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Geothermal Country Update for Hungary

Aniko N. Toth[1] and Annamaria Nádor[2]

[1]University of Miskolc, H-3515 Miskolc-Egyetemvaros, Hungary

[2]Supervisory Authority of Regulatory Affairs, H-1051 Budapest, Alkotás str. 50

toth.aniko@uni-miskolc.hu

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ABSTRACT

This paper gives a brief review of the history of geothermal energy in Hungary and discusses the present state of Hungary's geothermal energy production and utilization. Hungary's excellent geothermal potential is of course well-known. Traditionally, the country's geothermal energy production was used for direct heat supply, with most of the thermal water used in spas. Many such projects are currently underway. These focus on geothermal power-plant, CHP, district-heating and GSHP incentives. In 2022, more than 900 active thermal water wells produced about 90 million m^3 of thermal water in Hungary. Geothermal district-heating and thermal-water heating cascade systems represent a major part of Hungary's direct use, available in 26 towns representing about 235,29 MW_{th} installed capacity and 641,37 GWhth/yr. Major new projects have been established in Szeged. Individual space heating (mostly associated with spas) is available at nearly 50 locations These represent altogether an installed capacity of 94,11 MWth and 163,39 GWh_{th}/yr production. The agriculture sector is still a key player in direct use, especially in the SE of Hungary, where the heating of greenhouses and plastic-tents have long traditions. These account for ~ 402 MWth installed capacity and ~ 880 GWhth/yr production. Balneology has historical traditions in Hungary, more than 270 wells yield thermal water, sometimes medicinal waters which represent a total installed capacity of about 263 MW_{th} with an annual use of about 778,5 GWh_{th}/yr (Nádor et al, 2022). Recently, the first Hungarian geothermal power plant project was implemented in Tura, and has a 3 MW_e capacity. Unfortunately, the underdeveloped geothermal sector is not showing many other signs of progress, with the lack of reliable registry documentation making it hard to estimate the real GSHP number. In the family house market and in other official and industrial applications, air-based heat pumps have become dominant. The majority of these new applications are installed in new office buildings.

1. INTRODUCTION

The Pannonian basin in Central Europe is well-known as a positive geothermal anomaly, where rich geothermal resources have long been utilized, mainly as direct-use applications. Despite ongoing efforts to merge and harmonize existing databases available at mining authorities, research institutes and water management organizations, no one has yet succeeded in establishing a fully harmonized and up-to-date national geothermal database. In part, the reason for this has been the high number of thermal water wells (around 800-1000), along with the dissimilar registers being used, all adapted to the specific needs and purposes of the organizations they serve. These heterogeneous datasets do not allow for exact calculations and comparisons, because of the such discrepancies as the following: differences between actual flow rates and reported well-data; lack of information on the real temperature gradients; inaccurate reporting of the amount and use of thermal water; and inability to account for seasonal fluctuations in well production. For that reason, the data reported in this paper represent the author's own calculation based on data submitted by users and datasets from the various databases. These estimates show a more realistic growth in geothermal activity, compared to the data presented in previous country update reports (Tóth 2020, Nádor et al. 2022). The past country updates were continuously challenged by the diverse and unharmonized datasets available at mining authorities, research institutes and water management organizations, where the different registers were tailored to their specific needs and purposes of the above organizations. In this respect a major achievement was the establishment of Hungary's first digital online geothermal information platform (OGRE: https://map.mbfsz.gov.hu/ogre_en/) in 2019-2020 which made possible to make the present assessment based on reliable and a regularly updated national geothermal database (Nádor et al, 2022).

The steady increase of new wells in each year (Table 1) is partly associated with the expansion of previous projects, partly related to new projects (Nádor et al, 2022).

Table 1: New thermal water wells in Hungary drilled between 2020-2021

	Balneology	Agriculture	Space and District heating	Industry	Injection	Other	Power production	Total
2020	8	6	4	4	9	0	1	32
2021	2	2	4	1	3	0	0	12

