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Geothermic Energy in Energy Supply in Hungary

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ABSTRACT

The aim of the article is to focus on the exploitation of geothermic energy in energy supply, primarily in heat supply in reflection of the most important parameters of geothermic facilities in Hungary.

1. INTRODUCTION

The principal task of mankind - besides sustainable environment and development - is to perform best in order to minimize the increase of consuming fossil primer energy sources. This is necessary for environmental protection and also because the amount of the yet uncovered fossil primer energy sources is limited.

On 3rd, February, 2009, attitude of the European Parliament on the topic called 2nd Strategic Supervision of the Energy Politics confirmed the decision of 23rd, January, 2008, which states that by the Year 2020 it is advised to reach 20 % decrease of the emission of greenhouse gases, minimum 20 % decrease of energy consumption and 20 % share of the renewable energy sources from final energy consumption. Furthermore the MS of the European Union were requested to make their energy consumption most effective in order to play an active role in decreasing emission of greenhouse gases at least by 80 % by the Year 2050. The European Parliament requested the parliamentary Technical Committee to conciliate with all the partners involved and to elaborate a detailed energy scenario that demonstrates the possible solutions of the objectives and their technical and economical assumptions.

Table 1. shows the portion of the renewable energy sources in energy supply in some countries of the EU based on data from the Year 2005 and the requirements for the Year 2020.

Table 1: Requirements of the EU: the % proportion of the renewable energy sources of total final energy consumption

	2005 (%)	2020 (%)
Sweden	39,8	49,0
Romania	17,8	24,0
France	10,3	23,0
Germany	5,8	18,0
Poland	7,2	15,0
Great-Britain	1,3	15,0
Slovakia	6,7	14,0
Czech Republic	6,1	13,0
Hungary	4,3	13,0
Malta	0,0	10,0
EU altogether	8,5	20,0

In 2007 the primer energy consumption of Hungary according to Hungarian Energy Office database was 1.125,5 PJ, of which 62 % was imported. 79,3 % of the consumed primer energy sources was combustion medium, while 5,2 % was the renewable energy sources (57,8 PJ) and 15,5 % was the primer electric energy. About 70 % (794,3 PJ) of the primer energy were delivered to the final consumers of which 29 % (232,5 PJ) is the domestic use – as the main consumer. 4 % (34,1 PJ) is the renewable energy sources of the final energy consumed.

In 2007 only 6,4 % of the total renewable primer energy sources (58,7 PJ) was geothermic energy.

2. MOST IMPORTANT PARAMETERS OF HUNGARY'S GEOTHERMIC FACILITIES

The average value of the geothermic gradient on Earth is 30 ˚C/km. This value reaches 50 ˚C/km in average in Hungary. The maximum values are close to 60 ˚C/km concerning the total drillings and the conductive heat flow density is 100 mW/m^2.

From sandstone in 1200-2500 m depth maximum 100 ˚C, from limestone in 3200 m depth max. 150 ˚C, from 1000 m deep water aquifer 55-75 ˚C is the available water temperature. The exploited water amount of a pit is 200-3000 m^3/day, in energetic 30-80 m^3/hour output of well can be calculated. (Szita G., 2009).

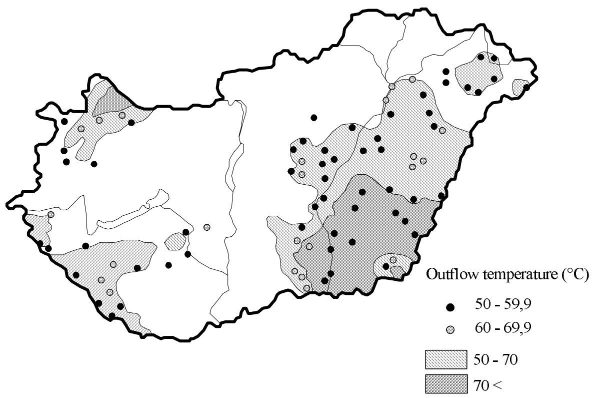

Figure 1: Outflow temperatures of thermal water from porous reservoirs' pits (Liebe, 2007)

Although Hungary has significant geothermic energy known worldwide, the heat flow density value and the geothermic gradient value are high, there are no large enthalpy geothermic fields in the country. According to deep drillings in most areas of the country 200 ˚C rock temperature can be reached in 3000-5000 m depth, which means the crystal or carbonate rock aquifers in most cases. (Dövényi – Horváth, 1988).

