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GEOTHERMAL HEATING PROJECT – ŽIAR NAD HRONOM (SLOVAKIA)

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ABSTRACT

Results of the geological research and investigations ranks the territory Slovakia, according the geothermal activity (Muffler, 1976), to the over average regions. The Žiar intravolcanic depression (Fig. 1) has very favorable hydrogeothermal conditions. In the middle of this depression lies the town of Žiar nad Hronom with 27 000 inhabitants. Until this time the heat consumption is covered with central heating system based on coal and with small system based on gas. The boiler station, which is installed in the ZSNP Aluminum plant, needs reconstruction and also is necessary to change the heating medium (coal) so the project of geothermal energy utilization as the substitution of existing system started to be created in the year 1995. During the years 1995 – 1996 the geophysical and geological survey was done. The feasibility study was worked out with Danish company in the year 1997. Several alternatives were solved in this study. It is assumed to be drilled 2 exploitation and 2 reinjection wells with total yield 150 l/s (pumping) with well head temperature 90 – 95 °C. The total investment of the project is ca 20 mln. USD. The payback period is about 6-7 years. After 3 years of implementation with the geothermal energy, it will be covered 75 – 80 % of total heat demand (949 TJ/year). The first drilling was finished in 1999.

1. INTRODUCTION

According to the mean value of heat flow density (q = 82 mW/m^2) the geothermal activity in the territory of Slovakia is quite higher. Similar the mean value of geothermal gradient is higher than world average (ca 38 °C/km). Temperature at the depth 1000 m is in the range from 20 °C in the Komárno high block to the more than 70 °C in the South Slovakian and East Slovakian basin.

Geothermal energy was considered in energy planning (Slovak Energy conception) for the Slovak Republic. The present situation in the geothermal energy utilization is shown in the table 1.

Table 1. Summary of geothermal direct heat uses (Franko, 1999)

	Ins. Ther. Power [MW_t]	En. Use [TJ/yr]
Space heating	15.2	277.5
Bathing and swimming	34.7	548.6
Agricultural drying		
Greenhouses	22.5	355.4
Fish and other animal farming	2.3	36.2
Snow melting		
Air conditioning		
Other uses [specify]		
Subtotal	74.7	1217.7
Heat Pumps	0.5	26.2
Total	75.2	1243.9

not included are the natural springs mainly in spa used for heating and bathing. The installed thermal power then reached more than 100 MW_t.

Renewable energy sources (RES) covered in the 1997 only 3.33 % from the total energy demand. The total technical utilizable potential of RES is 100 400 TJ/year
Development program up to year 2010 created for the RES the two scenarios:

- The total energy production from RES according to year 1997 will increase to 63 % (1st scenario) and to 133 % (2nd scenario).
- The heat production will increase 2 x (101 %) in 1st scenario and 3 x (213 %) in the case. of 2nd scenario

According to geothermal energy the installed power in the year 2010 can reached more than 200 MW_t
In this amount of utilizable energy is also included the project of geothermal energy utilization in the town of Žiar nad Hronom.
The town of Žiar nad Hronom lies in the middle of Slovakia in the Žiar depression (Fig. 1). Žiar nad Hronom with 27 000 inhabitants is the center of cultural, social and industrial life in this region. In the town is also one of the greatest industrial corporation in Slovakia the "ZSNP Aluminum plant". In the present time there are different heat consumers. ZSNP and surrounding factories are supplied with heat from co – generation unit based on black coal from boiler station installed at ZSNP plant. In the town there are 2 individual systems of central heating. One is supplied with hot water from ZSNP boiler station and the second small system is based on delivery of gas. The boiler station in the ZSNP plant burns the black coal and the emissions of contaminates is so high, that they do not fit the standard of the new environmental legacy. Also the equipment in the station are old and must be replaced or renewed. Due to fact that air pollution in this region is one of the highest in the Slovakia it was necessary to supply the new heating system from the renewable sources of energy. Based on the former investigations in this basin the new geophysical and geological survey was done in this area to define the hydrogeothermal conditions, mainly for the location of geothermal wells and to define the input parameters for the whole project. Following the feasibility study (Houe & Olsen, 1997) the first well was sited and started in the beginning of 1999.

