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Country Update for Hungary

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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 2019, more than 900 active thermal water wells produced about 90 million m^3 of thermal water in Hungary, representing 1023.7 MWt or 10,701 TJ/y. 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 ~ 358 MWth installed capacity and ~ 2,891 TJ/yr production.

Geothermal district-heating and thermal-water heating cascade systems represent a major part of Hungary's direct use, available in 23 towns representing about 223,4 MW_{th} installed capacity and 2,288 TJ/y annual production. Major new projects have been established in Győr and Szeged. Individual space heating (mostly associated with spas) is available in nearly 40 locations, representing an estimated installed capacity of about 77,2 MW_{th} and 299 TJ/yr production.

Balneology is historically the country's most important geothermal application, with more than 250 wells yielding thermal and sometimes medicinal waters. These represent a total installed capacity of 249,5 MWt with an annual use of about 3,684 TJ/yr. 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 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.

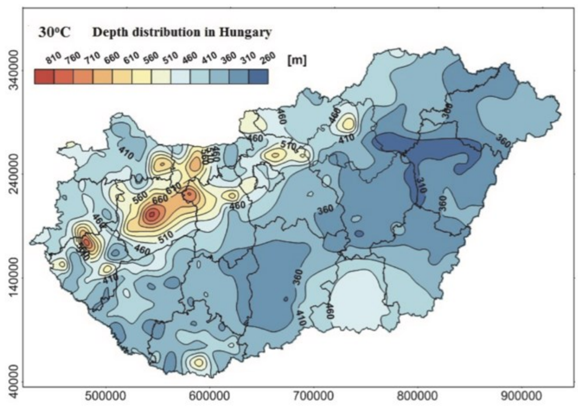
1. INTRODUCTION

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 2015, Nádor et al. 2019).

2. NATURAL CONDITION

2.1. 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 (≥ 200 °C) and favourable seismo-tectonic settings (extensional regime, low level of natural seismicity) provide promising settings for future EGS project developments.



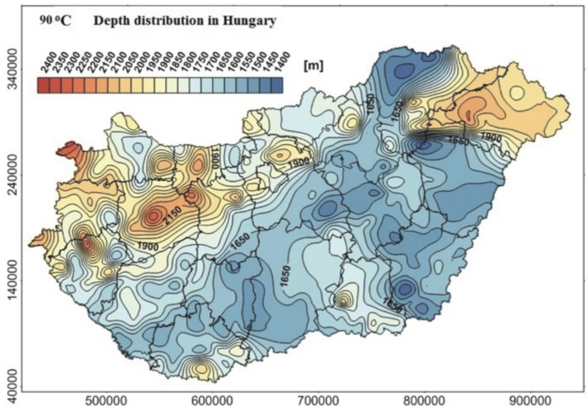


Figure 1: Geo-isothermal map 30 °C rock temperature **Figure 2: Geo-isothermal map 90 °C rock temperature**

2.2. History of geothermal

Surface manifestations have been known since ancient times: thermal springs in Budapest had been used in the Roman Empire and also later in the medieval Hungarian Kingdom. The artificial exploration of thermal waters began with the activities of V. Zsigmondy, the legendary drilling engineer who in 1877 drilled Europe's deepest well (971 m) in Budapest. Between the two World Wars, while prospecting for oil, huge thermal water reservoirs were discovered. Based on data from this exploration, Boldizsár (1944, 1956) recognized the high terrestrial heat flux and geothermal gradient in the Pannonian Basin.

During the 50's and 60's hundreds of geothermal wells were drilled, mainly for agricultural purposes. The peak of geothermal activity was in the late 70's: a total of 525 geothermal wells were registered, and the thirty best wells had a production temperature exceeding 90^{o}C.

The existence of high enthalpy reservoirs was proven by a dramatic steam blowout from the Fábiánsebestyén well in the southeast of Hungary in 1985. From an exploratory borehole, over-pressured steam had blown out at a pressure of 360 bars and a temperature of 189^{o}C. The flow rate was approximately 8,400 m^3/day, from a 3,800 m deep reservoir in a fractured-dolomite formation. The blow-out lasted 47 days, and the wellhead pressure as well as the flow rate remained constant. The well was finally killed and the borehole cemented. At present, feasibility studies are going on to determine the reservoir's dimensions and the geothermal potential. There may be yet more deep, high-enthalpy reservoirs in South-Eastern Hungary.

Many deep hydrocarbon exploratory wells have been drilled in South-Eastern Hungary during recent years, and exploration has revealed the high temperature of the region's impermeable basement rock. The obtained undisturbed temperature for the rock is 252^{o}C at a depth of 6,000 m. This area could be a promising target for future EGS development projects.

