Prospects for geothermal power projects in Hungary

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ABSTRACT

Hungary's excellent geothermal potential is well-known. Mostly the thermal water is used for direct heat utilization. Based on the 2016 Geothermal Atlas of Hungary, 1622 thermal wells produce hot water for direct heat utilization. In addition, many abandoned oil and gas wells could be converted to geothermal energy production.

In Hungary, district-heating systems are provided to about 93 towns or settlements, 657,8600 retail consumers and about 20,000 industrial consumers. The total available heating capacity 7,673 MW, and the available heating capacity of geothermal heat producers is 164 MW (MEKH, 2017).

This paper investigates the potential role geothermal could play in satisfying Hungarian energy demand. More specifically, the paper looks at what practical conditions and what levels of professional, financial and managerial competence are required for successful geothermal development.

1. INTRODUCTION

Hungary has never been energy-independent: it has always imported the energy it needed. Currently, however, Hungary's overall energy consumption has dropped to levels not seen since the 1970s. Hungary currently imports its energy, mostly from Russia. Natural gas makes up the larger part of the imported energy, although Hungary's natural gas consumption has decreased since 2008. 80% of this natural gas is imported from Russia through Ukraine and Austria. Nuclear energy plays a significant role in Hungary's energy mix of the country's electricity production is provided by the Paks nuclear plant near Budapest. About 20% of Hungary's electricity is imported directly. Again, this comes mostly from Russia. Coal is an insignificant player, both in terms of energy use and electricity production.

Renewables are an even more insignificant energy source, though steadily increasing (now at 8% of total energy production). This is in line with EU requirements. Geothermal energy utilization is stuck at 938.6 MWt (Toth, 2017), despite Hungary's favorable natural conditions. Hungary also uses biogas and biomass, the biomass usually taking the form of wood burned at electric power plants. Neither biogas- nor biomass-use is growing very rapidly.

Table 1: Primary energy consumption in Hungary in 2018 (MEKH, 2019)

	2015		2017		2018	
Energy	**Consumption [PJ]**	**%**	**Consumption [PJ]**	**%**	**Consumption [PJ]**	**%**
Natural gas	313,6	30	357,6	32	345,9	31
Petroleum	286,1	27	308,7	28	329,4	30
Nuclear	173,6	16	176,5	16	172,1	16
Coal	98,6	9	93,7	8	89,7	8
Biomass	103,9	10	99,4	9	89	8
Geothermal	4,4	0	5,6	1	5,6	1
Wind	2,5	0	2,7	0	2,2	0
Hydropower	0,8	0	0,8	0	0,8	0
Other	71,4	7	70,7	6	72,7	7
Export	-189,4		-312		-376,5	
Consumption	1054,9	100	1115,7	100	1107,4	100

At present, about 4 million Hungarian homes - more than 60% - fail to meet EU standards for good thermal insulation. The Hungarian government would like to improve this figure and reduce the heating/cooling demand in buildings. It has also tried to encourage greater use of renewable-energy sources and of geothermal energy use especially.

2. GEOTHERMAL STATUS IN HUNGARY

2.1 Geological background

Hungary lies in the Pannonian basin, an area nearly surrounded by the Carpathian Mountains. In Europe, the Pannonian basin stands out as a positive geothermal anomaly, with heat-flow density ranging from 50 to 130 mW/m^2, a mean value of 90-100 mW/m^2 and a geothermal gradient of about 45 °C/km (Dövényi et al. 1983).

Hungary has two major types of geothermal reservoirs: the first type occurs in multi-layered porous sediment (Upper Miocene-Pliocene "Pannonian" basin fill sequence) with low heat conductivity. At a depth of 700-1800 m the temperatures range is from 60 to 90 °C. This reservoir type has a virtually uniform hydrostatic pressure. It is widely used for direct heat purposes.

The second type of reservoir is Palaeozoic-Mesozoic basement carbonates. Its fractured zones of crystalline rocks are characterized by high secondary porosity. At this depth (on average 2000 m or more) temperatures can exceed 100-120 °C. This type of reservoir can offer favourable conditions for the development of medium-enthalpy geothermal systems (e.g. CHP plants).