2. HYDROGEOTHERMAL CONDITIONS

The Žiar basin belongs to the territory of the Central Slovakian Neovolcanics (Neogene volcanic) which occupy an extensive area in the center of the Inner West Carpathians. Geothermal activity in the area is suggested by a multitude of natural

thermal springs. This activity has considerably increased and ranges from 74.0 to 109 $mW.m^{-2}$ averaging 94.3 $mW.m^{-2}$ (Franko et al., 1995). Temperature field at a depth of 1000 m has a quite different pattern with several centers of the high or low temperatures. The highest temperatures, between 50 – 70 °C, have been recorded in depressions (Žiar and other basins), whereas the lowest ones, between 35 – 40 °C, occur in the crests of mountain ranges.

2.1 Geophysical survey

According to complicated surface (aluminum plant, railway etc.) and subsurface (tectonic, neovulcanic) conditions three geophysical methods, DC sounding, gravity and magnetometry survey, were applied in the area of Žiar nad Hronom (Houe & Olsen, 1997). From the geophysical methods the aims of this project were divided as follows:

- estimation of total thickness of tertiary vulcanic-sedimentary filling of Žiar basin
- estimation of depth and topography of pre-tertairy substratum
- tectonic formula of Žiar basin
- identification and place of volcanic bodies and sediments in filling of Žiar basin
- estimation of resistivity distribution in filling of Ziar basin to depth 1 km (to have information of lithological composition of volcanic-sedimentary filling)

2.2 Hydrogeothermal setting in the surroundings of Žiar nad Hronom, geothermal wells proposal

The geological, geophysical and hydrogeothermal assessment (Remšík et al., 1997) have shown that the most favorable area, in respect of occurrence of potential geothermal waters aquifers at suitable depth level (depth of borehole 2000 - –500 m) is in the SE part of Žiarska kotlina depression, around the town Žiar nad Hronom.
The Triassic carbonates, as geothermal water aquifers, crop out at the surface in the area of Bukovec triangular point, from where they dip below the Neogene volcanic rocks and continue in a form of a cascade towards NW and terminate at the SE boundary of the Žiarska kotlina depression. The accumulation of geothermal waters is associated with the depressions, while the springs with higher elevations. The basement of the Neogene volcanic rocks is formed by limestones and dolomites and is also assumed that Mesozoic rocks occurs in the Žiarska kotlina depression below the Tertiary filling. This assumption is supported by the borehole ST – 4 situated between spa Sklené Teplice and Žiar nad Hronom. This well intersected the Triassic carbonates in the depth interval 1448 – 1820 m. The presumed distribution of Triassic carbonates in the Tertiary basement of Žiar nad Hronom area is in a belt running roughly SW-NE between the margin of Štiavnické vrchy hills and the Hron river. In this belt the Triassic carbonates are fractured by faults running SW-NE towards a block cascade located at a depth of some 2000m. The step-like cascade of sunken blocks of Triassic carbonates is cut by yet another system of N-S striking faults, in which the blocks moved along each other. The geothermal field of the interests area is characterized by the following temperatures: 50 – 54 °C (1000 m depth), 80 – 85 °C (2000 m), 92 – 98 °C (2500 m), 105 – 111 °C (3000 m). The heat flow density ranges between 80 – 100 $mW.m^{-2}$ (Franko et al., 1995). In this area should occur similar waters as in the borehole ST – 4 (yield 15 l/s, well head temperature 53 °C, TDS ca 2,5 g/l, Ca – Mg – SO_4 type. The temperature of water will depend on the depth of aquifer, the mineralization should exceed roughly 4 – 5 g/l.
There were indications that the above assumptions to find geothermal waters meet the site between the margin of the ZSNP aluminum plant a.s. in Žiar nad Hronom, from Hlinik nad Hronom towards Žiar nad Hronom, as well as the area between the Hron river and Ladomerská Vieska village. In both areas were assumed the depth of Triassic carbonates about the same (some 1750 – 1850 m) and their inferred thickness is also roughly identical (about 500 m). The Triassic carbonates are more likely to occur in the former area (the distance from the ST – 4 borehole, which intersected these rocks is 2.5 km) so in this area was located the first borehole RGŽ-1. Anyway is necessary to mentioned that with exploitation of geothermal water from the well ST – 4 (free flow 16 l/s), the springs in the bath Sklené Teplice was influenced up to yield 5 l/s. Based on the expert's report (Franko et al., 1997) it was not recommended to drill the first well in this area. So definitely it was decided to drill the first geothermal well in the are between the river Hron and Ladomerská Vieska village directly in the town Žiar nad Hronom.

