Geothermal Energy in Hungary

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ABSTRACT

Hungary's excellent geothermal potential is well-known. Traditionally, the country's geothermal energy production was used for direct heat supply, with most of the thermal water used in spas. As yet, there is no developed ground-source heat-pump market or operational geothermal power-plant in Hungary. There are many current projects being prepared. These focus on geothermal power plant, CHP, district heating and GSHP incentives. Ongoing and increasing financial support is needed, as well as simplified, transparent and reliable legislative frameworks. The key environmental issue in the Hungarian geothermal sector is still injection. Only a minor part of the produced thermal water is re-injected. Hungary has traditionally had strong geothermal education, and despite the recession such courses are still being given.

This paper gives a brief history of geothermal energy in Hungary, and discusses the present state of geothermal energy production and utilization in the country. In 2015 877 active thermal water wells produced about 79.46 million m^3 of thermal water in Hungary, representing 863.80 MWt / 12,819 TJ/y. The majority of the produced water was used for balneology (295 active wells providing 41.18 million m^3 287 MWt / 6,149 TJ/year) in Bükk*ürdő, Hévíz, Harkány, Zalakaros and other spa towns*. For direct-heat utilization, the main sector was agriculture, where altogether 181 wells produced 10.97 million m^3 of thermal water, representing an installed capacity of 307 MWt and an estimated use of 3,350 TJ/y. Of this about 75% was used to heat greenhouses and plastic tents, and the rest for animal husbandries. In 23 locations there is thermal water heating, as for example in Hódmezővásárhely, Szeged, Miskolc, and Szentlőrinc. In 2015, total thermal-water heating used 11.67 million m^3 of thermal water, which represented an estimated installed capacity of 229.66 MWt and 2,496 TJ/y in terms of actual use. In 2015, the industrial use was relatively low (8.52 MWt / 174.53 TJ/y). In the 'other' or 'miscellaneous' category (including public water supply) the figure was 14.10 million m^3 (47.37 MWt / 650 TJ/y).

Between 2010 and 2015 more than 25 deep geothermal projects were supported with grants of 29.2 million Euros, as for example in Szolnok Hospital, Makó Thermal Bath and Heating System, and Gyopárosfürdõ Thermal Bath. Since 2010, two large district heating projects have been underway in Szentlőrinc and in Miskolc, both operated by PannErgy Ltd. According to the decision of Brussels, the EGS Hungary Consortium co-owned by the Hungarian firm EU-FIRE and the Icelandic firm Mannvit was awarded funding amounting to 39.3 million Euros for the development of the 116 million Euro project plan titled "South Hungarian Power Plant with an Enhanced Geothermal System." This is the first EGS (enhanced efficiency geothermal system) project in South-Eastern Hungary.

Other current projects focus on geothermal power plant, CHP, district heating and GSHP incentives, as for example in Mosonmagyaróvár, Szolnok and Győr.

1. Introduction

The current report was based on the integrated evaluation of two datasets. The first is from the Hungarian Office for Mining and Geology, and is based on the self-declaration of users paying mining royalties, i.e., data for energy users only. The second major source of information was the registry of thermal-water production (i.e., water with outflow temperature > 30 °C). This is second dataset is maintained by the National Institute for Environment, and contains data from all operating thermal wells.

There were many discrepancies between the two databases, with complete accuracy impeded by such factors as seasonal-operation differences, substantial differences between actual flow rates and reported well-data, and — in many cases — the lack of information on real temperature gradients. The numbers reported are the best expert estimates of the authors and show a realistic growth compared to the estimates of previous country update reports (see Arpasi 2005, Tóth 2015).

2. Natural Conditions

The Pannonian Basin is encircled by the Carpathian Mountains. The Earth's crust here is relatively thin (~25 km) due to sub-crustal erosion. The thinned crust had sunk isostatically, and mostly tertiary sediments fill the basin thus formed. Pannonian sediments are multilayered, composed of sandy, shaly, and silty beds. Lower Pannonian sediments are mostly impermeable; the upper Pannonian and Quaternary formations contain vast porous, permeable sand and sandstone beds. The latter forms the upper Pannonian aquifer, the most important thermal water resource in Hungary.

