DEVELOPMENT OF REGION BY UTILIZATION OF GEOTHERMAL POWER PLANT

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Abstract
It is obvious that Geothermal Power Plant is the kind of projects, which may be very attractive in certain regions but may seems difficult and risky on the first look and if not properly developed. Specially in the regions and countries where are missing references for such kind of projects this project may be “pioneer” type and from the beginning will for sure request lot of ambitions and patience from site of developer and project owners and lot of confidence from administration and official governmental bodies and or banks and investors. It is therefore necessary to have a precise formation in the early beginnings in the individual feasibility studies. On this particular example can be seen as specifically described below in respect of this project geothermal energy.
The case study compares three possible alternatives, not only technically but also economically. Also, comparing the results through dynamic economic indicators, which taking into account in particular the aspect of time, thus are leading to significantly greater objectivity and project implementation.
Keywords: geothermal energy; geothermal power plant; innovative project; geothermal energy; economical parameters

1. INTRODUCTION

The company interested in preparing Gothermal Power Plant projects (GPP) in accordance with the EU principles in energy policy – energy efficiency and renewable energy sources utilization will need to consider much specific information. The specific GPP project relates to the utilisation of geothermal potential of underground hot water for electricity production, eventually also heat production, if appropriate (waste heat in this case to be understand as the heat, which cannot be further utilised by GPP) and as additional activity if so decided also for building of thermal aqua park or to supply geothermal water for such activity.

Also municipality and local heat Distribution Company of the interested city must declare they interest in geothermal heat utilization in the form of heating source for citizens and offices as well as potential development of tourist attractions. For the city this may bring lot of savings and stable heat supply and prices as well as employment opportunities.

2. METHODOLOGY

The main goals of this paper is to compare the chosen methodology - possible alternatives based on the geological exploration of the territory and choosen which one is the best, most cost-effective due to the economics. It was evaluated with respect to the construction project of geothermal power plant and heat recovery from her for Trebišov town. Described project is situated in eastern Slovakia and compares three alternatives. For this reason, it can be categorized as a case study, which will ultimately allow a better understanding and clearness in similar projects that are similar due to the abundant occurrence of geothermal waters in Slovakia.

2.1. Development Activities Plan and Projects Stages

From the reasons described below, it is most important for successful development to appoint very professional partners in development and to split the project to the logical development stages each describing the specific futures and targets for individual stages (Edwards et al., 1982, Brown, 1991).

Development of the project from technical point of view and basic analyse

This stage will include:

- Licence (rights) from Ministry of environment and Ministry of economy to explore geothermal investigation and use the geothermal energy;
- PPA and heat supply (if any) agreements of agreement about the future agreements;
- Feasibility Study including economical analyse and technical options (capacity);
- Underground measurement (without capacity test drills);
- Localisation of the best place of capacity drills;
- Engineering works for building of Power plant and infrastructure;
- Territorial permission;
- Building permission;
- Other legislative needs (if any).

Development of project financing and investment structure

This stage will include:

- Based on successful first stage – Tender for investors, selection of strategic partner;
- Securing of complete project financing, equity including project finance;
- Signing of "Turn-key" contract with EPC contractor (based on NTP till financial close);
- Investment for first test drill and evaluation.

Project execution and operation

This stage will include:

- Based on successful 2. stage – Securing of governmental approval of project execution;
- Project execution;
- Long term plant operation.

Each of the assumed stages above will have own specific target and specific criteria, which are important for successful GPP project (Brown, 1996).

2.2. Scopes of Feasibility Study

This Feasibility Study is part of first stage of GPP project. Feasibility study will be issued after detailed analyse of all potential options which could happened during the project (Brown, duTeau, 1996).

From the point of view of general conditions and technology availability for the Geothermal Power Plant, the project can be split in two main parts:

- "Under-ground part" the overall conditions and equipment for scooping and transporting of underground water to the GPP and its return back to the underground basin
- "Above-ground part" the references and actual status of development and production of equipment for conversion of geothermal potential of underground hot water to electricity production, eventually also for heat production.

The scope of this study consists of feasibility analysis of the project „Geothermal Power Plant", as a first stage of implementation of the project „Geothermal potential of city surrounding region". In its framework the conditions and technical solution of both under-ground and above-ground parts of power plant will be described in that manner, so technical specifications would indicate the real technical solutions, having the corresponding references and overall conditions shall investigate the availability of hot water

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sources and conditions for produce electricity from this renewable source (Duchane, 1994, DuTeau, Brown, 1993).

