Proceedings World Geothermal Congress 2026
Calgary, Canada, June 8 – 11, 2026

Country Update: Hungary

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Keywords: Pannonian Basin, direct use, district- and town heating, national strategy

ABSTRACT

Hungary shows a steady growth of geothermal energy use following its ambitious growth path envisioned in its National Geothermal Strategy (2024) of increasing geothermal energy use from the base value of 6.4 PJ (2022) to 8 PJ by 2026, and to 11-12 PJ by 2030. As of 2024 (Nádor et al. 2025) geothermal district-heating and thermal-water heating cascade systems represent a major part of direct use available in 28 towns, which altogether represent an installed capacity of 280.12 MWt and 2722.68 TJ production. The agriculture sector is still a key player in direct use, which account for about 424.5 MWt installed capacity and about 3456 TJ/yr production. Balneology has historical traditions in Hungary, which represent a total installed capacity of about 268 MWt with an annual production of about 2810 TJ/yr. There is one operating geothermal power plant in Tura, with a gross electric capacity of 2.3 MWe.

1 INTRODUCTION

Due to the favorable geological situation, the Pannonian basin is one of Europe's best known geothermal areas. Hungary is lying in the central parts of this extensive hot sedimentary aquifer complex, where the rich geothermal resources have been utilized for direct use purposes since the historical times. This extensive use has steadily put Hungary on the 3-5th place on the European ranking list in terms of direct use during the past decades.

1.1 Policy

The development of the huge, but untapped geothermal potential of Hungary has been in the focus of the Hungarian energy policy over the past years. The impacts of the Russian-Ukrainian war accelerated the transformation of the Hungarian energy system, being heavily reliant on the Russian gas import (cca. 80% of the annual 8.5 BCM gas consumption). Several expert analyses revealed that about 1-1.2 BCM gas could be replaced by geothermal until 2035.

The Hungarian Geothermal Energy Utilization Concept ("national geothermal strategy") was launched by the Ministry of Energy in 2024 (Energiaügyi Minisztérium 2024) which depicts the ambitious grow path of increasing geothermal energy use from the base value of 6.4 PJ (2022) to 8 PJ by 2026, and to 11-12 PJ by 2030. Thus, the share of geothermal energy in the gross heat production should increase from the current 7.5% (2024) to 12% by 2030 and to 25-30% by 2035. The document also summarizes the main intervention areas. On short term (2-4 years) projects targeting industrial, agricultural and communal heat (thermal water town heating) should be prioritized, as well as combined heat and power projects on areas with moderate geological risks. On mid-term (4-6 years) the development of geothermal district-heating and combined heat and power projects on areas with higher geological risk should be in the focus. The document also emphasizes that both in district- and thermal water town heating the synergies between shallow- (heat pumps) and deep geothermal technologies should be considered. The important role of the State in performing exploration campaigns reducing geological risk, and assuring a stable and predictable financing environment are also highlighted.

Hungary also achieved significant progress during its EU Presidency (July 1 – December 31, 2024) by formulating Council Conclusions on promoting geothermal energy, which was adopted on December 16, 2024 (EC 2024) as an official document. This set of conclusions highlights the potential of geothermal energy as a local renewable energy source and its role in decarbonizing European energy systems. The Council calls on the Member States to speed up licensing procedures, to ease access to financial schemes and elaborate incentives in order to face the high upfront costs and associated risks related to drilling and exploration – areas where Hungary achieved significant progress over the past few years (see 1.2 and 1.3). The Conclusions also propose measures to increase the capacity of European industries in drilling, construction and equipment manufacturing, which the emerging Hungarian market is also looking for.