3. FEASIBILITY STUDY RESULTS

Based on the previous information the town Žiar nad Hronom has a favorable geothermal conditions and also appropriate heat consumers. According to this situation, together with the Danish company Houe & Olsen, was worked out the feasibility study of geothermal energy utilization for heating of the town and ZSNP aluminum plant. In the feasibility study were solved several variants which evaluated different condition which will occur after implementation of geothermal energy heating in this region.
The feasibility study worked out four variants (No. II, III, IV, V) based on the closed cyclic geothermal system. The implementation of these variants will divided the future central heating system to the three individual cycles, the geothermal circuit, central heating circuit and consumers net. Variant No. I was the existing system and in the Variant VI was solved the heating system based on the gas. The implementation of each geothermal variant will take three years and will be provide in three phases. The heat production based on the each geothermal variant is shown in the table 2.

Tab. 2 Heat production – geothermal variants

	Variant			
	II	**III**	**IV**	**V**
Year heat demand	803,4	806,1	846,1	803,4
Heat production from geoth. Wells (GJ/year)	559,1	712,7	567,7	692,1
El. Consump. (MWh/y)	8760,0	13140	8760	8760
Heat production from ZSNP boiler station (TJ/year)	244,3	93,4	278,7	111,3
Coal demand (T/year)	20948	7984	23829	9569
El. Consump. (MWh/y)	82,0	46	86	53,0

Environmental aspects

The application of geothermal energy will have a great influence in decreasing the emission decreasing of contaminants as CO_2, CO, SO_2, NO_x and dust.

To fulfill the demands for heat and steam in present time the boiler station in ZSNP burns 167 000 t of coal and 12 832 154 Nm^3 of earth gas per year. Geothermal variants can generate heat production of 846 TJ/year and to cover this demand it is necessary to consume 72 000 t of coal. The emissions produced by burning of this amount of coal are shown below.

CO_2	101 800 t
CO	1 692 t
SO_2	1 402 t
NO_x	270^7 t
Dead oil	72 t
Dust	270^7 t

It is estimated that 72 000 t of coal produced about 13 680 t of ash.
The year environmental benefits from the decreasing of the air pollutants are presented in the table 3.

Table 3. Environmental benefits

Geothermal variant	**1000 USD**
Variant II	2 505
Variant III	3 192
Variant IV	2 520
Variant V	3 099
Variant VI	987

Economic and finance analysis

Economic and finance evaluation of different variants was based on the different investment costs. Different investment costs are described in table 4.

Tab. 4 Investment costs

Phases	**Variant (USD)**			
	II	**III**	**IV**	**V**
Phase 1	8389700	11392700	8389700	8389700
Phase 2	6793600	6739700	6792600	6793600
Phase 3	3135000	3135000	0	3135000
Sum	18318300	21318400	15183300	18318300

For the evaluation of the investment two evaluating methods were used, the net present value method (NPV) and internal rate of return method (IRR). The sum of calculations in the basic version according to geothermal variants and one variant (VI) based on the gas is presented in the table 5.

Tab. 5 Economic and finance calculations

	Variant (Sum in Thousand of USD)				
	II	**II**	**IV**	**V**	**VI**
Investment	18318	21267	15183	18318	9270
Working costs	35589	23305	36642	24572	72476
Heat income	69655	69655	73366	69655	72889
Environ. Income	35591	47195	36808	45329	14810
Economic Income	106246	116850	110174	114984	87698
NPV finance (12%)	-1799	602	688	2589	-8110
NPV econom. (12%)	12650	19466	15222	20514	-2106
FRR	9,6 %	12,7 %	13,0 %	15,3 %	-
ERR	27,2 %	31,9 %	31,8 %	36,3 %	7,0 %

FRR-finance rate of return
ERR-economic rate of return
According to the results of feasibility study it was decided that Variant V will be utilized.