Technical solutions would be detailed prepared to give the possibility of budget generation, as well as the technical feasibility of whole project undertaking. Investment and operational costs are determined; economical evaluation is related to the whole project (Dash, Murphy, Cremer, 1978).

In this meaning, the feasibility study is elaborated in the following sections:

1. Prospect of geothermal energy resources use in the East Slovak basin area, definition of geological source locality, definition of amount and quality of underground water at disposal to be scooped up.
2. This Chapter will be supported by a separate geological study, which will be worked-out by a specialised geological subject.
3. City heating, possibility of heat delivery from geothermal source - balance, conditions, induced works.
4. Alternatives of electricity and heat plant proposal.
5. Based on thermal and material balances of underground water at disposal to be scooped up, alternatives of electricity and heat plant, grounded on the technology are proposed.
6. Specification of individual equipment.
7. Possibility of electrical output connection to the national distribution network checking-up.
8. Plant layout proposal.
9. Time schedule for project implementation.
10. Human resources demand.
11. Environmental impact.
12. Economical evaluation:
13. Total investment costs of turn-key delivery basis, which all costs shall be taken into consideration, including:
    - Geological Prospection research;
    - “Under-ground part” of Power Plant project, delivery and erection

- Projecting-engineering works (working-out of Investment Intention conform § 22 of law no. 24/2006 Z.z, Documentation attached to request for territorial adjudication, Documentation attached to request for building permit, Detail Design);
- "Above-ground part" of Power Plant project, delivery and erection.

14. Material balance of electricity and heat production, and individual media consumption,
15. Operational costs for water handling and for energy source,
16. Economical evaluation of whole plant for 15 years of production,
17. Principal economic indicators of project (Present Value - PV, Net Present Value - NPV, Pay-Back Period - PBP, Internal Rate of Return - IRR),
18. Sensitivity analysis of the project concerning water source richness variation and sale price of electricity variation.

3. GEOTHERMAL CHARACTERISTICS OF TOPIC REGION

Slovakia belongs to the countries with comparable young underground conditions created by latest movement of the earth in the Europe. By this movement there where many water lakes covered underground as well as the underground structure allows to cumulate the ground water long time and heat it up by natural earth deep heat. There are hot water sources as well as hot rocks which both may be available as a renewable source of geothermal energy.

Recently there is geothermal heat frequently used for tourist attractions and thermal baths, which are having also medical treatment effects, which are very popular world-wide. These sources are available shortly underground and they are sign of better conditions in the deeper distances.

During the stage of governmental investigation of potential fields of fossil fuels there were executed more than 120 exploration drills over Slovakia in different regions and different deepness. The results are cumulated in several studies and professional reports and they are the best library for evaluating also the Slovakian Geothermal potential and availability of geothermal sources.

Based on the executed drills there was issued a complete map of geothermal sources within Slovakia (Figure 1):

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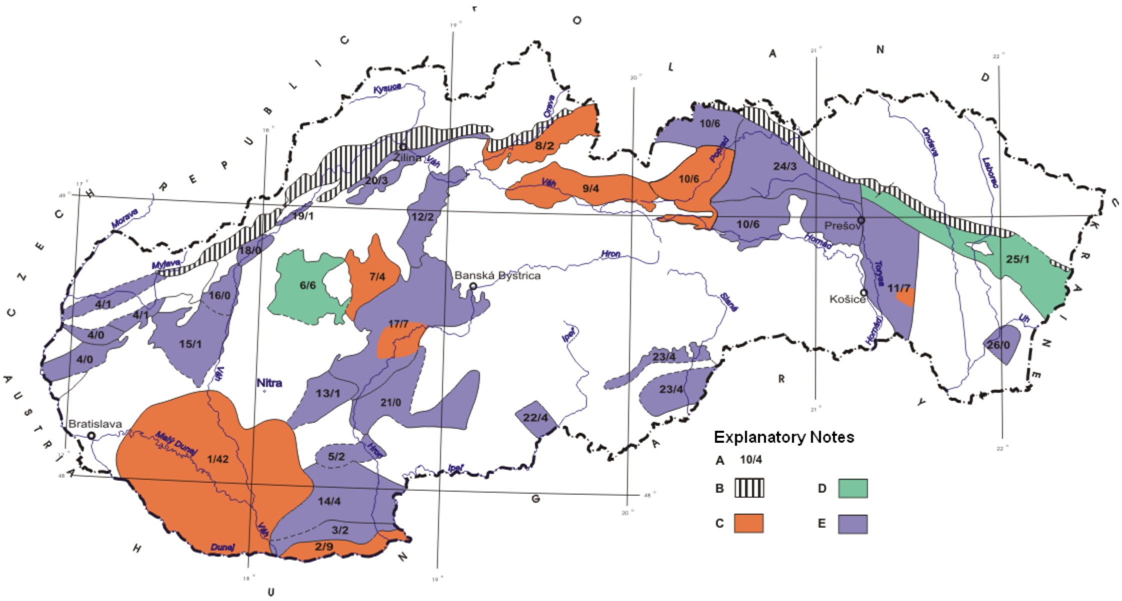