1.2 Regulatory framework

In line with the above requirements a major step that initiated the boost of the Hungarian geothermal sector was the amendment of the Mining Act from March 1, 2023, which introduced a new licensing system. According to the new legislation, all geothermal direct use and power projects, irrespective of depth, are licensed by the Mining Authority (except for the agriculture use and balneology which remained under the auspices of water management). The new licensing systems identified 3 main stages. The first (exploration) stage may last max. for 4 years, when the project developer must perform a detailed exploration program and drill min. 1 well. The number and size of exploration blocks is limited per applicant (8 blocks, max size 400 km2/block). A financial guarantee is also requested. After completing a successful exploration, in the second stage, a so-called geothermal protection zone is designated from where the project will have exclusive production rights. This refers to a 3D subsurface space, delineated on the basis of a numerical heat and flow model that identifies the allowed max. temperature and pressure changes. In the third stage, the Mining Authority signs an exclusive utilization contract valid for max 35 years (can be extended by 17,5 years) which describes the exact ways of utilization, annual energy production rates, reinjection, etc.

1.3 Financial incentives and other market supporting initiatives

A national geothermal risk mitigation scheme was launched in Hungary in 2021. The total budget was 6 billion Hungarian forints (appr. 15 million euros) and was open till December 31, 2023. The reimbursement rate was determined as 30% in case of success, 40% in case of partial success and 60% in case of unsuccessful projects. The rate of success was determined by comparing actual flow rates and temperatures to those values pre-defined in the feasibility study submitted in the application. In the frame of this Call altogether 4 projects were awarded and about 75% of the available funds were spent.

In the frame of the Swiss-Hungarian Cooperation Program (Swiss Fund) the call for applications under the sub-program SM06-GEO “Geothermal energy sources for district and municipal heating” primarily aimed at the expansion and development of surface systems (modernization of heat centers, construction of heat pipelines and connection of new consumers to existing geothermal sources, as well as modernization and renovation of wells in order to increase capacity). The program's steering committee made a funding decision on the submitted applications in 2024 and decided to support 11 applications out of the 12 submitted. The amount of the awarded grants was 5 billion Hungarian forint (appr 12,5 million euros) including domestic co-financing.

A major funding source for geothermal developments is provided in the frame of the “Environment and Energy Efficiency Operative Program” co-financed by ERDF (85%) and national sources (15%). Three Calls were announced in 2025 and early 2026 that build on each other: (1) A renewed geological risk mitigation scheme for the drilling of the first well with a reimbursement rate of 45-50 % in case of unsuccessful and 10% in case of successful wells, with a total budget of 10 billion Hungarian forints (appr. 25 million euros), (2) a preferential loan construction that provides a financing framework for drilling a geothermal well and subsequently for the construction of surface equipments, pipelines, power plants and heating centers with a total budget of 20.32 billion Hungarian forints (appr. 50.7 million euros), (3) development of grid-connection for geothermal-based CHP systems (with already existing doublet) with a total budget of 12 billion Hungarian forints (appr. 30 million euros).

In addition to financial incentives, Hungary has put a special attention to FAIR (Findable, Accessible, Interoperable and Reusable) data policy related to geothermal. The first digital online geothermal information platform (OGRE) was established in 2019-2020 which provides a national scale overview on the main geological framework of the potential reservoirs, subsurface temperatures, key borehole data, data of running geothermal projects, surveillance, etc. This is annually updated. In addition to this platform which provides a general overview and mainly metadata, the Hungarian Geological Survey has been compiling geothermal data packages about 250 sites of potential investment interest, that are all available in data room services. As part of a national geothermal exploration program, state financed seismic exploration campaigns are executed on data-poor areas to better understand the subsurface geology, thus to mitigate the geological risk of future projects.

In order to bring together the actors involved in the extraction and use of geothermal energy, the Hungarian Geothermal Cluster was established in 2023. The 40 members of the Cluster are representatives of the state-regulator, scientific associations, academia, suppliers, investors, project developers. This is fully in line with the envisioned European Geothermal Alliance, to be set up by the Commission that would bring together policymakers, industry and investors.

