

GEOHERMAL POWER PLANT CONCEPTS IN THE PANNONIAN BASIN IN HUNGARY

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ABSTRACT

The Pannonian Basin has one of the best geothermal potential in the European continent. However, no geothermal power plant facility exists in Central-Eastern Europe. There are professional investors in Hungary, their focus is on geothermal power plant project development.

Having reviewed the available geological and geophysical data, the existing and potential geothermal areas, three main geothermal power plant model groups can be set up according to their power. The first model has a capacity below 2 MW_e. Medium depth sandstone reservoirs can be appropriate to achieve this capacity. In order to increase the effectiveness of these small-scale power plants hybrid systems are to be designed or existing technologies are to be utilized.

The capacity of the second model is between 2 – 5 MW_e. From the output enthalpy direct heat can be provided in a cascade system.

From deeper fractured carbonate reservoirs the enthalpy of the produced thermal water makes the opportunity to establish 5 – 12 MW_e capacity power plants. During the exploration of these projects there are really big challenges to be solved (extremely high overpressure, water salinity).

The development of the geothermal business strongly depends on the macroeconomic background. Based on the power plant models there is a pessimistic, a realistic and an optimistic schedule of the Hungarian geothermal power plant establishment process till 2020.

The presentation describes the models and the development schedules.

1. BACKGROUND

This Study reviews the opportunities of the geothermal power plant establishment in Hungary. The whole subject is too large, therefore there are some issues that cannot be part of the scope of this Study. There is no room to discuss the exploration,

deep drilling, reservoir engineering and water chemistry issues concerning the establishment of geothermal power plant.

However, this Study deals with the heat energy, machinery effectiveness and power plant capacity issues. The focus is on the questions; what size power plants can be established in Hungary? What kind of geothermal power plant models can be set up? How much geothermal power generation capacity can be established in Hungary in the next decade?

Finally three feasible complex models are set up based on their size and three versions of a ten-years geothermal power establishment program is drafted in order to estimate the nationwide geothermal power generation opportunities till 2020.

2. POSSIBLE POWER PLANT TYPE

The following table was prepared based on PiPippo's calculations. It shows the powers of the different systems at 100 kg/s mass flow rate.

Table 1: Power plant capacities of different generating systems

Mass flow rate	Temperature, °C	Power, MW	Conversion system
100 kg/s geoliquid	150	2.63	Binary
100 kg/s geoliquid	175	4.43	Single flash
100 kg/s geoliquid	200	8.24	Double flash
100 kg/s geoliquid	235	11.52	Double flash
100 kg/s geosteam	175	42.48	Dry steam

Actual plants may differ from these values.

The electricity conversion system of the Hungarian power plants can be selected after the revision of the geological and water chemistry opportunities.

Figure 1 describes that the whole Pannonian-Basin constitute an intermediate enthalpy, high temperature basin. Shallow and moderate depth wells are prevalent and there are only a few deep wells (deeper than 2500 meters), which are able to provide higher temperature thermal water (above 150 °C). The shallower wells are generally not appropriate to supply thermal water for geothermal power plants because of their temperature, therefore deeper wells are needed to employ.

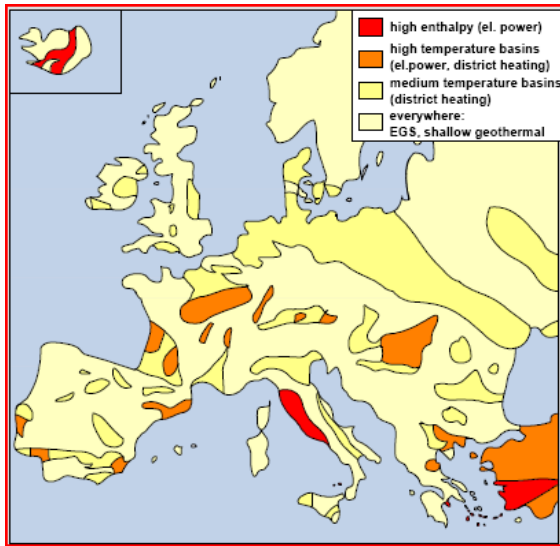


Figure 1: The most prospective geothermal regions in Europe (map of EREC)

Reviewing the possible power generating cycles the following statements can be taken.

- The Hungarian geological environment is not appropriate for dry steam plants, because the temperature is not exceed 200 °C even at 4500 meters depth. Moreover, geothermal fluids under the surface of Hungary are in water phase because the pressure increase towards the depth is more dominant than the increase of the temperature.
- The brine parameters are not prospective for flash type systems as well. The temperature generally is not high enough and the total dissolved solid content and scaling risk is often too high.
- Binary systems seem to be prospective in Hungary for power generation. As the enthalpy is not extraordinary, the utilization of the heat of the waste brine is necessary in all facilities. Therefore the establishment of combined heat and power facilities is advisable.