2. NATURAL CONDITION GEOLOGICAL BACKGROUND

Hungary lies in the Pannonian basin, a positive geothermal anomaly with a 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 (Lenkey et al. 2002). There are two major types of geothermal reservoirs in Hungary. *Type 1* is a multi-layered porous sediment (Upper Miocene-Pliocene "Pannonian" basin fill sequence) of low heat conductivity, composed of successively clayey and sandy deposits. Within this thick basin-fill sequence the main thermal-water bearing aquifers are those 100-300 m thick sand-prone units (former delta-front facies deposits) found at depths of ca. 700-1800 m in the middle of the basin. There, the temperature ranges from 60 to 90 °C. This reservoir type has an almost uniform hydrostatic pressure and is widely used for direct heat purposes. *Type 2* is associated with the uppermost karstified zones of the deeply buried Palaeozoic-Mesozoic basement carbonates, as well as the fractured and weathered zones of crystalline rocks, characterized by high secondary porosity. At this depth (on average 2000 m or more) temperatures can exceed 100-120 °C, and may provide favourable conditions for developing medium-enthalpy geothermal systems (e.g. CHP plants). In addition, deeply-buried granitoid rocks with high in-situ rock temperatures ($\geq$ 200 °C) and favourable seismo-tectonic settings (extensional regime, low level of natural seismicity) provide promising settings for future EGS project developments.

3. PRODUCTION AND UTILIZATION

3.1 Deep geothermal

In the last few years the driving force in deep geothermal project development was the EU, which co-financed the Environmental and Energy Operative Program. This in turn supported the development of heating/cooling supply in local systems, as well as preparing and developing geothermal-based heat and electricity-producing projects. This included seismic acquisitions and the work of deepening initial "exploratory" wells.

3.1.1. Power generation

The first Hungarian geothermal power plant project (Fig. 2, red dot) has been implemented in Tura, although it was not part of a concession tender. This project is located in a well-explored former hydrocarbon block, where an uplifted Triassic carbonate block was found in basement rock, in the depth range of 1500-1800 m. Due to its depth range this area does not require a geothermal concession. The production well produces 108ºC, 2200 l/min hot water. The total water volume is injected at 8 bar pressure into the reservoir by means of two injection wells. The project aimed to achieve a 3.0 MW_e capacity. Actual gross electricity production is however only 2.3 MW_e, of which nearly 1 MW_e is the electricity demand of the power plant. Thus, it is capable of 1.3 MW_e net. An 11-hectare greenhouse complex is also planned.

Since the introduction of the concessional system in 2010 (obligatory for the exploration and exploitation of geothermal energy at a depth below -2,500 m, the typical depth range for power production and CHP projects), a preliminary complex vulnerability and impact assessment (CVIA) has been prepared for over 20 potential geothermal areas as a pre-requisite for concessional tendering. The aim of the CVIA is to provide a general overview of the future concessional area (geology, hydrogeology, geothermal conditions, etc.), and to determine those factors and areas within the planned concessional block where future "mining activity" cannot be performed due to several restrictions (environmental- and nature protection, water management, protection of cultural heritage, agriculture, national defence, land-use, etc.). So far, 3 geothermal concessional contracts have been signed for 35 years. These can be extended only once more for a maximum of 17,5 years. The 3 contracts cover Jászberény, Battonya and Győr - the latter to be used for heating.

Figure 2: Geothermal concession areas in Hungary, and the first geothermal power plant

3.1.2. Direct heat utilization

Geothermal "district" heating is available in 26 towns in Hungary in 2019, which altogether represent an installed capacity of 235,29 MWth and 641,37 GWh_{th}/yr production. Some of these are partial geo-DH systems, where geothermal energy contributes to the already existing district heating infrastructure (operated otherwise by gas), and geothermal's share is anywhere from 30 to 100%. This is the case in Makó, Csongrád, Hódmezővásárhely, Szentes, Vasvár, Szentlőrinc, Miskolc, and Győr. The majority of the systems are so called "thermal water heating cascade systems", where the gas-based heating of some public buildings (town halls, libraries, schools, hospitals, etc) is replaced by geothermal. Such systems are not currently connected to existing district heating systems, which only supply heat to a separate part of the settlement through a heat supply centre (Kistelek, Veresegyház, Bóly, Mórahalom, Gárdony, Mezőberény, Szarvas, Szeged, Barcs, Cserkeszőlő, Szolnok, Szigetvár, Törökszentmiklós, and Tamási). These local systems are commissioned on the basis of a water license and are often run by local municipalities, or municipality-owned service providers. This contrasts with the district-heating systems where heat is provided by a trading company on a contract basis, regulated by the Hungarian Energy and Public Utility Regulatory Authority.

The largest geothermal district heating project, developed by Pannergy Plc., is Miskolc in NE of Hungary. It was commissioned in 2013. This site has 2 production and 3 reinjection wells, producing thermal water from karstified-fractured Triassic basement carbonates at a depth of 1500-2300 metres, and with a total installed capacity of 55 MWth. This system supplies the district heating and domestic hot water for the large housing complexes in the Avas district of Miskolc.