The chemistry of the Hungarian thermal waters is quite varied. Thermal groundwater of the porous Upper Miocene (Pannonian) reservoirs generally has an alkaline $NaHCO_3$ characteristic. Where thermal water of the carbonate basement aquifers has an active recharge, it is characterized by a $CaMgHCO_3$ composition. Where there are deep basement reservoirs without direct hydraulic connection (supply), the water generally has higher salinity, usually NaCl-type (fossil waters).

Regarding the geothermal potential of the country, several assessments have been done over the last 15 years. According to the latest survey the heat in place down to a depth of 10 km was estimated to be as much as 375,000 EJ. The inferred resources between a depth of 0-5 km is 105,500 EJ, with probable reserves of 60 PJ/y for the porous and 130 PJ/y for the basement reservoirs (assuming full re-injection) (Zilahi-Sebess et al. 2012).

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

There is one geothermal power plant in Hungary (Table 2). Regulatory changes and ongoing project investigations ensure that geothermal based power production will make an appearance by the 2020s.

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.). These reports are public and can be downloaded (in Hungarian) from the website of the Mining and Geological Survey of Hungary (www.mbfsz.gov.hu). 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 3: Geothermal concession areas in Hungary, and the first geothermal power plant

The first Hungarian geothermal power plant project (Fig. 3, 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 1700-2200 m. Due to its depth range this area does not require a geothermal concession. The production well produces 125ºC, 6000 l./min hot water from a depth of 1500m. 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.

3.1.2. Direct heat utilization

Geothermal "district" heating is available in 23 towns in Hungary in 2019, which altogether represent an installed capacity of 223,36 MWth and 2,288 TJ/y 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 77,2 MWth and 299 TJ/yr production.

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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 383 MWt or 3.188 TJ/year.

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 249 MW_t or 3684 TJ/year.

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 reported numbers in Table 4 are the best estimates of the authors (Nádor et al, 2019).

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.

In the case of shallow geothermal systems, the system sizes continue to increase. Many international companies operating in Hungary made significant investments in heat-pump systems in recent years (e.g. Telenor and TESCO). The size of individual units ranges from 10 kW to 14 kW for residential use. In 2018, a 1650 kW heating and 720 kW cooling capacity heat pump system was developed and began operation at the NATO base in Pápa.

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 (Tóth 2015, Nádor et al2019), so in this paper we highlight only the most important changes since 2015.

83% of Hungary's hydrocarbons and about 20 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, rhe 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. The other important point is that it addresses geothermal risk mitigation: it calls on the Minister for Innovation and Technology and the Minister for Finances to make a joint proposal on introducing financial tools for the mitigation of high upfront risks for geothermal projects (i.e. a risk insurance scheme) by June 2019.

5. RESEARCH AND INNOVATION

5.1 Geothermal Database and Atlas of Hungary

The Hungarian Energy and Public Utility Regulatory Authority requested in 2016 that a study be made to analyze and summarize the geothermal potential of every one of the country's 19 counties. 1622 thermal wells and more than 70 abandoned hydrocarbon wells were also analyzed. To make it easier for the average user, five different isothermal maps of Hungary were created, showing the different depths at which a particular temperature was attained. Those temperatures were 90 °C, 70 °C, 60 °C, 50 °C and 90 °C (Fig. 1, 2). In addition to creating a solid informational basis where none had existed before, the study was valuable as a means of showing all 19 Hungarian county governments how they might profit from their geothermal potential.