Natural conditions in Hungary are very favorable for geothermal energy production and utilization. The anomalously high terrestrial heat flow (~0.09 W/m^2), the high geothermal gradient (~0.05 °C/m), and the vast expanses of deep aquifers form an important geothermal resource.

The individual sandy layers have various thicknesses between 1 and 30 m. Their horizontal extension is not too great, but the sand lenses are interconnected, forming a hydraulically unified system. This upper Pannonian aquifer has an area of 40,000 km^2, an average thickness of 200-300 m, a bulk porosity of 20-30%, and a permeability of 500-1,500 mD. The hot water reservoir has an almost uniform hydrostatic pressure distribution; local recharge or discharge can slightly modify this pattern.

Another type of geothermal reservoir is found in the carbonate rocks of Triassic age, and has a secondary porosity. These can be fractured or karstified rock masses with continuous recharge and important convection. About 20% of the Hungarian geothermal wells produce from such carbonate rock formations, mainly in the western part of the country. (Bobok, et al., 2003).

Surface manifestations have been known since ancient times: thermal springs of 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. Using data from this exploration, Boldizsár (1944, 1956) recognized the high terrestrial heat flux and geothermal gradient in the Pannonian Basin.

During the 50s and 60s hundreds of geothermal wells were drilled, mainly for agricultural utilization. The peak of geothermal activity was in the late 70's: a total of 525 geothermal wells were registered, and the best 30 of them had a production temperature exceeding 90°C. Total thermal power capacity of these wells was 1,540 MW, but utilization was seasonal and the efficiency was rather low.

The existence of high enthalpy reservoirs was proven by a dramatic steam blowout from the Fábiánsebestyén well in Southeast Hungary in 1985. From an exploratory borehole, drilled into a 3,880-m deep fractured-dolomite formation, over-pressured steam exploded at a pressure of 360 bars and a temperature of 189°C. The flow rate from this reservoir was approximately 8,400 m^3/day. The duration of the blow-out was 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 dimensions and the geothermal potential of the reservoir. Existence of other deep, high-enthalpy reservoirs in the Southeastern part of Hungary seems possible.

In recent years, many deep hydrocarbon exploratory wells have been drilled in Southeast Hungary, and these have proven the existence of high-temperature, impermeable basement rock. The measured, undisturbed temperature of the rock was 252 °C at a depth of 6,000m. Obviously, this area is a promising site for future EGS development projects.

In general, it has been demonstrated that the Southeastern part of the Pannonian basin is one of the most promising regions in Europe for EGS systems (Dövényi et al. 2005), because of its sufficiently high in-situ rock temperatures (≥ 200 °C), favorable seismo-tectonic settings (extensional regime, low level of natural seismicity), and suitable lithologies (wide-spread granitoid rocks) in the pre-Tertiary basement.

The chemistry of the Hungarian thermal waters is quite varied. Thermal groundwater of the porous Upper Miocene (Pannonian) reservoirs generally has an alkaline $NaHCO_3$ character. 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 of the NaCl type (fossil waters).

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

3. Production And Utilization

Most Hungarian geothermal wells produce hot water from the upper Pannonian reservoir system. A smaller portion of them tap the deep karstic aquifer. At present (2015), 877 active wells produce thermal water warmer than 30°C. Another 179 wells are abandoned and 220 are temporarily closed.

A typical geothermal well in Hungary might be from 1,000 to 2,400 m deep. Typically, the well is completed. Typically, a 13⅜ in (349 mm) conductor casing is set at a depth of 50 m, in a 17 ½ in (444,5 mm) hole. That is followed by a surface casing of 9⅝ in (244.5 mm) at 500-1,800 m in a 12 ¼ in (311.1 mm) hole. Finally, a 7 in (177,8 mm) liner runs down an 8 ½ in (215.9 mm) hole to a depth of 1,000-2,100 m, with its top at 30-50 m above the shoe of the surface casing. Each string is cemented in such a way as to totally fill the casing-hole annulus.