3. DETERMINING POWER OPPORTUNITIES

There are only a few deep-drilled wells have exact thermal water production and reinjection tested data. It is the key constraint of the Hungarian geothermal deep-zone projects. However, the few existing well files can be analyzed and the power opportunities of plants can be determined.

The analysis is based on the following calculations.

a. Thermal output calculation

$$P_{th} = c_w \times m_w * (T_i - T_o) , \text{ where}$$

P_{th} is the thermal heat provided by the thermal water to the power machinery (kW_{th})

c_w is specific heat of the thermal water (4.187 kJ/kgK)

m_w is mass flow rate of the thermal water (kg/s)

T_i is the thermal water inlet temperature (K)

T_o is the thermal water outlet temperature (K)

b. Binary thermal efficiency calculation

As binary power plants are in consideration, the method of Massachusetts Institute of Technology is utilized. Their formula is:

$$\eta_{th} = 0.09345 * T_i - 2.32657 , \text{ where}$$

η_{th} is the thermal efficiency of the power plant (%)

T_i is the thermal water inlet temperature (K)

c. Electricity power calculation

This calculation is related to one production well, therefore the result is power per well doublet. The formula is:

$$P_{el} = P_{th} * \eta_{th} , \text{ where}$$

P_{el} is the gross electric power of the plant (kW_{el}),

P_{th} is the thermal heat provided by the thermal water to the power machinery (kW_{th})

η_{th} is the thermal efficiency of the power plant (%).

The well-head temperature and measured or calculated mass flow rate of three existing abandoned hydrocarbon wells were taken into consideration in the following cases.

Case 1

In Case 1 a correctly tested well was analyzed. The well head temperature was 135 °C. The long term mass flow rate was 11.72 kg/s.

Case 2

In Case 2 a well testing provided a large amount of information, but was not a full scope thermal water production and reinjection test. The measured well head temperature was 171 °C.

The mass flow rate was 22 kg/s through a 41 mm choke.

Case 3

In case 3 the measured well head temperature was 190 °C. The mass flow rate was 90 kg/s.

The temperature could be appropriate for a flash type energy conversion system, but the brine is to be reinjected in closed system because of extreme high well-head pressure and high salinity. A heat-exchanger is needed to gain the heat energy, so binary system can be applied.

Table 2 includes the calculated thermal power, thermal efficiency and electricity power opportunities in the three cases.

Table 2: Electric power opportunities taking into consideration three existing wells

	Case 1	Case 2	Case 3
Well head temperature, °C	135	171	190
Long term mass rate, kg/s	11.72	22	90
Thermal power, MW _{th}	2.7	8.388	41.481
Thermal efficiency, %	10.289	13.653	15.429
Electricity power, MW _{el}	0.278	1.15	6.4

It is noted that the parasitic power is to be subtracted from the calculated gross electricity power. In Case 1 the small gross power is sensible for parasitic power very much.

4. POSSIBLE POWER PLANT MODELS

Based on the calculations summarized in Table 2, different Hungarian geothermal power plant models can be set up.

The conceptual model design presented below is based on the Hungarian thermal heat potential proved by tested wells. International analogies of operating geothermal power plants were also taken into consideration.

Independently of the concepts the exact project opportunities in Hungary are to be analyzed case by case.

Three main sizes of geothermal power plants can be established as below.

If the thermal heat potential is low, a micro power plant is recommended to install.

The tables below include the necessary temperature and mass flow rate parameters that are needed in order to achieve a minimal gross 0.26 MW_{el}, 2 MW_{el} as well as 5 MW_{el} power. The thermal output, the binary thermal efficiency and the power output was calculated with the same method as it was described above.