2 GEOLOGY BACKGROUND

A great number of papers have discussed the outstanding geothermal potential of the Pannonian Basin (e.g. Horváth and Royden (1981), Horváth et al. (2015), Lenkey et al. (2002), Nádor and Lenkey (2024) and references therein). The existence of the rich geothermal resources is due to the complimentary combination of the eminent heating sources and the regionally extended aquifers, where stored groundwater is heated up. The elevated heat flow density (50-130 mW/m2) and high geothermal gradient of about 45 °C/km is resulting from the Miocene tectonic evolution of the basin (crustal extension and thinning), whilst the geothermal aquifers are represented by 2 main types: (1) several thousand m thick sandy-clayey sediments deposited during the subsidence of the basin (porous reservoirs), and (2) deep-lying fractured and karstified Mesozoic carbonates and fractured Palaeozoic rocks that form the basement rocks of the sedimentary basin (Fig. 1). According to the resource assessment calculations (MBFSZ 2021) the realistically recoverable amount of deep geothermal energy is 127.6 PJ/year (57.6 PJ/year from the porous geothermal aquifers, and 70 PJ/year from the basement reservoirs), which is about 16 times more than the current use (around 7.8 PJ/year), which underpins the great untapped potential.

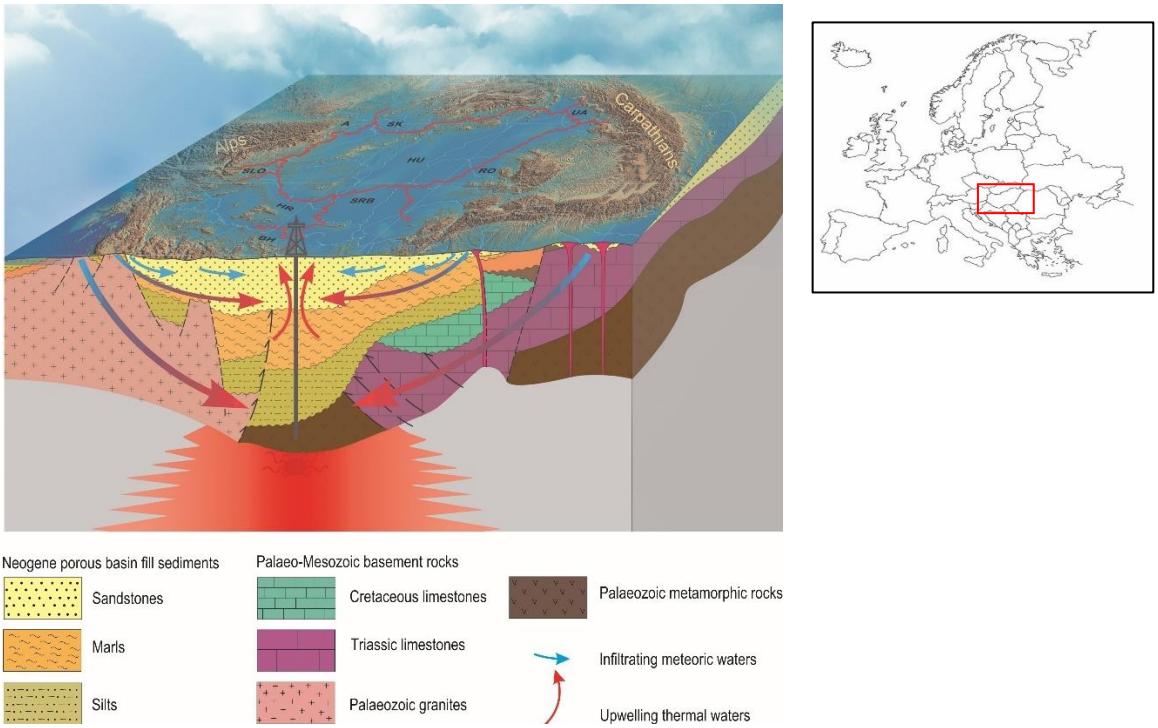


Figure1: Theoretical model of the Pannonian basin with the main porous basin fill and fractured-karstified basement reservoir rock types and thermal water flow systems

The present paper, based on the country update for EGC 2025 (Nádor et al. 2025) is describing the development of the Hungarian geothermal sector on the basis of assessing datasets (mainly borehole data) available at mining authorities, research institutes and water management organizations. Different datasets underwent a massive harmonization process and comprise data of appr. 1220 active thermal water wells. (those having outflow temperature higher than 30 °C). Latest data underpin the steady growth (in total 52 new geothermal wells were drilled between 2022 and 2024) of installed capacities especially in the district heating sector due to the completion of ongoing developments and some new projects.