In the beginning of 2007 in Hungary 1409 pits existed, of which 947 pits were thermal water producing with more than 30 ˚C outflow temperature. 50 % of the these pits were used for balneology purposes, 23 % were used for agricultural purposes and 20 % were involved into water supply utility service. Only 5 out of the pits operating have greater then 100 ˚C outflow temperature. (Liebe, 2007).

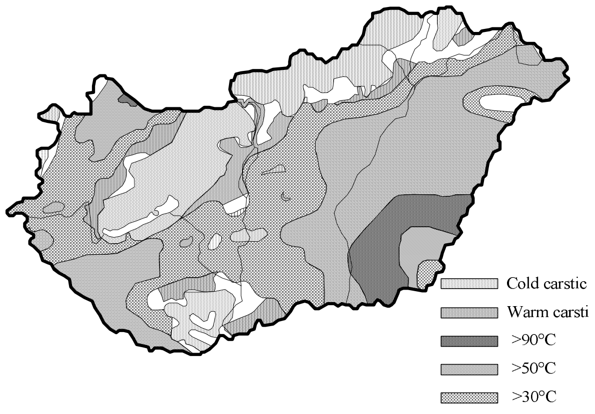

Figure 2: Combined thermal water map (Szita, 2009)

3. GEOTHERMAL ENERGY IN HEAT SUPPLY

The possible usage of the geothermal energy is based on the temperature and enthalpy of the exploited fluid. The utilization of geothermal energy has two main fields in energy supply: power production and heat utilization.

Low temperature thermal water utilization for direct power and heat/power energy is not effective even among optimal conditions. According to presently known technologies the real efficiency is about 10 %. However the low enthalpy fluid can be used in power production – e.g. for preheating the supply water of gas turbines, or for cooling the comprimed air of gas/steam combined cyclic power plant. (Böszörményi, 2008)

Geothermic energy lower than 90 ˚C temperature can be exceedingly used in central heat supply. The usage can possibly work with or without thermal water exploitation.

The 10-15 ˚C low temperature systems without exploitation are the 50-150 m deep ground source heat pumps. Heat pumps also can be used in case of exploitation of 10-30 ˚C temperature thermal water. If the exploited thermal water temperature is high, then at the end of the procedure heat pumps are also used before reinjection of the 20-40 ˚C temperature thermal water. In Hungary regarding the systems without exploitation the ground source heat pump systems have been built so far.

3.1 Heat Utilization with Exploitation of Thermal Water

The centralized heat supply with thermal water can be as follows:

– *Directly*, when thermal water has favourable physical and chemical qualities, has no corrosion effect to pipes and equipment and the thermal water is not inclined to precipitate formation. In this case thermal water is directly transported to final consumer. Buildings can be heated directly and hot water equipment can be supplied directly by thermal water.

– *Indirectly*, when thermal water has unfavourable physical and chemical qualities. In this case thermal water occurs as primer fluid in heat utilization and a secondary fluid transports the heat to the consumer by an installed heat exchanger. In this case consumers are basically: heating systems, domestic hot water producing systems, absorption and adsorption chillers.

The geothermic systems based on the thermal water cycle and connection of the utilization system can be the followings:

– *Opened system*, when the thermal water – after exploitation and utilization – is transported directly into water reservoir or drain. The thermal water is transported to the consumer by its own pressure or by pumps and reaches water reservoir after cooling down. After heat retrieval, environmental and economical aspects of thermal water – as water is still warmer then its surroundings and contains solutes – must be calculated.

– *Closed system*, when the used thermal water is reinjected into its aquifer by pressure. Some technical books use the term ‘closed system heat mining’ when the heat energy of the natural reservoir is exploited and brought to the surface by fluid, circulated in a separate secondary system. (Halász, Kozák, Kalmár, Budai, Papp, 2008) In this case the pressure of the aquifer is barely reduced, the solute content of under surface water does not or minimally changes and stays unrevealed thus there is no corrosion and incrustation in pits and heat exchangers. (Kovács-Kozák, 2007).

In Hungary the salt and chemical content of the exploited thermal water does not allow direct heat utilization. Thermal water exploited exclusively for energy utilization purposes must be reinjected according to 219/2004. (VII.21.) Government Edict – therefore the opened system is not a suitable solution.