Table 3: Key technical parameters of a 0.26 MW_{el} binary geothermal power plant

Mass flow rate, kg/s	Temp., °C	Thermal output, MW _{th}	Thermal efficiency %	Electric power output MW _{el}
9	145	2.451	11.224	0.275
10	140	2.514	10.756	0.270
12	135	2.765	10.289	0.284
14	130	2.933	9.822	0.288
15	125	2.828	9.355	0.265

Table 4: Key technical parameters of a 2 MW_{el} binary geothermal power plant

Mass flow rate, kg/s	Temp., °C	Thermal output, MW _{th}	Thermal efficiency, %	Electric power, MW _{el}
33	180	13.827	14.49	2.004
36	175	14.330	14.03	2.010
40	170	15.084	13.56	2.045
44	165	15.671	13.09	2.051
48	160	16.090	12.63	2.032

Table 5: Key technical parameters of a 5 MW_{el} binary geothermal power plant

Mass flow rate, kg/s	Temperature, °C	Thermal output, MW _{th}	Thermal efficiency, %	Electric power, MW _{el}
61	200	30.671	16.36	5.018
66	195	31.802	15.90	5.057
71	190	32.724	15.43	5.049
78	185	34.316	14.96	5.134
83	180	34.777	14.49	5.039

All the three opportunities are realistic in Hungary, the mass flow rate and temperature parameters can be achieved. However, the high thermal efficiency rate in case of 5 MW_{el} is to be proved.

5. SETTING UP A GEOTHERMAL POWER PLANT ESTABLISHMENT CONCEPT

From the models above the nationwide total generated geothermal electric power can be estimated. A dynamic development is taken into consideration till 2020.

Pessimistic version

Only the presently well known potential areas are taken into consideration in this version.

Table 5: Estimated Hungarian total generated geothermal electric power in 2020, pessimistic version

Power Plant Model MW _e	Reservoir temperature range (°C)	Average power MW _e	Estimated number of the power plants	Total power MW _e
5 - 12	160 – 200	6	2	12
2 - 5	120 – 160	2.5	4	10
max. 2	< 120	0.75	8	6
Total		2	14	28

Realistic version

Seasonal energy management of the existing geothermal systems, the hybrid opportunities and all kind of cascade systems are taken into consideration in this version.

Table 6: Estimated Hungarian total generated geothermal electric power in 2020, realistic version

Power Plant Model MW _e	Reservoir temperature range (°C)	Average power MW _e	Estimated number of the power plants	Total power MW _e
5 - 12	160 - 200	8	3	24
2 - 5	120 - 160	3	8	24
max. 2	< 120	1.0	12	12
Total		2.6	23	60

Pessimistic version

Significant external financial support, successful research and development activity is taken into consideration in this version. New enhanced geothermal system power plants are also included. It is noted that according to the European Geothermal Energy Council it is not an optimistic but a realistic version.

Table 7: Estimated Hungarian total generated geothermal electric power in 2020, optimistic version

Power Plant Model MW _e	Reservoir temperature range (°C)	Average power MW _e	Estimated number of the power plants	Total power MW _e
EGS	160 - 300	6	6	36
5 - 12	160 - 200	8	5	40
2 - 5	120 - 160	3	12	36
max. 2	< 120	1.0	18	18
Total		3.2	41	130

The following remarks has to be added:

- The implementation of this program depends mainly not on technical issues. It depends on
 - Technical research and development
 - Regulations
 - Macroeconomic background
 - EU and Governmental subsidies
 - Existence of investors.

6. SUMMARY

The objective of this Thesis was to evaluate the geothermal power plant establishment opportunities in Hungary.

After the summarizing of the opportunities in Hungary three main geothermal power plant model groups was set up.

The first and the smallest model has a power below 2 MW_e. There is no an exact limitation, what is the lowest thermal water temperature at which is appropriate for generate electricity. Medium depth sandstone or fractured reservoirs (2 - 3 km) can be appropriate to establish this capacity.

The power of the second model is between 2 – 5 MW_e. Deeper (2.5 – 3.5 km) and good permeability fractured carbonate reservoirs can be appropriate to establish this size of facility. From the “waste” water direct heat can be provided in a cascade system.

From deeper fractured carbonate reservoirs the enthalpy of the produced thermal water makes the opportunity to establish medium size plants over 5 MW_e power. During the exploration of these projects there are really big technical challenges can be solved (extremely high overpressure, water salinity) in Hungary. However these reservoirs and plants provide the largest energy output.

There is a risky exploration phase in a micro power plant project as well and provides a lot of times smaller output, therefore the exploration of higher enthalpy geothermal resources is more promising in the Pannonian Basin.

Based on the power plant models there is a pessimistic (28 MW_e), a realistic (60 MW_e) and an optimistic (130 MW_e) schedule described concerning the Hungarian geothermal power plant establishment process till 2020.

The development of the geothermal business strongly depends on the macroeconomic background. There is a significant uncertainty concerning the future of the Hungarian geothermal energy industry, therefore it is a big difference between the pessimistic and the optimistic version. However, in any version the geothermal power establishment program describes an opportunity to increase the Hungarian domestic energy production with a clean, renewable and sustainable energy source.

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