Hungary also has deeply-buried granitic rocks with high in-situ rock temperatures (≥ 200 °C) and favourable seismic-tectonic settings (extensional regime, with little natural seismicity). These zones could provide promising settings for future EGS project developments.

2.2 Geothermal atlas

To stimulate the geothermal market, the Hungarian government commissioned a 2016 study to comprehensively analyze and summarize the geothermal potential of Hungary's 19 counties. Data was gathered for 1622 thermal wells, plus about 170 abandoned hydrocarbon wells which showed geothermal promise. The data yielded a national geothermal atlas, as well as numerous smaller-scale charts, graphs and maps.

Five different geo-isothermal maps were created. The first geo-isothermal map was that for 30 °C. This rock temperature is reached at the 250-450 m depth almost everywhere in Hungary. At this temperature, the water is primarily used for spas, but with the addition of a heat pump heat various other industrial applications are possible. The 50 °C rock temperature can be reached at the 700-900 m depth. SE Hungary has 90 °C rock temperatures, a temperature attained at the depth of 1600-1700 m. This 90 °C thermal water is hot enough to satisfy practically any industrial or communal heat requirement.

2.3 Geothermal energy production

Most of Hungary's thermal water, about 70%, comes from the Upper Miocene-Pliocene "Pannonian" basin. The remaining 30% comes from the karstified, deeply buried Palaeozoic-Mesozoic reservoirs. Thermal water production varies in intensity, but has been growing steadily over the last 50 years.

Every Hungarian well that's been registered officially as a geothermal well is certified to produce at least 30 °C water at the wellhead. According to the Hungarian Office for Mining and Geology, there are 1622 of these registered geothermal wells. About 25 million m^3 of thermal water were produced in Hungary (Toth, 2016).

Traditionally, most of the country's thermal water has been used for spas. Most of the country's geothermal energy production is used as a direct heat supply to heat housing projects and agriculture businesses.

The first geothermal plant was developed in Tura, which is an agricultural town 40 km from Budapest in 2018. The power plant has an installed capacity of 3 MW electric and 7 MW thermal. The heat will be delivered to a greenhouse that will operate nearby.

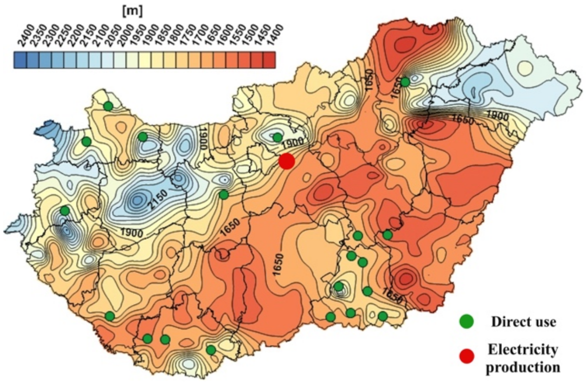

Figure 1: Existing geothermal systems in Hungary.

3. GEOTHERMAL EENERGY TARGET MARKETS

3.1 Current situation

In Hungary, 93 municipalities are supplied by district heating companies, representing 657,860 residential customers and about twenty thousand industrial and other consumers. Residential usage data per settlement is shown in Figure 2.

Figure 2: Residential district heating systems

In 2017, of the 7,673 MW meant for district heating only about 164 MW came from geothermal heat sources. The rest of the total heat output was provided by a conventional district heating plant using natural gas, and partly using biomass, coal and other energy carriers. According to our estimate, 60 to70 percent of that conventionally sourced district heating (roughly 6,500 MW) could realistically be replaced by geothermal sources (MEKH, 2017, Toth, 2017).

3.2 Possible strategic scenarios

As with all central European countries, heating for residences accounts for 75% of Hungary's total energy usage. Using geothermal for most of this residential heating would significantly reduce national energy costs, increase energy independence and reduce the pollution related to the combustion of sub-optimal fuels.

Figure 3 presents the locations of existing geothermal systems and indicates the potential domestic projects on the 90 °C geo-isotherm map. The existing geothermal locations are indicated by green dots, and the potential development opportunities are shown with black circles. The red dotted circle indicates Budapest area, which of special importance.