After the completion of the Miskolc project, Pannergy Plc. accomplished its next large direct use project near Győr in NW-Hungary, where the system was commissioned in 2015. The exploration targeted the fractured Triassic dolomite basement at a depth of 2300-2850 m, which provided a very high yield (150 l/sec) and outflow temperature (100-105 °C). The technology supplies heat to a large industrial user (Audi Motor Hungary) in the town's suburbs as well as to the town's district heating system. Its heat capacity is 52 MWth. There are three production wells with 101-102°C outflow temperature at the well-heads.

In Szeged, a city of nearly 163,000 habitants at the Hungarian-Serbian-Romanian border, an ambitious project recently began, with the aim of introducing geothermal energy into the district heating network. Presently, two triplets are operating, with one production well (at a depth around -2000 m) and two injection wells (at a depth range of -1400 to -1700 m) targeting porous basin fill reservoirs. The systems have 4,4 and 4,5 MWth capacity. Another nine triplets, with similar layout and a capacity of 3 to 5 MWth each are under development: 4 triplets already have licenses; the other 5 triplets are still in the permitting stage.

In Tótkomlós a 22 MWth capacity geothermal project is currently being developed. The depth of the wells is 2200 m, and the planned well head temperature is 135°C. About 1000 private heat consumers and a 13 hectare greenhouse park will be supplied by geothermal heat. If the project succeeds, a 3 – 5 MWe electricity may also be produced.

The Mosonmagyaróvár geothermal district heating project has just begun. The depth of the production well is at -2200 m, and well-head temperature is 82°C. The brine will be reinjected at production depth.

The city of Tamási is a good example of effective utilization of low enthalpy resources. The temperature of the thermal water is 47 °C, but the municipality institutes are heated by a production-reinjection doublet.

In addition to district and thermal water town heating cascade systems, a significant number of individual space heating projects have been initiated, mostly associated with spas. These represent a total installed capacity of 94,11 MWth and 163,39 GWh_{th}/yr production

Agricultural use is an important branch of geothermal energy utilization in Hungary. Greenhouses use more than 80 Ha, and plastic tents and soil heating supplied with the heat of thermal water use more than 250 Ha. The major users are Árpád-Agrár Zrt in Szentes, Flóratom and Bauforg Ltd-s. in Szeged, and Bokrosi Ltd. in Csongrád and Primőr-Profit Ltd in Szegvár, but there are many others, especially in SE-Hungary. The estimated thermal power applied in the field of agricultural utilization is about 402 MWth installed capacity and ~ 880 GWhth/yr production.

For spas, the outflow temperature typically ranges from 30 to 50 °C. The hottest ones are at Zalaegerszeg in SW-Transdanubia (95 °C) and at Gyula in SE Hungary at the Romanian border (89 °C). There are equally renowned spas in Budapest, Bük, Hajdúszoboszló, Harkány, Hévíz, Sárvár, and Zalakaros, among many other places. The estimated thermal power used for bathing and swimming in Hungary is about 263 MWth with an annual use of about 778,5 GWh_{th}/yr (Nádor et al, 2022).

Thermal water for "public water supply" is mostly considered to mean drinking water. "Drinking thermal water" is a characteristic concept in Hungary, where 90% of the drinking water supply is provided from groundwater. Where the shallow aquifers are contaminated (such as in SE Hungary, where there is a naturally high arsenic content) the preference is to use lukewarm thermal waters with low TDS from slightly deeper confined aquifers.

3. Shallow geothermal

There are still no reliable GSHP registers available in Hungary, as systems shallower than 20 meters do not require a license, not even a notification to the authorities.

The increase of GSHP numbers has continued over the last several years. In the family house market and in other official and industrial applications, air-based heat pumps represent a significant portion. The majority of the new applications such as communal heating/cooling are installed in new buildings by the builders. The cooling function makes GSHPs more competitive in the greenfield constructions market.

According to the national geothermal potential assessment (Zilahi-Sebess et al. 2012), the GSHP potential of Hungary is 23 PJ/year. The 2012 estimation of the Hungarian Heat Pump Association forecast a 3,6 PJ/year by 2020, a goal which unfortunately will not be met. Currently there are two types of incentives:

The eco tariff ("H tariff") provides a preferential tariff for the electricity consumption of heat pumps and other renewable energy heating equipment (e.g. thermal solar collectors, circulation pumps, etc.) used for the heat supply of buildings from renewable energy sources.