FIGURE 1 – GEOTHERMAL SOURCES IN SLOVAKIA

The geothermal gradient of indicated prospective regions is above 58°C/km and the average in Slovakia is about 38°C/km. The density of heat flow is from 60 mW/m2 up to 120 mW/m2 in the most active undergrounds. The total geothermal potential available in the form of geothermal water is around 5,538 MW, considering the sources already confirmed as well as most probably available and assumed.

The map of the individual geothermal sources and potential (Figure 2):

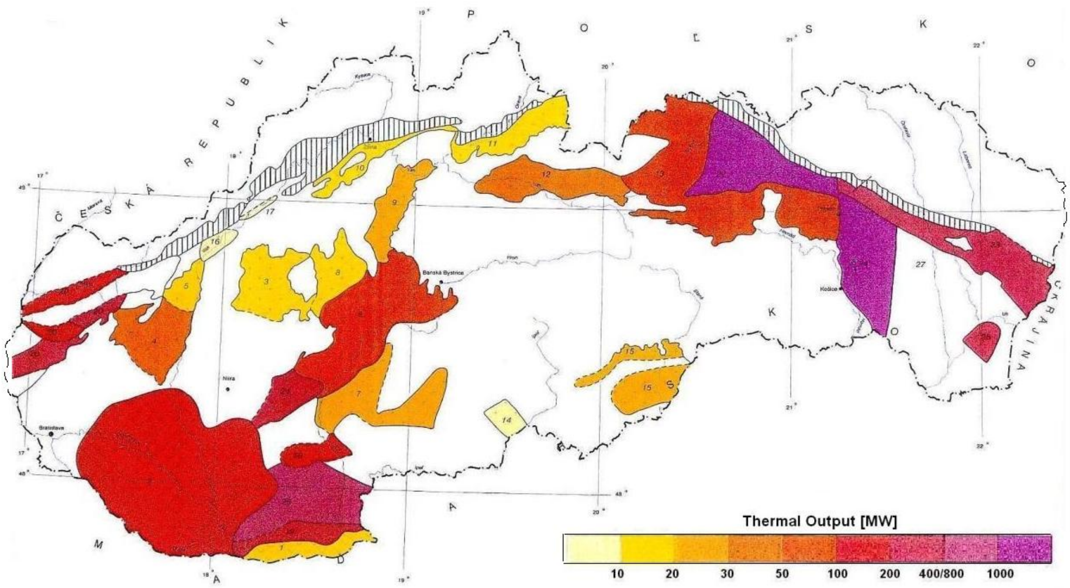

FIGURE 2 – GEOTHERMAL SOURCES AND ITS POTENTIAL

3.1. Prospects of geothermal energy resources use in East Slovak basin area

The Eastern Slovakian Basin is situated between the West and East Carpathians. The surface of the pre-Tertiary substratum is very rugged and is characterized by four main structures. In the west, the pre-Tertiary formations of the Košice Basin and volcanic complexes of the Slanske vrchy Mts. and form several benches separated by north-south faults. Another major morphologic structure, most conspicuous morphological element of the basin's pre-Tertiary substratum, the Trebišov depression as much as 7,000 m deep, lies amidst the above structures. This depression includes several partial elevations and depressions.

In the East Slovak Basin there were delineated 16 hydrogeothermal structures in Neogene, volcanic and clastic sedimentary rocks or in Mesozoic carbonate underlier. The most prospective of them are Ďurkov in Mesozoic carbonate underlier, Trebišov in Neogene formations and Beša-Čičarovce in a buried stratovolcano. Besides that there is a possibility of dry rocks heat utilization from crystaline rocks complex of deeper underlie.

East Slovak Basin is from geographic-geological viewpoint situated in a dividing area between the West and East Carpathians. This basin represents western part of a higher order regional unit so called Trans-Carpathian Depression, eastern part of which is situated in Ukrainian territory (Figure1).