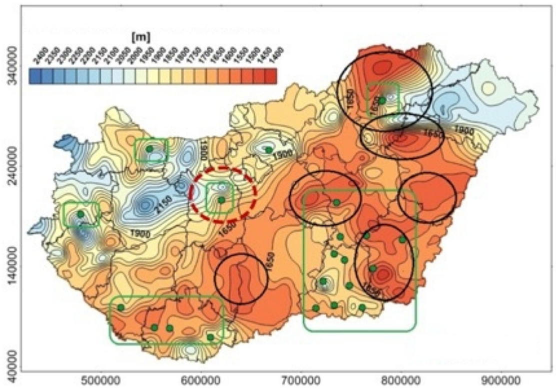

Figure 3: Promising geothermal areas

The two most obvious improvements would be to expand existing geothermal heat generation systems, and improve their efficiency by developing 'cascade' utilizations. The Mályi - Kistokaj - Miskolc area of NE Hungary would be an excellent place to start, as Miskolc, a city population of 158,000, is a significant heating market. Miskolc already boasts Hungary's largest geothermal district-heating system, which takes advantage of 95-105 ^{o}C geothermal water produced from a depth of 1500-2300 m, from a karstified-fractured Triassic basement. Presently, only approx. 30 to 35^{o}C of the geothermal heat is used. By adding additional heat exchange equipment, another 15 to 25 ^{o}C could be used, for a large gain in efficiency. For the current district heating service in Miskolc, the 50 MW heating capacity would thus increase to 70-90 MWt. After this improvement, yet another efficiency could be achieved by installing heat pumps, providing a further 15-25 MWt of energy for such applications as greenhouses, wood drying or crop dryers (Toth, 2017).

Further potential development opportunities exist in Eastern Hungary, primarily in Debrecen, Hajdúszoboszló, Szolnok, Kecskemét, Szekszárd and Baja.

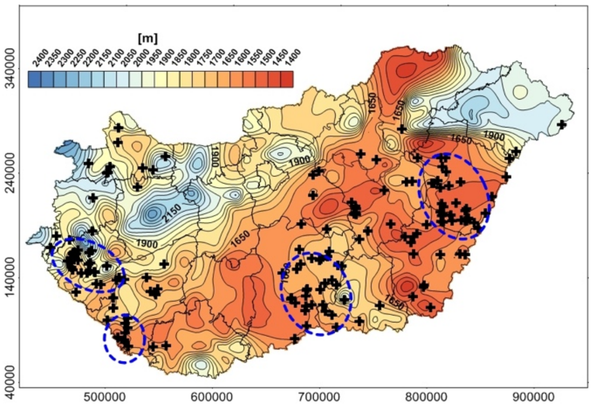

Figure 4: Abandoned and promising CH wells

Re-using abandoned hydrocarbon well for geothermal energy production represents another opportunity. Based on the 2016 Geothermal Atlas of Hungary, about 170 abandoned or temporarily closed hydrocarbon wells have been rated as very good geothermal sources. These wells, characterized by medium to high terrestrial heat flows (75-100 mW/m^{2}), are mostly located in sedimentary layers and are sometimes characterized by a more fractured geology.