3.2 Possibilities of Geothermal Energy Utilization in Extant and New District Heating Systems

We are trying to find solutions to involve usage of low temperature thermal water in district heating, thus the fossil energy source can be partly or fully replaceable.

Establishing the Hungarian district heating systems started in 1960-s along with urbanism, with the high amount of industrialized house production, panel technology and the highly populated housing estates. Between 1970 and 1990 95 % of the district heated buildings were established. Today in 104 settlements 650.000 flats are supplied by district heating in Hungary. This number is 17 % of the total number of flats in the country. 2-2,5 million people are living in district-heated homes, which is 20-25 % of the total population. The number of the district heating systems is 250. 85 % of the district-heated flats were built with prefabricated elements, panels, and industrialized technology.

The partial reconstruction procedures of the present systems are continuous since 1996, because the systems – as well as in other Central European and Eastern European countries – reflects the technical standards, system requirements and the lack of financial sources of that time. The heat production was mainly carbon hydrogen based. The heat/power stations are supplied primarily with heating oil and natural gas, while the heat stations are supplied primarily with natural gas. According to statistical data from 2007, 7 % of final energy consumption is district heating, of which 71 % is produced in heat/power stations, were heat is produced, combined with power production and only 29 % is produced in heat stations.

The present district heating systems are two-piped-systems, with hot water primer fluid. The nominal temperature drop of primer fluid is maximum 135/75 ˚C, minimum 90/70 ˚C; in summer: 60/40 ˚C as only domestic hot water usage is supplied. The nominal temperature drop of the secondary side heating systems is 90/70 ˚C, or 85/65 ˚C. The temperature of the produced domestic hot water is max. 50 ˚C. The consumer systems are basically one or two-piped vertical systems with radiators.

Assume that a gas boiler of a heat station produces the heat supply (heating and domestic hot water) of the building. The radiator heating system was calculated and designed with 85/65 ˚C temperature heating fluid and the temperature of the fluid is controlled according to outdoor temperature. Assume that the heating balance point temperature of the building is 12 ˚C, in which case the number of heating days in Hungary is 195 days per year. The temperature of the potentially available thermal water is not greater then 65 ˚C. If nor the reconstruction of the building and neither the reconstruction of the heating system has been executed, then only the hot water supply can be supported by thermal water all year long. For supplying the heating an additional gas operated heating system is also necessary. The temperature controlling diagram of the flow heating fluid depending on the outdoor temperature is described by the following equation:

$$t_e = \left(\frac{t_i - t_a}{t_i - t_{a,N}}\right)^{\frac{1}{1+m}} \cdot \left(\frac{t_{eN} + t_{vN}}{2} - t_i\right) + 0{,}5 \cdot \left(\frac{t_i - t_a}{t_i - t_{a,N}}\right) \cdot \left(t_{e,N} - t_{v,N}\right) + t_i \quad (1)$$

With a similar equation the temperature controlling diagram of the return heating fluid can be determined:

$$t_v = \left(\frac{t_i - t_a}{t_i - t_{a,N}}\right)^{\frac{1}{1+m}} \cdot \left(\frac{t_{e,N} + t_{v,N}}{2} - t_i\right) - 0{,}5 \cdot \left(\frac{t_i - t_a}{t_i - t_{a,N}}\right) \cdot \left(t_{e,N} - t_{v,N}\right) + t_i \quad (2)$$

Where t_i, t_e, t_v, N, m are internal temperature, external temperature, return heating medium temperature, nominal calculation value, radiator parameter value – 0,16 in our calculation example.

On controlling diagram (Figure 3) – a result of equation (1) and (2) – apparent that above 0 ˚C outdoor temperature, the temperature of the flow heating fluid must be below 60 ˚C.

Knowing the temperature distribution function (Figure 4) it is apparent that below 0 ˚C outdoor temperature occurs on 35 days out of 195, therefore it can be stated that thermal water for building heating is utilized in 82 % of the heating period.