3 GEOTHERMAL UTILIZATION

3.1 Power generation

There is still one operating geothermal power plant at Tura, which is located in a well-explored former hydrocarbon block in N-Hungary. The production well produces 108 °C, 2200 l/min hot water from an uplifted Triassic carbonate block at a depth of 1500-1800 m, which is fully reinjected. The actual gross electricity capacity is 2.3 MWe, of which nearly 1 MWe is the electricity demand of the power plant.

A prosperous development site for a binary plant is at Tótkomlós, S-Hungary is where 2 doublets were drilled in 2019-2020 yielding high temperature (122-132 °C) water from a depth of 1600-1800 m from Triassic dolomites. Originally the project aimed at town heating and heat supply to a greenhouse park, but due to the lack of a sizeable heat market and the high temperature above expectations, now the site is a candidate for power production which development is under preparation.

3.2 Direct heat utilization

Geothermal "district" heating is available in 28 towns1 in Hungary in 2024, which altogether represent an installed capacity of 280.12 MWt and 2722.68 TJ production. These are partly (1) geo-DH systems (in 13 towns with 215.27 MWt), where geothermal energy contributes to the already existing district heating infrastructure (operated otherwise by gas) with a 30 to 100% share, partly so called "thermal water town heating systems" (16 towns with 64.85 MWt), where the gas-based heating of some public buildings (town halls, libraries, schools, hospitals, etc.) is replaced by geothermal. These local systems were commissioned in the past 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.

Over the past couple of years some already existing sites expanded, and some new systems started to operate as well. The largest growth happened at Szeged, a city of nearly 163,000 habitants at the Hungarian-Serbian-Romanian border. The ambitious project started in 2018 with the aim to introduce geothermal energy into 9 of the existing 23 district heating circuits fed by imported gas, and supplying heat to 28 000 flats and 500 public buildings. A geothermal triplet is being drilled for each heating circuit with one production well (target reservoir at a depth between 1700-2000 m yielding thermal water of 90-95 °C) and two reinjection wells into the porous basin fill reservoirs. Out of the 9 planned triplets 4 were already completed before, and in 2022-2023 3 additional circuits were finalized with a further installed capacity of 17.4 MWt and 63 TJ/yr annual production. In addition to these 7 operating loops, another circuit is in test mode and the last one is under construction. Once the entire system is finalized, it will be one of the largest geoDH systems in Europe.

After successfully deepening the production and reinjection wells between 2017 and 2020 in Mosonmagyaróvár (NW-Hungary), the geothermal district heating system became operational by the completion of surface installations in this period with an installed capacity of 6.6 MWt and annual heat production of 20.16 TJ/yr.

Some progress also happened in the development of geothermal heating provided by thermal water town-heating systems. In Lenti (SW-Hungary) the system was completed by the drilling of a reinjection well and thus became operational with an installed capacity of 1.4 MWt and annual heat production of 20.16 TJ/yr. A new system providing heat for some public buildings in a cascaded arrangement was established at Nagyszénás with an installed capacity of 1.5 MWt and annual heat production of 11.88 TJ/yr. Furthermore the already existing and operational town heating systems expanded by new wells / doublets in the towns of Bóly, Mórahalom and Veresegyház, this latter being the largest of such systems with 14.5 MWt.

The other major sector for direct heat utilization in Hungary is agriculture. Heating of greenhouses and plastic tents and other energy purposes (e.g. heating for animal husbandry) represents an installed capacity of 424.5 MWt and about 3456 TJ/yr production. The major users are found in SE-Hungary. Between 2022 and 2024 altogether 15 new wells were drilled for agriculture purposes (mostly heating of greenhouses) at 12 locations.