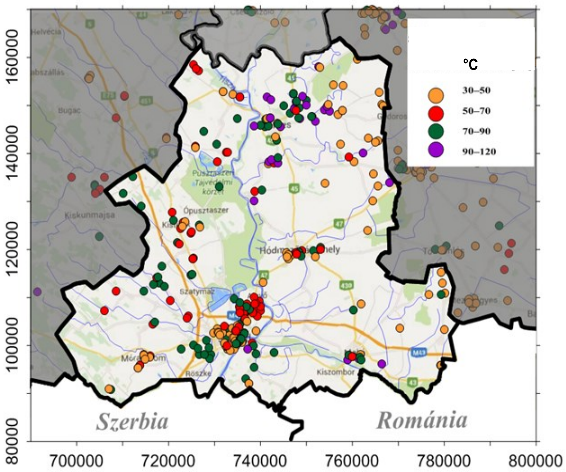

Figure 4: Geothermal wells in Csongrad county

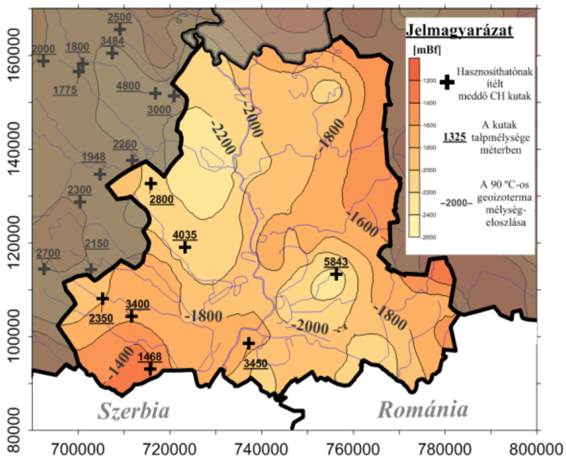

Figure 5: Abandoned hydrocarbon wells with good geothermal potential

5.2 Geothermal Budapest

In 2018 a report was developed to geothermally analyze and describe Budapest, the capitol and largest city of Hungfary, where more than 1.7 million people live. Specifically, the idea was to look at Budapest's geothermal energy supply possibilities. The report deals with the location and economic role, energy demand, and current energy supply of Budapest. The report investigates the city's geological and geothermal background, looks at its existing geothermal and water wells, makes suggestions for developing further geothermal energy sources, and looks at how we could partially replace the metro area's energy demand with clean, renewable, self-supplied energy. Written as a commissioned project for Hungary's Energy Authority, this report is now being made available in a more easily readable version for the greater public.

5.3. Universities and Research Institutes

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

geothermal district heating

reinjection of brines into sandstone reservoirs

extraction of minerals from thermal water

mitigation of technical risks in geothermal energy exploration and production activity

geothermal risk insurance

assessment of transboundary geothermal reservoirs

The University of Miskolc and the University of Szeged are partners in the H2020 project CHPM-2030, which aims to develop a novel technology that will serve as the basis for combined heat and power use and strategic metal extraction by converting ultra-deep metallic mineral formations into an "ore body-EGS". This 42-month project finished in June 2019.

The Mining and Geological Survey of Hungary is the lead partner of the DARLINGe project (funded by the Danube Transnational Program) which, together with Mannvit Hungary, InnoGeo Ltd, the Hungarian Ministry of Foreign Affairs and Trade, and other partners from 5 neighbouring countries, aims to assess the transboundary geothermal energy resources of the Southern part of the Pannonian basin. This project was scheduled for 2017-2019.

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The Eötvös Loránd University (ELTE) in Budapest was granted a 3 year program (ENERAG) to strengthen research and innovation capacity in the field of subsurface fluids, taking advantage of international networks of excellence. For this purpose, ELTE is co-operating in this project with the Geological Survey of Finland (GTK), and the University of Milan (UMIL) which is the leader of the consortium. This project was scheduled for 2018-2021.

Funded by the Economy Development and Innovation Operation Programme, a large scale exploration project has been undertaken with the goal of studying the geothermal potential south of the Mecsek Mountians. It was led by Mecsekérc Ltd. The project also looks at the possibility of creating a geothermal (power) plant to supply environmentally friendly energy to the city of Pécs.

8. 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.

REFERENCES

Lenkey, L., Dövényy, P., Horváth, F. and Cloetingh, S.A.P.: Geothermics of the Pannonian basin and its bearing on the neotectonics, *GU Stephan Mueller Special Publication Series*, 3, pp 29–40, European Geosciences Union (2002)

Nádor, A., Kujbus, A. and Toth A.: Geothermal energy use, country update for Hungary. *Proceedings, European Geothermal Congress 2019*, Den Haag, Netherland (2019)

Tóth, A.: Hungarian Country Update 2010-2014, *Proceedings WGC2015,* ISBN: 9781877040023 1877040029, Melbourne, Australia, (2015)

Tóth, A.: The Geothermal atlas of Hungary, Hungarian Energy and Public Utility Regulatory Authority, , ISBN 978-963-12-849-1 (2016)

Zilahi-Sebess, L., Merényi L., Paszera, Gy., Tóth, Gy., Boda, E. and Budai, T.: Nyersanyag készletek, A hazai ásványi nyersanyag-potenciál, 5. Geotermikus energia, Nemzeti Energiastratégia, Készletgazdálkodási és hasznosítási cselekvési terv, 84 p. (2012)

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	3		6,046	21,057	50	250	2,000	14,500	521	2,100	8,617	32,700
Under construction in December 2019												
Funds committed, but not yet under construction in December 2019												
Estimated total projected use by 2020	3		6,046	21,057	50	250	2,000	14,500	521	2,100	8,617	32,700

TABLE 2. **UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2019**

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)
2F = Double Flash H = Hybrid (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

3) Electrical installed capacity in 2019

4) Electrical capacity actually up and running in 2019

Locality	Power Plant Name	Year Commissioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe[3)]	Total Running Capacity MWe[4)]	Annual Energy Produced 2019 GWh/yr	Total under Constr. or Planned MWe
Tura		2018	1		B	3	1		
Total						3	1		

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)