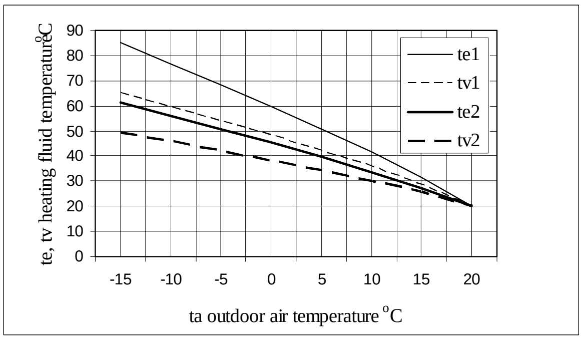

Figure 3: The temperature diagram of the flow and the return heating medium depending on the outdoor temperature

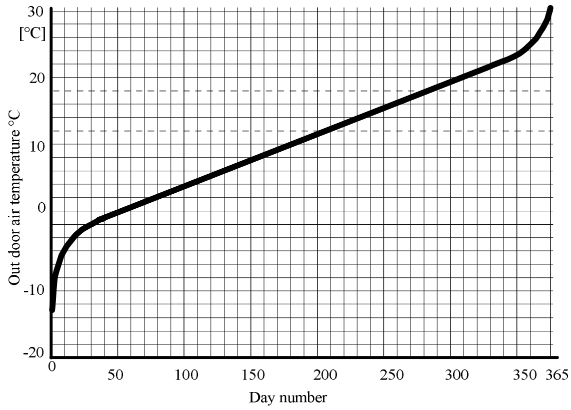

Figure 4: Hungary's temperature distribution function (Fekete, 1985)

When thermal water is involved into heat supply through heatcentrals connected to great district heating systems and the extant heatcentral is an indirect type, the mass flow rate of the primer fluid is altering, its nominal heat temperature is 125/70 ˚C, in summer it is 60/40 ˚C. The nominal temperature of the secondary side heating systems is 85/65 ˚C. The simplified connection schema of the present and suggested technical solution is shown on Figure 5 and Figure 6. In order to cooling down more the thermal water, the hot water is produced by preheater and reheater.

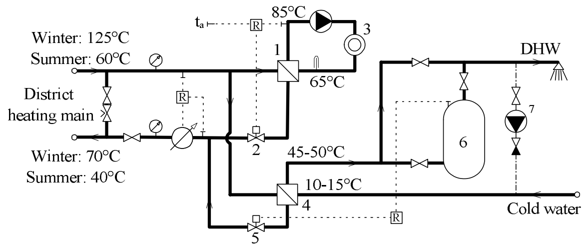

Figure 5: Heatcentral connected to the extant district heating system (1 heat exchanger, 3 secondary heating system, 4 hot water heat exchanger, 6 domestic hot water storage, 2, 5 primer side control equipment)

According to 91/2002 Directive of European Committee and European Parliament, Hungary has determined new energy regulations in 'TNM 7/2006' Hungarian Ministerial Order. In case of reconstruction and designing new buildings these regulations are to be taken into consideration. Reconstructions of panel building are being executed according to this edict nowadays. The specific energy consumption need of the panel buildings in Hungary is between 100-190 kWh/m^{2}a. As a result of a extra heat insulation of the buildings and the exchange of façade windows the heating needs can be decreased by 40-45 %, while the annual heating energy consumption can be decreased by up to 50 % (Kalmár, 2004). If the heaters remain still meanwhile this procedure, as a result of the 40-50 % reduction of heating needs the relation of the necessary temperature of the heat fluid and the load factor can be determined by the following equation:

$$\varphi = \frac{\dot{Q}}{\dot{Q}_N} = \left[\frac{\Delta\vartheta_K}{\Delta\vartheta_{K,N}}\right]^{1+m} = \left[\frac{\dfrac{t_e - t_v}{\ln\dfrac{t_e - t_i}{t_v - t_i}}}{\dfrac{t_{eN} - t_{vN}}{\ln\dfrac{t_{eN} - t_i}{t_{vN} - t_i}}}\right]^{1+m} \tag{3}$$

Where φ is the load factor that is the relation number of every time heat flow and nominal (calculus state) heat flow (Halász, 2001).

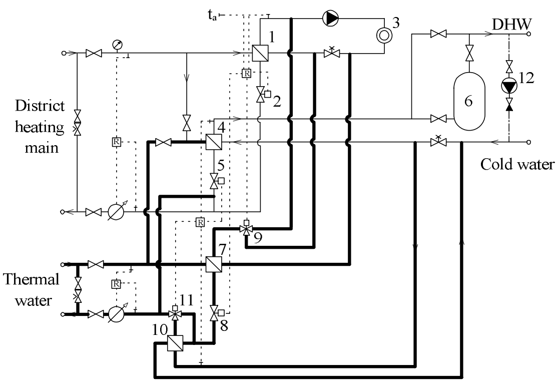

Figure 6: Heatcentral integrated with thermal system (10 domestic hot water pretheater, 5 domestic hot water reheater, 7 thermal water primer fluid heat exchanger, 9 changervalve, 2, 5, 9, 11 primer side control equipment, 1,4 remaining heat exchangers)

The control diagram has changed as well. (Figure 3, t_{e2}, t_{v2} values). The diagram proves that the thermal water can supply also hot water production and heating needs all year long.