From genetic viewpoint this area represents longitudinal intramount depression filled by Neogene sediments and volcanics. This basin morphologically represents north-eastern promontory of Pannonian Basins System.

During more than 50 years of systematic oil-geological exploration a quantity of knowledge was gathered here, as on geological structure and hydrocarbon fields as on thermal setting and geothermal waters. It is a case of nearly 20,000 analysed water samples and temperature measurements in the depth span from surface up to 4,200m what enables us to distinguish in this region several prospective geothermal areas. Geothermal energy resources can be gained either from aquifers or by utilization of hot dry rocks.

3.2. Geological Setting and Hydrogeological Conditions

Geothermal water is bound to three types of rock environment:

- Mesosoic carbonate rocks with secondary void and fracture porosity in the undrelier of Neogene sedimentary filling.
- Sands and sandstones with primary porosity in Neogene sedimentary filling.

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- Fractured andesites and volcanoclastics of buried Sarmatian stratovolcanoes (Winchester, 1993).

Hot dry rocks energy can be gained from Young-Palaeozoic low-metamorphosed clastic rocks and Old-Palaeozoic crystalline complexes of Neogene sedimentary filling underlier.

Evaluation of the East Slovak Basin thermal setting is based on measurements of stabilized temperatures in 45 deep wells. Thermal field in 1,000 m depth below the surface is a relatively stable. In marginal parts of the basin temperatures fluctuate about 50°C and in central part about 60°C. Temperatures on pre-Neogene underlier surface fluctuate in a very wide span, depending on depth of burial, from 25°C in marginal parts up to more than 325°C in central parts of the basin.

Knowledge of thermal properties of rocks has an extraordinary significance primarily for structures recovered by re-injection system because of their need for the modelling of geothermal water recovery and its re-injection regarding to the optimization of withdrawal – re-injection systems life. Heat capacity of geothermal water reservoir rocks, i.e. Neogene sands and sandstones, has a mean value of 1091.2 ± 46.2 J/kg.K, Sarmathian volcanics 1175.0 ± 111.3 J/kg.K and Mesozoic carbonates 811.4 ± 14.5 J/kg.K. Earth's heat flow density in the East Slovak Basin was established on 30 wells and fluctuates in span of 82.1 – 121.6 MW/m2.

Mineralization of geothermal waters in the East Slovak Basin depend on depth of their burial and position. Water in shallow horizons (approximately to 1,500m) and on basin margin is low to medium mineralized up to 10 g/1. In deeper parts of the basin there are very highly mineralized brines with a total mineralization frequently above 100 g/l.

3.3. Trebišov Depression

Enhanced geothermal activity in Eastern Slovakian Basin refers to its geodynamic and tectonic evolution which was increased by volcanism. This verify high amounts of heat flow density from 0 – to 110 mW/m2 and average amount 101 W/m2.

Heat flow higher than 110 mW/m2 is typical for south – eastern part of Basin. Geothermal gradient fluctuates from 35 to 53°C/km and in rocks of underlie temperature fluctuate from 25 to 33°C /km. Geothermal water inflow with reservoir rocks temperature of 130 – 140°C can be expected from depth approximately of 2,500 – 4,000 m. There are expected better conditions with geothermal gradient as in the Košice Basin. Regarding this effectiveness prospective thermal-energy potential of Trebišov depression then represents 110.0 MW.

Note: as per this general description taken mainly from literature and investigation of close areas, the future investor company can decide to insert to governmental application "Project of geology mission Trebišov – surround.

- Supposed underground water flow to extract 120 l/s (360 t/h) per one well
- Extracted water temperature 140 °C
- Water temperature at outlet of Power Plant 75 °C

3.4. Definitions of Underground Water Parameters

After detailed study of Slovak geothermal potential and expected geothermal water sources there is strong probability that the selected region may have even better geothermal conditions that already tested and widely investigated neighbouring locality Ďurkov. In selected Trebišov surrounding region there were also executed several test drills by company exploring fossil fuels and they find enough resources of thermal water with acceptable salinity and suitable temperature. Considering development of the drilling technology and latest investigation possibilities investor and engineers of this study decided to start the project development with using the base geothermal water quality as follows (Edwards et al., 1982, Dash, 1989).

The new geothermal Power Plant should have the following technical parameters:

- Electric output supplied to the distribution network (net) cca 3 – 10 MWe
- Temperature of geothermal water at converter inlet 140 °C
- Temperature of reversion water 75 °C
- Thermal output for district heating 150,000 GJ/year

3.5. Possibility of Heat Delivery to Trebišov City

Trebišov city has around 22,000 habitants, around 50% of them live in 76 buildings, each having 8 + 1 floors. These blocks consist of 3,800 flats connected to the regional heating system owned by Municipality. They are supplied from 8 boiler-houses. Besides these sources, 38 blocks have an own particular boilers. In total of 80 % habitants are connected to existent regional heating system.

