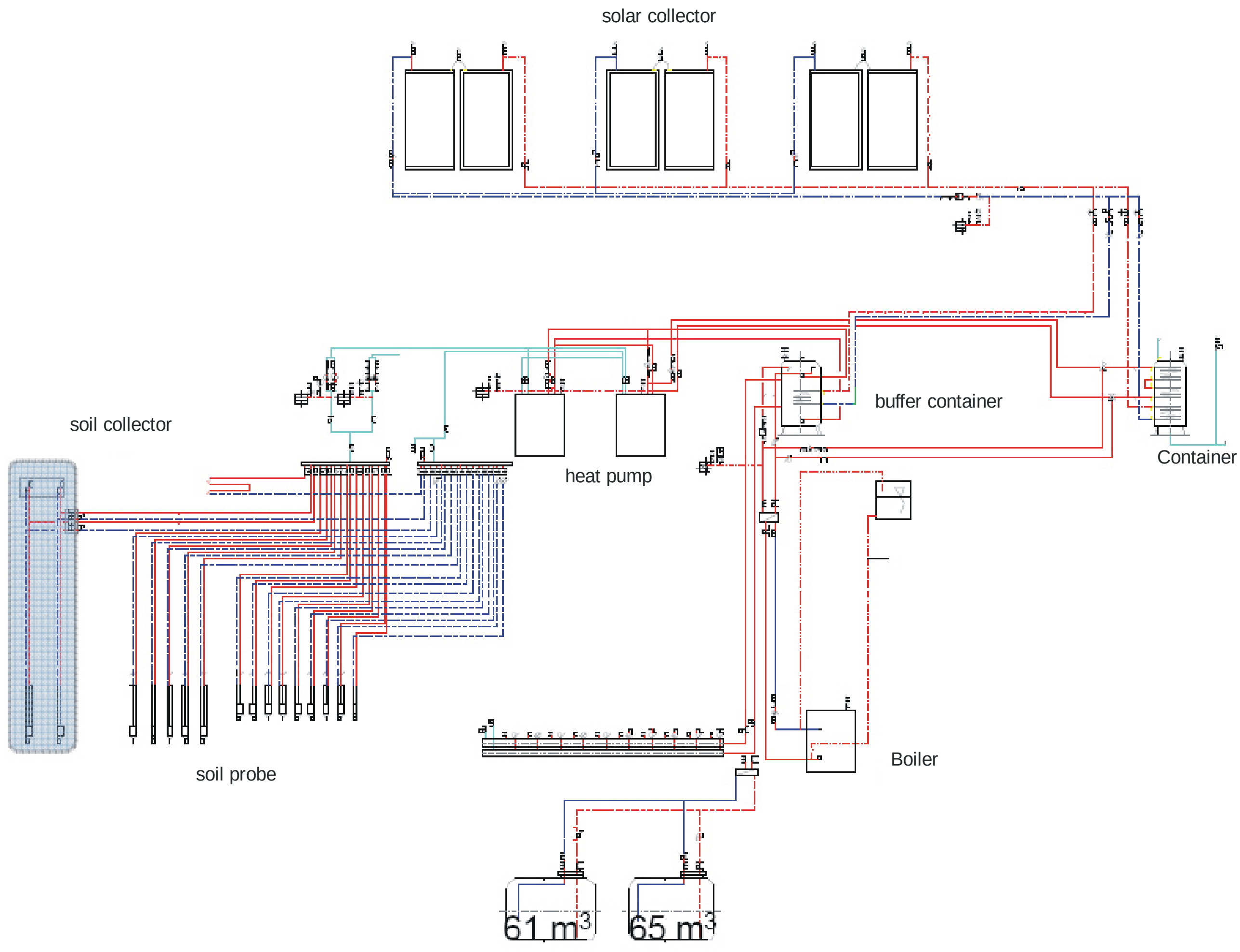

Figure 6. Winter operation mode

I have observed that at a 25 m deepness the temperature is constant (14 ^oC) while at lower deepness (2.5 m) the temperature varies according to seasons between 11-17 ^oC. The diagram presented in Figure 8 shows the mean values of 6 month of measurements.
Obviously the temperature values depend on the soil type, water content and climate but the main tendencies can be seen.

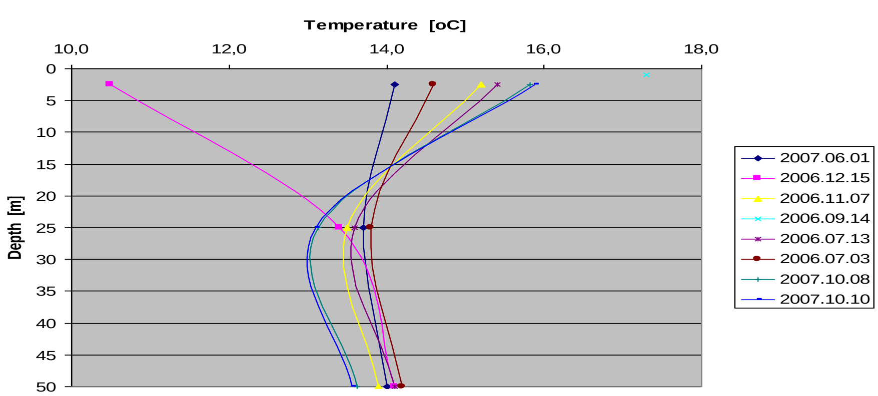

Figure 7. Temperature gradient

5. CONCLUSIONS

In Hungary the average outdoor air temperature in the 2006 year heating season was +4 ^{o}C. The COP value for air-water heat pumps is given for +2 ^{o}C which means that in Hungary in 2006 the COP of these type of heat pumps was higher. With 1 kW power 2.6-3.5 kW heat can be produced. The better energy saving possibility is the heat pump because is environmental friendly which produce heat at lower costs than boilers based on traditional fossil fuels. Combining heat pumps with collectors the efficiency can be further increased.

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