4. DRILLING OF THE FIRST GEOTHERMAL WELL

The drilling of the first well started in the early of January 1999. The well RGŽ – 1 was located in the area of the town Žiar nad Hronom close to the river Váh, railway line and ZSNP aluminum plant. Geologically it was situated near the tectonically complicated area – tectonic contact of the of 2 basic Carpathian units (veporicum and tatricum) (Franko et al., 1997).
The designed depth of the well was 2500 m. Concept geological profile of the well was based on the results from existing wells and results from geophsical measurements. It assumed the following geological profile:

0-12 m	soil, sandy-clay deposits, gravels
12-100 m	Panonian, Pliocene sandstones, siltstones,
100-1850 m	Sarmatian, neovolcanics-andesites, tuffs, andesite tuffs, ryolite tuffs etc.
1850-2450 m	Triassic, dolomites and limestones - reservoir
2450-2500 m	Createcous, shales marly limestones, sandstones

The drilling of the well was stopped when the reservoir rocks, Triassic dolomites and limestones, were not encountered. The well drilled to depth 25 m encountered Qarternary, Panonian and Pontian sediments and from this depth to 1767 m drilled through neovulcanics rocks as rhyolites, andesites and its variets etc. From the depth 1767 m to 2325 m well drilled through subsurface intrusive body consist from quartz – dacites porphyries. This intrusive body is not known in the surroundings of this locality. At the depth interval 2290 m to 2305 m was founded the residues of Cretaceous layers consisting graphitic shales and sandstones. From the depth 2325 m to the final depth 2 500 m well drilled through the neovulcanic rocks – quartz diorites.
In the interval 1700 – 1800 m occurred great mud loses so it was decided to test this interval for the presence of geothermal water.

4.1 Seismic investigation

Based on the results from the first well it was decided to make seismic measurements. Two seismic profiles were done in the length of 12 km.
The first seismic profile (7 km) crossed the well RGŽ-2 and runs through the center part of the depression.
Second profile (5 km length) cross the existing well ST – 4 which includes the reservoir rocks Triassic dolomites and limestones in the depth interval 1400 – 1800 m. Also this profile runs towards the center part of Žiar depression. The distance between these two profiles is approximately 4 km.
From the preliminary results of the seismic measurements it is clear that the part where the first well was located is tectonically destroyed and occurrence of volcanic intrusive is evident. It looks better that the next planned wells be located in the central part of Žiar basin.

5. PRELIMINARY CONCLUSION

Based on the hydrogeothermal conditions (one of the most favorable in the Slovakia) of Žiar basin and on the results of feasibility study the project of the geothermal energy utilization is very possible and feasible. By the drilling of two doublets it is possible to cover more than 70 % of the total heat demand in the town of Žiar nad Hronom and ZSNP aluminum plant.
The localization of the next three wells will be clear after complete analysis of the drilling of the first well and also after finishing of the seismic measurement interpretation. The utilization (exploitation or reinjection) of the first well will be decided after finishing the testing.

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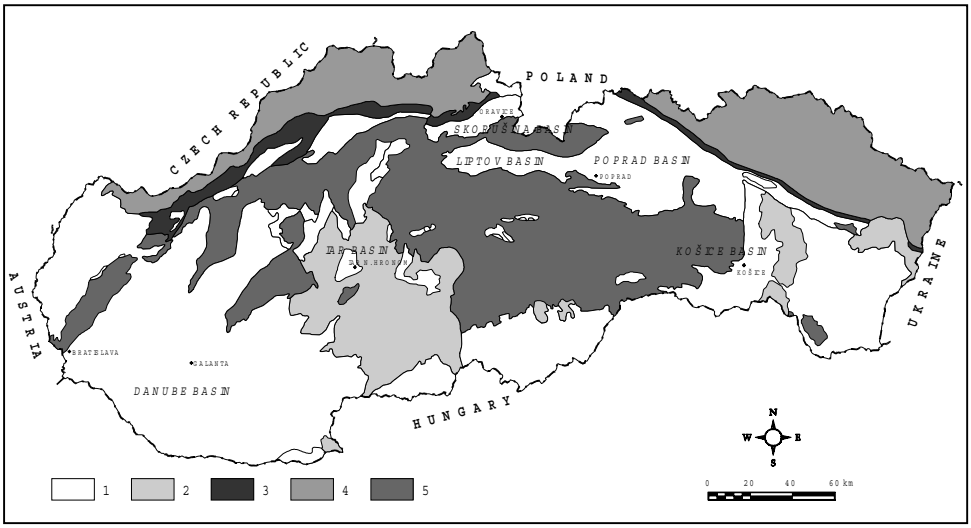

Figure 1: Perspective geothermal areas (1- Neogene and Paleogene basin; 2- Neovolcanics; 3- Klippen Belt; 4- Flysch Belt; 5- Core Mountains, Mesozoic and Paleozoic)