There was no major development targeting industrial applications, the total estimated installed capacity is still around around 28 MWt and about 162 TJ/yr production. Nevertheless, some of the new exploration licenses (see

1 In the city of Szeged both types (geothermal district-heating and thermal water town-heating) are available

1.2.) aim the heat supply (heating of buildings as well as process heat) of industrial complexes, thus this number is also expected to grow in the near future.

A large proportion of the wells are used for balneological purposes. The outflow temperature typically ranges between 30 and 50 °C, but there are some hot ones as well (e.g. Zalaegerszeg (SW-Transdanubia) - 95 °C, Gyula (SE Hungary) - 89 °C). The estimated installed capacity of the wells used for balneology is about 268 MWt with an annual use of about 2810 TJ/yr. Between 2022 and 2024 altogether 10 new wells were drilled at 6 locations for balneological purposes, all at sites, where thermal water is already used in spas. These are mostly replacing older wells or expanding the sites.

3.3 Shallow geothermal

In recent years, regulatory changes in Hungary have made closed-loop shallow geothermal system installations faster and easier. Prior to 2022, developers had to obtain an installation permit before drilling, followed by an operation permit to start the operation after completion. Under the updated framework boreholes with depths shallower than 150 meters no longer require a license, however they still need to be reported to the mining authority with appropriate documentation. Given that the average borehole heat exchanger (BHE) system depth ranges between 80-120 meters, this modification has streamlined planning and installation processes.

A recent inventory of the BHE projects compiled a total of 2112 projects including the issued installation permit (pre-2022)/report (post-2022) and the operation permit/reports for the period 2007-2025. The actual number of installations is likely higher due to the incomplete databases and reporting gaps.

Capacity was estimated using the reported installed capacity data of the BHE systems reported between 2010 and 2025. Based on projects confirmed as completed (i.e. permitted for operation or reported as installed), the installed capacity is estimated at 55.5 MWt as low estimate. A high-estimate of 121.4 MWt installed heating capacity was derived by including all projects that obtained an installation permit or were reported for installation. This can be translated into a 99.6 to 874.08 TJ/year by assuming a 2000 hours of full load per year. Installed cooling capacity was also estimated at 7.0 MWt (low estimate) and 21.41 MWt (high estimate), using the same low/high methodology.

The increase in GSHP numbers has continued over the last several years, larger systems (e.g. for apartment buildings, offices, logistics centers, and industrial facilities) have also expanded considerably. Hybrid systems, which combine geothermal and air-to-water heat pumps, have also become more common within these larger-scale applications due to their high efficiency, reduced space requirements and optimized operation in varying climatic conditions.

Horizontal and open-loop systems remain rare, with the vast majority of installations being closed-loop vertical systems. The demand for shallow geothermal energy in new communal and industrial buildings continues to rise, particularly as cooling functions make GSHPs more competitive in greenfield construction projects.

Currently, the eco tariff (“H tariff”) is the main incentive supporting GSHP deployment in the domestic sector, offering preferential electricity pricing for heat pumps (including air-to-water systems) and other renewable heating technologies during the heating season. Given Hungary’s estimated GSHP potential of 23 PJ/year, the expansion of shallow geothermal energy remains promising, especially in commercial and public sector applications.

4 PROJECTS UNDER DEVELOPMENT AND EXPLORATION

Under the new licensing system (1.2) 138 applications were submitted to the Mining Authority (January 2026), 73 exploration licenses were issued, actual exploration is ongoing at 21 locations, and altogether 18 deep wells have been already drilled (Nádor 2025).

The ongoing 21 exploration projects all over the country show a great variety in terms of depths, purpose, expected capacity, type of applicant, etc.

Though the geothermal conditions of the Pannonian Basin are not especially ideal for power production, some applications target combined heat and power (CHP), whilst others focus only on heat production. The explorations depth of the projects on CHP is typically below 2-3000 m and the target reservoirs are the fractured karstified Mesozoic basement carbonates with expected reservoir temperature of 100-120 C or sometimes well above and yield of 3000-6000 l/min. The total expected new capacity of these explorations is about 13 MWe.