The voluntary preferential tariff ("B" GEO tariff) for heat pumps of COP higher than 3. This scheme is available only in those areas where the service provider (at the moment only ELMÜ-ÉMÁSZ) introduced this system; it is however accessible for the whole year.

The currently existing incentives are far from sufficient to maintain the development of the heat–pump market experienced earlier.

There are several hybrid renewable and UTES projects being planned in Hungary. They include solar-geo hybrids for building energy-efficient development projects.

4. NATIONAL GEOTHERMAL ENERGY POLICY AND REGULATORY FRAMEWORK

Hungary has never been energy-independent, and has always had to import the energy it needed. Currently, however, Hungary's overall energy consumption has dropped to levels not seen since the 1970s. The regulatory and policy framework of deep geothermal have been summarized in the previous country updates (Nádor et al, 2022), so in this paper we highlight only the most important changes since 2015.

83% of Hungary's hydrocarbons and about 10 billion m^3/year of natural gas is imported mainly from Russia. This threatens the country's energy security, especially in the heating sector. Hungary's National Renewable Energy Action Plan target is 14,65% RES by 2020 with geothermal given a 17% share of the total RES goal. By 2020, the geothermal target numbers are 5,99 PJ (GSHP), 16,43 PJ (direct use) and 57 MW_e (power production).

There has been a delay in the implementation of the NREAP targets in the case of both shallow and deep geothermal capacity and production, especially in power production. Nonetheless, the government has often expressed its strong intention to support geothermal energy in Hungary. The EU2030 targets, including the 32% RES proportion at EU level, are also taken into consideration.

The newly established (2018) Ministry of Innovation and Technology coordinates developments of the entire energy sector, thus also geothermal energy. An important action was the establishment of the Energy Innovation Council in 2018 with the aim to provide expert inputs to the review of the Energy Strategy of Hungary. The Council has several thematic sub-groups, one dedicated to Renewable Energy, where geothermal energy has an important role, including the review of the subsidies and supports.

A new feed-in tariff system has been issued. This system follows the related EU regulations and ensures a competitive takeover price for geothermal power plants.

The 1345/2018 (VII. 26.) Governmental Decision on the Action Plan of the Utilization and Management of Energetic Mineral Resources is an important piece of recent legislation as it sets up concrete tasks with deadlines and responsible ministries concerning deep geothermal energy. It states that during the development of national RDI programs and funding schemes geothermal power production without water abstraction and reinjection technologies should be treated as priorities. A major achievement of the reported period was the introduction of a national geothermal risk mitigation scheme, which was launched in June 2021. To foster geothermal project development, the Ministry of Innovation and Technology announced a Call to support geothermal heating via handling the geological risks of the first wells. The Call is supporting projects only with reinjection, i.e. drilling of doublets, or drilling only reinjection wells to complete already existing systems. The target depth is 1000-2500 m below the surface. The total budget is 6 billion Hungarian forints (appr. 16,6 million euros). The Call is open till December 31, 2023, the application is continuous. Individual projects may range between 100 million to 2 billion Hungarian forints (appr. 278 keuro to 5,5 million euros). Eligible costs are related to drilling and testing. The reimbursement happens after the well tests are performed. The rate of success is determined by comparing actual flow rates and temperatures to those values pre-defined in the feasibility study submitted in the application. The reimbursement rate is 30% in case of success, 40% in case of partial success and 60% in case of unsuccessful projects.

5. RESEARCH AND INNOVATION

Hungarian institutes, universities and companies have coordinated or participated in several research, development and innovation projects. The scope of these projects covers:

- reinjection of brines into sandstone reservoirs
- extraction of minerals from thermal water
- mitigation of technical risks in geothermal energy exploration and production (including operational problems, such as scaling)
- development of deep borehole heat exchangers (geothermal energy production in closed systems without thermal water abstraction)
- application of laser technologies for drilling operations and well-maintenance activities

The University of Miskolc offers Geothermal Engineering programs, and has done so since 2008. This 4-semester program covers twenty curricula topics. Its students can receive the equivalent of a BSc or an MSc in Geothermal Engineering. In partnership with the University of Colorado, the University of Miskolc has also brought together international professors and geothermal experts to create an up-to date geothermal curriculum for e-learning undergraduates.

6. CONCLUSIONS

Although Hungary has favorable natural conditions for geothermal energy production, production and utilization has lagged behind expectations. Nevertheless, there are promising signs. But for the Hungarian geothermal industry to progress, it needs a well-considered energy policy together with a framework of supportive legal and financial conditions.

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