Typical mass flow rates of the upper Pannonian wells can range between 10 and 30 kg/s. The Malyi wells are truly exceptional in this regard, as they have mass-flow rates exceeding 100 kg/s and wellhead temperatures as high as 100 °C.

In most Hungarian geothermal wells no artificial productions are used, their reservoirs exploited solely by means of compaction and dissolved gas. Submersible pumps are installed in those wells where the reservoir pressure has been depleted substantially.

Deep Geothermal

Deep geothermal exploration focuses on Pannonian sandstone thermal aquifers as well as reservoirs in the fractured-karstified basement rocks. Deep geothermal exploration -- usually the result of earlier hydrocarbon, drinking water or balneology projects -- contributes significantly to the increase of direct heat utilization and provides the basis for the establishment of geothermal based electricity production.

In the last few years the driving force in deep geothermal project development was the EU co-financed Environmental and Energy Operative Program, which supported the development of heating/cooling supply in local systems, as well as preparing and developing activities of geothermal based heat and electricity producing projects. This included seismic acquisitions and the work of deepening initial 'exploratory' wells. Between 2010 and 2015, altogether 24 such projects were supported and 29 million euros was granted. Depending on the project, this EU support ranged from 30 to 70% of the total budget. Preparations for two large successful district heating projects for the period 2010-2015, operated by Pannergy, were also co-financed by the Environmental and Energy Operative Program.

Miskolc-Mályi is the first "large-scale" project in Hungary, where geothermal-based district-heating system will service several hundred apartments in the Avas housing estate in Miskolc, Hungary's second largest city. According to the investor firm's report, the investment cost was 25 million EUR, with the EU support more than 9.7 million EUR.

A total of 5 wells were drilled. Two production wells went to depths of 2305m and 1514 m, yielding 6600-9000 l/min fluids with a temperature between 90 and 105 °C from a karstified-fractured Triassic limestone reservoir. Three injection wells were also established, along with a 22 km pipeline. The planned heat capacity is 55 $MW_{t,}$ with a heat demand of 695,000 to 1,100,000GJ. To further exploit the used heating water, a 10-hectare greenhouse project is also under development. A city-owned company was contracted as an off-take partner for the Pannergy projects, for a contracted duration of 15+5 years. It should be be emphasized that these two 'super wells' in Miskolc-Mályi, recently developed by the Pannergy company, were the first such 'large-scale' projects in Hungary.

Table 1. Number of active geothermal wells based on wellhead temperature and type of utilization.

T_{WH}	S	A	C	I	MP	Σ
30-40	73	69	1	44	45	232
40-50	119	13	2	13	27	406
50-60	53	15	23	11	45	321
60-70	35	14	41	6	29	272
70-80	9	17	46	6	34	237
80-90	3	19	3	3	13	153
90-100	3	33	6	1	-	84
100<		1	1	-	1	46
Σ	295	181	123	84	194	877

Abbreviations: T_{WH} means Wellhead Temperature in °C, S Spa, A Agriculture, C Communal, I Industrial, MP Multi Purpose, and Σ Production Well.

It can be seen that many wells are being utilized for water supply and balneology. It would nonetheless be misleading to make any thermal-power assessment on the basis of the various well-test data, since many thermal wells operate seasonally, with substantial differences between well-test data and the actual flow rates.

The theoretical total thermal power capacity of these wells is 1,845 MW_t , with a total obtained mass-flow rate of 6,661 kg/s. The Hungarian Office for Mining and Geology, however, recorded 20,315,678 m^3/year thermal water production—based on users' declarations. That's equivalent to an average mass flow rate of 612.26 kg/s. It is obvious that the total available thermal capacity of Hungarian geothermal wells is substantially greater than the effective utilized geothermal energy, which can be estimated at only about 863.80 MW_t. This obtains an assumed load factor of 46 %.