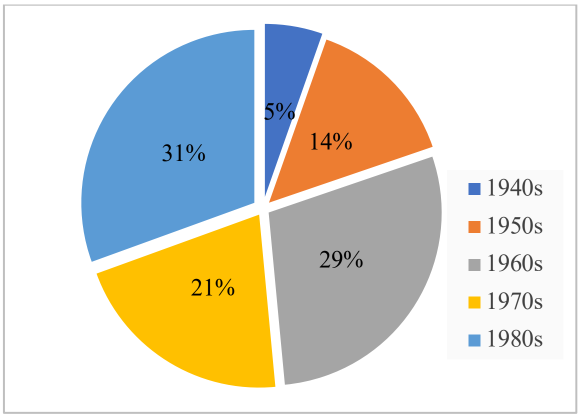

Figure 5: Abandoned oil and gas wells' ages

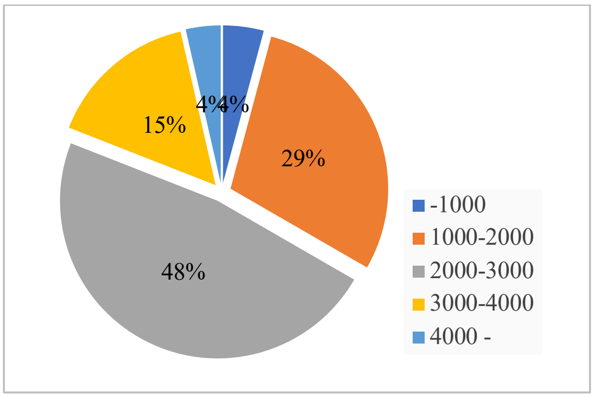

Figure 6: Abandoned oil and gas wells' depth

For purposes of analysis, three clusters were identified, each characterized by a high number of wells with sufficiently high rock temperatures. For each cluster, we analyzed the wells' depth, age, condition and likelihood that they would provide thermal water production. The wells' thermal water productions productivity varied between 0-30 kg/s. Where thermal water production seems possible, further investigation is required as to how best exploit the resource for which specific geothermal application. Even in wells where no water can be produced, however, dry, deep, high-temperature (≥150^{o}C) holes have geothermal potential which merits further investigation. For such cases, we have created a numerical simulation model to try to calculate and describe heat transfer in a dry hydrocarbon well, one which behaves as a coaxial heat exchanger (Toth, 2018).

The data provided by these wells also provides valuable subsurface information regarding lithology, temperature, and formation porosity. For the purposes of developing a geothermal project Wall and Dobson (2016) gave the CapEx breakdown shown in Table 2.

Obviously, well-drilling is the highest-cost engineering component. To drill one 2.5-mile (4-kilometer) well, which is considered middle-range, costs about $5 million, per Augustine et al. (2006). Today, more than ten years later, the drilling cost would be about the same.

Table 2: CapEx breakdown for a geothermal project (Toth, 2018)

Project stage	**Spending**
Exploration-Feasibility	12%
Exploration-Drilling	6%
Drilling	44%
Field Gathering System	8%
Plant Construction and Startup	30%
Total	100%

The second scenario involves developing new CHP plants in the catchment area of the largest heat markets.

Budapest and its metropolitan area have a population of 3,303,786, or 33 percent of Hungary’s total population It represents the greatest heating market in Hungary. Budapest’s heating demand, mostly for residential and district heating, is mostly satisfied by the provision of natural gas.

Budapest has 59 thermals wells. The temperature range of these wells is 40-76^{o}C. Their wellhead temperature distribution is shown in Figure 7.

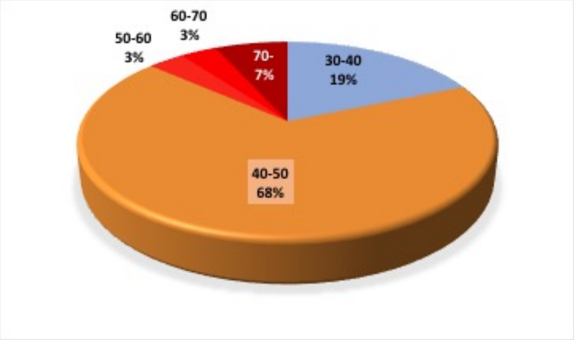

Figure 7: Wellhead temperature distribution

On behalf of the Hungarian Energy and Public Utility Regulation Authority, a report was developed in 2018. The aim was to examine and analyze the possibility of satisfying or partially satisfying Budapest’s heating energy demand with geothermal energy. The report revealed that about 30-50% of Budapest's fossil-based district heating supply could be replaced by geothermal sources. To achieve this goal, the Budapest metro area would optimally require three geothermal-based thermal feeds in Kelenföld, Kispest and Újpest.