Because of the different building physic parameters of the existing buildings there are different amounts of heating needs decrease during reconstructions. Therefore different heating fluid temperatures are taken into consideration during the calculation period.

Table 2: nominal heating fluid temperatures depending on the heating needs decrease

Decrease of heating needs (%)	te_N (oC) (flow)	tv_N (oC) (return)
25	70,39	55,39
30	67,40	53,40
35	64,40	51,40
40	61,36	49,36
45	58,30	47,30

If the existing heating system of the district-heated building is antiquated not only regarding the technical and energetic requirements, but also its physical condition, the complete reconstruction of the building service system is required. In this case there is a possibility to create a system where it is assured that the building has a larger comfort level. There is a possibility to deal also with the cooling of the building after the reconstruction. In Hungary if the cooling balance point temperature of a building is 18 ˚C, then the number of cooling days is about 90. (Figure 4). The actual number of cooling hours depends on the outdoor temperature but also depends on many other circumstances like: number of sunshine hours, altering and non-average interior heat load, whether the building is used continuously or periodical, whether the building is ventilated at night. (Halász, Kalmár, Hámori, Marcsó, Csiha, 2005).

In panel buildings with 4-5 cm thick additional heat insulation in the floors of flats above each other we can create circumstances for low temperature radiant slab heating. The low temperature heating system is a favourable energetic solution, furthermore it also allows larger rate of cooling down of thermal water. The practical construction of low temperature heating system is to be also convenient for cooling. A radiant heating-cooling system is favourable to cooling equipment as it allows the usage of higher temperature chilled water. Similar possibilities are given during designing new residential districts.

In Figure 7 there is a connection drawing of a suggested technical solution. The drawing is a simplified schema of a thermal water operated heatcentral. The temperature of the thermal water is no greater then 65-85 ˚C. The consumer system (3) is a radiant heating-cooling system. The heat exchanger (1) produces the low temperature secondary heating fluid, which is controlled according to the outdoor temperature by flow regulation valve (2). The heat exchanger (1) and the preheating domestic hot water producing system (7) are in series connection because of the larger rate of cooling down of thermal water. The reheater (4) is supplied by a regulation valve and it is in parallel connection. Domestic hot water tank (6), circulation pump (25). Heat exchanger (10) provides heating fluid for adsorption chiller (12). Equipment (11) is the puffer tank for heating water. It provides cooling water through cooling tower (14) and heat exchanger (13). The chilled water reaches the consumer through a puffer tank (15), a two-way regulation valve (17) and a chengervalve (16).

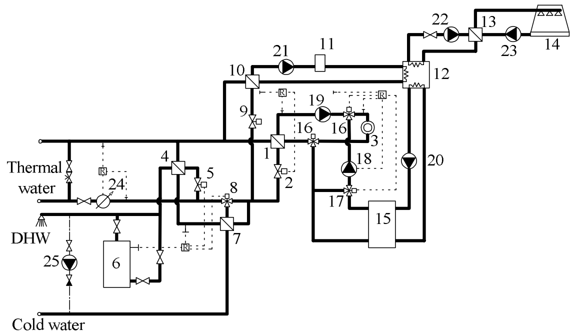

Figure 7: Simplified schema of a heatcentral connected to thermal water

4. CONCLUSION

Utilization of geothermal energy – including district heating and cooling – can only be evaluated when the complete energy supply of the country is known. In Hungary the heating is basically based on natural gas while cooling is based on compressor refrigerating machines using electric power. The consumed electric energy used for cooling is based on natural gas as primer energy source; therefore it is practical to consider utilization of geothermal energy as replacement energy of natural gas in this special case. We are appropriate if we take into account – in our calculation – the primer natural gas usage for bringing to surface the thermal water, transporting it, reinjecting it to aquifer, operating the sorption equipments – pumping work, operating pumps with electric energy. It is also important that if a procedure is not effective due to today's technical level, energy prices and investment costs, may be an affordable and well-running solution in some years considering possible technological improvement and changes of circumstances.

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