1) I = Industrial process heat — H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling) — D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables) — B = Bathing and swimming (including balneology)
F = Fish farming — G = Greenhouse and soil heating
K = Animal farming — O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (^{o}C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Barcs	D,H, B		57	22			2.00	5.00	23.08	0.36
Bóly	D,H	16.20	80	55			2.50	10.25	33.80	0.43
Cserkeszölő	H,B	7.08	86	45			2.00	4.20	22.71	0.36
Csongrád	D,A,B,G	66.57	65	34			8.63	31.00	126.76	0.46
Felgyő	D,A,B,G	40.11	84	33			8.56	17.10	115.03	0.42
Gárdony	B,H	8.12	68	25			1.80	5.02	28.47	0.50
Győr	D,H,B	290.00	101	55			52.00	96.00	582.47	0.35
Hódmezévásárhely	D,H,B,A	76.11	86	23			21.00	39.20	325.74	0.49
Kistelek	D,A,B,G,I	22.57	72	38			3.39	10.50	47.09	0.44
Makó	D,A,B,G	47.87	85	45			9.01	21.50	113.43	0.40
Mezőberény	D,H,A,B	110.00	83	45			4.60	16.00	80.20	0.55
Miskolc	D,A,B	150.00	103	45			65.00	125.00	956.28	0.46
Mórahalom	H,B	16.66	70	48			1.53	8.10	23.50	0.48
Szarvas	D,A,B,G,F	43.50	92	32			11.28	26.20	207.35	0.58
Szeged	D,A,B,G,I	116.30	90	35			18.00	41.60	301.79	0.53
Szegvar	D,A,B,G,I	113.00	92	35			24.11	39.60	297.72	0.39
Szentes	D,A,B,G,I	285.90	100	40			55.00	140.20	1109.54	0.64
Szentlorinc	D	25.00	86	60			3.45	13.20	45.27	0.41
Szigetvár	H,B	12.00	58	35			1.50	8.00	24.27	0.51
Szolnok	H,B	110.00	63	55			3.00	32.00	33.77	0.35
Tamási	H,B	120.00	55	48			2.50	39.00	36.01	0.45
Törökszentmiklós	H,B	90.00	75	65			2.70	45.00	59.36	0.69
Vasvár	D,B	15.00	72	45			1.76	9.00	32.05	0.57
Veresegyhaz	H,B	65.00	64	35			14.00	37.00	141.53	0.32
Others	D,A,B,G,I,H	6050.00	58	32			588.73	1800	6172.92	0.33
TOTAL		7896.99					908.05	2619.67	10940.13	0.46

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling rejected to the ground in the cooling mode as this reduces the effect of global warming.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate - typically 3 to 4

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

6) Cooling energy = rated output energy (kJ/hr) x [(EER - 1)/EER] x equivalent full load hours/yr

Note: please report all numbers to three significant figures
Due to room limitation, locality can be by regions within the country.

Locality	Ground or Water Temp. (°C)1)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type2)	COP3)	Heating Equivalent Full Load Hr/Year4)	Thermal Energy Used5) (TJ/yr)	Cooling Energy6) (TJ/yr)
udapest and the country sid	15	10	6500	v	4	5200	1075	204
TOTAL	15	10	6500		4	5200	1075	204

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
not operate at 100% capacity all year

4) Other than heat pumps

5) Includes drying or dehydration of grains, fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

Use	Installed Capacity1) (MWt)	Annual Energy Use2) (TJ/yr = 10^{12} J/yr)	Capacity Factor3)
Individual Space Heating4)	77.20	299.00	0.31
District Heating 4)	223.40	2288.00	0.32
Air Conditioning (Cooling)			
Greenhouse Heating	358.10	2891.00	0.33
Fish Farming			
Animal Farming			
Agricultural Drying5)	25.00	297.00	0.38
Industrial Process Heat6)	19.00	220.62	0.32
Snow Melting			
Bathing and Swimming7)	249.00	3684.00	0.35
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps	72.00	1022.00	0.45
TOTAL	1023.70	10701.62	0.34

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)					
Production	>150° C			0		
	150-100° C			4		7.356
	<100° C			51		60.681
Injection	(all)			2		2.510
Total				55		70.547

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	5	21	11	6		44
2016	5	22	11	5		45
2017	6	22	13	7		46
2018	7	23	13	6		43
2019	7	23	14	6		48
Total	30	111	62	30		226

Data in Table 8 are estimated.

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$

Period	Research & Development Incl.	Field Development Including Production	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0.25	0.10			40.00	60.00
2000-2004	0.30	0.15			80.00	20.00
2005-2009	3.70	2.80			70.00	30.00
2010-2014	3.80	4.80			65.00	35.00
2015-2019	6.00	5.50			40.00	60.00

Data in Table 8 are estimated.