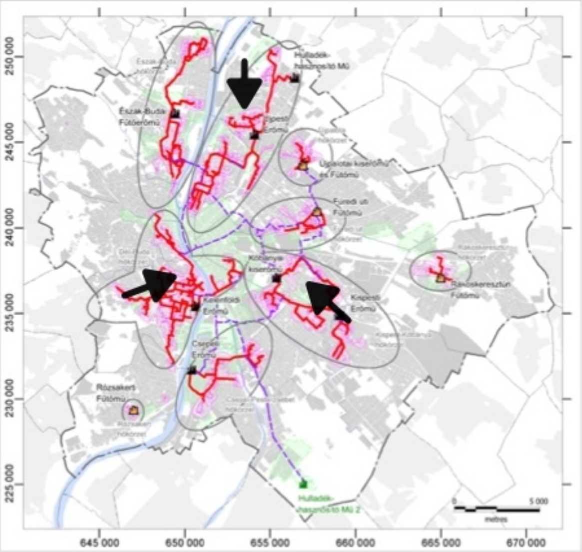

Figure 8: District heating systems in Budapest

There are no two identical GeoDH projects, as each project may differ in rock composition, drilling depth, water temperature, water quantity and chemical composition, TDS (and accordingly the quality of the required pipeline), type of cleaning / filter / degassing equipment used, type of district heating supplier, and distance of the user from the thermal well.

The estimated minimum cost of an average geothermal project (without power plant) is 20-30 million Euros (Toth, 2018). This is summarized in Table 3.

Table 3: Estimated cost of an average geothermal project

Phase	Minimum million €	Maximum million €
Research/Exploration	1.0	2.0
Wells/pumps	10.0	15.0
Risk insurance	0.5	0.5
Heat station/control	1.0	1.0
Network of pipelines	10.0	15.0
Total project cost	**22.5**	**33.5**

Different sources of financing are tapped in series at each stage of geothermal project development. Each source earns a return commensurate with the risk accepted at that point in the project life cycle. At later stages, some of the new financing pays off a portion of the existing debt from previous stages. Figure 9 depicts an estimation of the probability a project will be built at each stage of geothermal project development along with the relative investment magnitude for a 50 MW plant; in addition, the bottom part of the figure captures the type of financing that is available for each stage (Salmon et al, 2011).

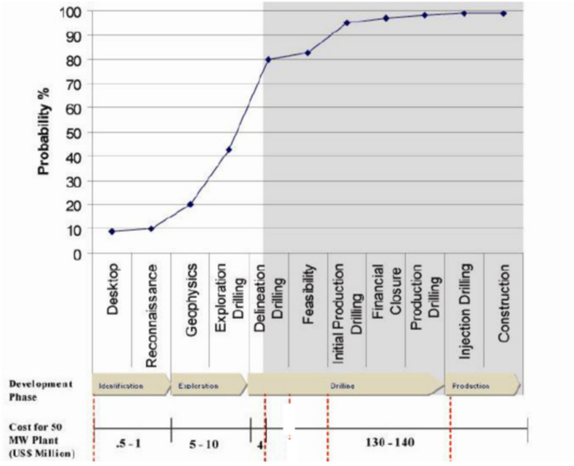

Figure 9: Geothermal project development and financing by stage

It can be said that the biggest risk and cost items are the exploration and the drilling of thermal wells, which are 30-50% of the total project cost. When creating a thermal well for energy purposes, one should always account for at least two wells (producing and injection wells). Drilling costs can also be drastically reduced (up to 25%) in a previously researched area by using local drilling experts and professionals. Abandoned hydrocarbon wells which are accessible and geothermally promising are always to be treated as an especially valuable resource.

3. CONCLUSIONS

Although Hungary has favorable natural conditions for geothermal energy production, geothermal still plays a disproportionately weak role in the Hungarian energy market. Any remedy would require a thoughtful, comprehensive and long-term national plan for the expansion of existing geothermal systems and the development of new geothermal systems, together with their efficient integration into the national energy grid.

Since Hungarian geothermal sources have a relatively low enthalpy, CHP projects should play a more serious role, considering how important it is to satisfy the great and ever-increasing demand for consumer heating and cooling. Especially important are the large number of abandoned hydrocarbon wells throughout Hungary -- for every one of these wells, the CapEx for an associated geothermal project could be reduced by as much as half. (This paper has shown two scenarios for helping achieve such results.) Although some recent projects such as the Tura geothermal power plant provide some hope for more positive developments, there clearly remains much to be done before Hungary can fulfill its geothermal potential.

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