The target depth of the projects for direct heat is 1000-2500 m with expected temperatures of 60-120 C and yield of 1000-3500 l/min. In addition to the basement carbonates some of these projects focus on the shallower Miocene porous basin fill sandstone-siltstone sequences. The total expected heat capacity of the new projects (also accounting the heat production from the CHP projects) is about 120 MWt. Most of these applications target individual space heating of industrial complexes and commercial sites rather than communal heating (district or town-heating).

One project in Budapest has been successfully finalized and is already in operation, where a doublet provides heating for a sport center.

5 DISCUSSION

Hungary's excellent geothermal potential due to its favorable geological setting is well known, and although the growth was steady over the past decade (Tóth 2020, Nádor et al. 2019, 2022, 2025), it was still moderate, mostly due to non-technical barriers (lack of supportive policy framework, lack of finances, complex regulatory system, etc.). Nevertheless, most of these challenges were successfully handled over the past 3 years which are summarized below:

(1) A National Geothermal Strategy published in 2024 set up ambitious targets to double the geothermal energy use (to 11-12 PJ) by 2030. The document also outlined the main intervention areas.

(2) A simplified - however rigorous - one-stop-shop licensing system was introduced in 2023, which resulted in a big boom of new applications.

(3) From 2025 about 105 million euro funds are available (risk mitigation for drilling, interest-free loan for subsurface and surface constructions, development of grid-connection for geothermal-based CHP systems).

(4) Subsurface (geological) data are publicly accessible via an online web-based information system (OGRE), also in English. Furthermore geothermal data packages are available for dedicated areas of potential investment interest via data room services.

(5) The Hungarian Geothermal Cluster was established in 2023 which brings together all stakeholders along the entire geothermal value chain.

As a recognition of all this progress, Hungary has successfully applied to be the host country of the next European Geological Congress in 2028.

Nevertheless, there is still a lot to be improved. Although the current licensing system kick-started a high number of new project concepts, the system has its downsides (e.g. the agriculture sector is not part of the new licensing system, which impedes establishing a comprehensive geothermal resource management). Business models should be improved. The relatively high number of failed or withdrawn applications for exploration licenses show that there are still not enough resourceful project developers on the market (lack of finances, lack of a firm project concept, etc.). A main technical barrier is the low-share of reinjection into the porous geothermal aquifers (especially in the agriculture sector), which seriously threatens the sustainable and long term operation of these systems (and others in the impacted regions), furthermore is not in line with the requirements of EU policies (Water Framework Directive - good quantity status of groundwater bodies).

Hungarian universities, research institutes and companies have coordinated or participated in several basic and applied research, development and innovation projects, both national and international ones. The scope of these projects covers: (1) reinjection of brines into sandstone reservoirs, (2) mitigation of technical risks in geothermal energy exploration and production (including operational problems, such as scaling), (3) development of deep borehole heat exchangers (geothermal energy production in closed systems without thermal water abstraction), (4) application of laser technologies for drilling operations and well-maintenance activities, (5) Combined Heat, Power and Metal Extraction, (6) local and regional coupled heat and transport models of geothermal reservoirs and sedimentary basins, (7) play-based analysis of geothermal systems in the Pannonian Basin.

The University of Miskolc offers Geothermal Engineering programs 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. The University of Szeged is another centre of excellence in terms of geothermal research and education, which held the European Geothermal PhD Days in April 2025. In addition Eötvös Loránd University Budapest offers

bachelor and master programs of earth sciences, geology and geophysics supplying the Hungarian and international geothermal sector with qualified professionals.

In 2025 the Supervisory Authority for Regulatory Affairs organized a 5-day International Geothermal Short Course attended by 30 MsC, PhD students and young professionals from 17 countries all over the world. The lectures covered the entire spectrum of geothermal research and project development. This was complemented by a field-trip, where the participants visited geothermal projects and investments in and around Budapest, the capital of Hungary. The event has received serious international recognition and is part of the considered strategy, which aims to make Hungary one of the leading geothermal knowledge centers in the Central European region, so the highly successful event will be held again in 2026.

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