Worldwide-known spas in such places as Budapest, Bük, Hajdúszoboszló, Harkány, Hévíz, Sárvár, Zalakaros and elsewhere in Hungary represented the first utilization of thermal waters. Altogether 295 thermal wells and 132 natural springs produce water for sport and therapeutically purposes. The outflow temperature typically ranges between 30 and 50 °C. These wells mostly discharge from the Miocene porous sandstone reservoirs, from an average depth between 500 to 1500 m. About 50 wells had outflow temperatures exceeding 60 °C, many of them discharging from the fractured-karstified basement aquifers. The hottest ones are at Zalakaros (SW-Transdanubia - 99 °C) and at Gyula (SE Hungary at the Romanian border - 91 °C). The estimated thermal power applied in the field of bathing and swimming utilization is about 41.18 million m^3 287 MWt / 6,149 TJ/year.

Agricultural use is one major segment of Hungary's geothermal energy utilization, involving 181 operating thermal wells and producing 10.97 million m^3 of thermal water. This includes 70 Ha of thermally heated greenhouses, and more than 250 Ha are devoted to thermally heated plastic tents and soil heating. More than 50 farms also use thermal water for animal husbandry, heating chicken, turkey, calf, pig and snail enclosures. Near Szarvas and Győr, low-temperature released waters supply fish ponds. In total, installed capacity in the agriculture sector was 291.25 $MW_{t.}$. The estimated annual use in 2013 was 3,350 TJ. The major users are Árpád-Agrár Zrt in Szentes, Flóratom and Bauforg Ltd-s. in Szeged, Bokrosi Ltd. in Csongrád, and Primőr-Profit Ltd in Szegvár -- but there are many others, especially in SE Hungary.

Geothermal district and space heating begin near balneology centers, between the two world wars, in a few apartment houses and at the Budapest Zoo. In the late 50s, district heating projects were initiated in Southeast Hungary, in *Hódmezővásárhely, Szeged, Szentes, Makó,* and Kistelek. The technical level of these geothermal heating systems varies greatly. Some are sophisticated, well-designed and -controlled sophisticated systems, where a dozen geothermal wells supply a cascade of sub-systems: greenhouses, plastic tunnels, and soil heating are connected in series. Hódmezővásárhely is a good example of that. In other cases, a single well provides thermal water directly to greenhouses, after which the still relatively hot water is simply dumped. This causes low efficiency and sometimes environmental problems.

Hungary's largest operational geothermal-based district heating system, fed 100% by geothermal, started daily operation on January 1, 2011 in Szentlőrinc (SW-Hungary). It features an 1800 m-deep production well, with an outflow temperature of 87 °C and max. yield of 25 l/s, coupled with a reinjection well. The heat capacity is 3MWt, and the heat demand is 22,000-60,000GJ (Perlaky, 2012).

In 2015 altogether 11.67 million m^3 of thermal water from 123 wells supplied all these different heating systems, which represent an estimated installed capacity of 229.66 MW_t and an estimated annual use of 2,496 TJ/year.

It is a little known fact that since 1969, thermal water was already being used in the secondary oil production technology in the Algyő oilfield. Presently 5,400 m^3/s of hot water is reinjected into the oil reservoir for oil displacement. The utilized geothermal power during this secondary oil recovery technology is 12 $MW_{t.}$ Another interesting application is that the gathering pipes are heated by thermal water in the heavy oil producing oilfield Sávoly, in SW Hungary.

In Hungary, relatively little geothermal was used for industrial purposes in 2015: the total figure is 1.54 million m^3 of thermal water, representing an installed capacity of 8.52 MW_t and annual use of 174 TJ/y.

In the "other and multipurpose" category, 194 wells produced 14.1 million m^3 of thermal and drinking water. "Drinking thermal water" is a country-specific experience in Hungary, where 90% of the drinking water supply is provided from groundwater. Where the shallow aquifers are contaminated (e.g., because of natural-occurring high arsenic levels in SE Hungary), lukewarm thermal waters with low TDS from slightly deeper confined aquifers are used. This total amount of thermal water represents 47.37 MW_t of capacity and about 650 TJ/y in annual use.