Local Company "Miestna vykurovacia spoločnosť Trebišov s.r.o." manages the heat supply including the distribution network maintenance.

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In present, 35 GJ/year heat consumption on one average size flat (60m2) is registered, which means costs of 750 Euro per year.

Heating season (defined as season when the average outside temperature achieves less than 13°C) lasts from September 1 to May 31.

Total heat consumption of whole city varies between 185 – 220 TJ/year (47 – 55 GWh/year). Nowadays market for Miestna vykurovacia spoločnosť Trebišov s.r.o. presents 150,000 GJ/year (including distribution system losses). In next 10 – 15 years, increase of heat consumption by 85 – 95 % is supposed in the face of present status. Investor supposes a heat sale price of 13,277 Euro.

To assure today's consumption of heat 150,000 GJ/year, 330 t/h of 140°C water is need to feed in the heat exchanger situated at the geothermal water source.

3.6. Analysed Alternatives of Power Plant

Coming from assumed geothermal water quality this study will analyse different sizes of technology and GPP capacity considering that the goal is to build the largest one. But it is also possible to build up smaller one, because all steps depend on real thermal water capacity.

On basis of results, the following alternatives of Power Plant were analysed:

Alternative 1: 3.14 MWe

Alternative 2: 5.08 MWe

Alternative 3: 10.16 MWe

TABLE 1 – BASIC TECHNICAL PERFORMANCES OF SELECTED ALTERNATIVES

	Unit	Alt.1	Alt.2	Alt.3
Gross electric output at generator terminals	kW	3,560	5,820	11,640
Net electric output	kW	3,140	5,080	10,160
Temperature of water at ORC inlet	°C	140	140	140
Water flow	l/s	120	208	417
	t/h	431	750	1,500
Investment costs	€	13,800,000	28,376,000	43,253,000

3.7. Economic Evaluation

For the purpose of economical evaluation, the new plant has been considered as an independent economic unit purchasing media and services and producing electricity and heat. Method "incomes-costs" was used.

Economical evaluation has been performed using the following main input data on prices (identical for all alternatives) at level of I/2012 year:

- Price of sold heat 13.278 €/GJ
- Price of electricity sold to the network 195.844 €/MWh
- Price of water from geo-source 0.03 Euro/t
- Price of transfer medium 0.89 Euro/t
- Labour costs 1,500 €/month
- Annual price increase 3%
- Discount rate 7%

3.8. Investment Costs

Investment costs have been calculated for project implementation by one general turn-key supplier. All items beginning with the design documentation and ending with complex testing have been included.

Assumed total investment costs with prices on I/2012 level, including:

- Geological Prospection research;
- "Under-ground part" of Power Plant project, delivery, erection and commissioning;
- "Above-ground part" of Power Plant project, delivery, erection and commissioning.

4. CONCLUSIONS

The results of the technical-economic analysis proved the profitability of investment into the new independent plant assuming present energy prices (Table 2).

This type of energy has its origin in the hot core of the earth, from which heat escapes through cracks in the volcanic rocks. The core temperature is estimated at 7,000 °C, almost inexhaustible supply of energy in the bowels of the earth. Usually this kind of energy including among renewable sources. In ten

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kilometres land cover layer, which is available to current drilling technology, there is enough energy to meet our consumption for a period of several thousand years. Huge reserves of geothermal energy can be used to heat buildings so as to generate electricity, which is documented by a number of such facilities in many parts of the world. The effectiveness of such registration, however, never exceeds 20% and for smaller devices only 5%. While these values may seem low, it turns out that, given the huge reserves of geothermal energy is usually more economical to proceed by minimizing the specific cost than to increase production efficiency. Contribution this way refers theoretical knowledge backed up on specific projects from Slovakia to justify thinking about the active use of geothermal energy also in our country.

TABLE 2 – MAIN ECONOMICAL PARAMETERS SUMMARY

Parameter	Unit	1	2	3
Present Value (PV)	ths €	36,671	51,084	119,241
Net Present Value (NPV)	ths €	14,720	16,411	119,241
Pay Back Period (PBP): - simple	years	6.0	4.6	4.5
- discounted	years	8.1	5.6	5.4
Internal Rate of Return (IRR)	%	14.3	19.6	20.2

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