Geothermal Heat Pumps

Shallow geothermal heat utilization increased dynamically from 2000 to 2008, but the economic crisis stopped that growth. The last ten years has seen new market regulations. New training programs have also started for ground-source heat-pump systems, initiated by universities and by the Hungarian Heat Pump Association. Since 2013, rules have been eased to the extent that before installing new heat pumps, no official permission from the government or notification from the user is required. The government no longer even gathers geothermal heat-pump data, relying instead on estimates which are based on whatever heat-pump owners care to reveal!

The estimated installed capacity is about $42MW_t$. The actual number of installed units is more than 4,000 – of course, hard data supporting this figure is unavailable. The average COP is obtained as 4.0. The biggest Hungarian heat pump systems (around or over 1.67 MW capacity) are significant in the European market, but the technology has not really caught up yet. Many international companies operating in Hungary made significant investments in heat-pump systems in the recent years (e.g., NATO military base, Telenor and TESCO). The size of individual units starts at 10kW, for residential use.

Heat-pumps supplied 0.26 PJ in 2013 and are forecast to provide as much as 5.99 PJ by 2020. Of all the heat-pumps, ground-source heat-pumps account for approximately three quarters of the total heat: 0.238 PJ in 2013, with the 2020 target set at 4.48 PJ. Thus, twenty-fold growth is expected.

Despite these ambitious targets, sales of heat pumps in Hungary decreased in 2010 and 2015. The main causes are:

- the ongoing macroeconomic crisis
- very well-developed existing natural gas infrastructure
- insufficient supports and incentives
- the generally unfavourable costs compared to heating alternatives, especially when one considers the disadvantageous gas/electricity price ratio (gas price is relatively cheap, but the price of electricity is above the EU average).
- the favourable electricity tariff only applies to heat pumps used to heat during cold periods, and not for cooling in the summer.

4. Environmental Impact

Geothermal energy helps reduce carbon-dioxide emissions. It is evident that environmental considerations have a high priority when it comes to geothermal applications. The rational utilization of renewable energy sources, supplemented with energy saving and energy efficiency programs, may establish a basis for a new (green) economic sector.

Any geothermal activity needs to deal with the significant impacts on the surrounding physical, biological and socio-economic environment. The major concerns are: decreasing reservoir pressure, thermal pollution of fresh groundwater and surface waterways, dissolved-gas emissions, ground subsidence, and noise.

Hungarian geothermal reservoirs may be sedimentary, sandy or karstified limestone aquifers. Decreasing reservoir pressure occurs mainly in the sandstone aquifers. Some fields have been exploited for more than seventy years, with the piesometric head of the reservoir having subsided almost 70 m in the Hajdúszoboszló field, where production can be sustained only through artificial lifting methods. The supply from carbonate aquifers in Western Hungary, however, seems to be unexhausted.

The salinity of the Hungarian geothermal brines is comparable to that of seawater. The water of the upper Pannonian aquifer contains mainly sodium or calcium carbonate, the brine in the lower Pannonian formations mainly sodium chloride. The environmental impact of the released thermal waters can be serious. The wells of Bükkszék spa produce more than 1 m^3/min of very saline water, with dissolved solids of 24,000 mg/l. This means that 14,000 t/year are currently polluting the small Tarna River.

Thermal waters contain dissolved gases, mainly methane, nitrogen, carbon dioxide and hydrogen sulphide. Methane is separated from the water and utilized in auxiliary equipment. The H_2S is more harmful because of its acid, corrosive nature. This may lead to perforation of the casing and damage to the cement sheet as well. Fortunately H_2S is present only in a few Hungarian geothermal wells (e.g., Mezőkövesd).

Most environmental pollution can be avoided if the heat-depleted thermal water is re-injected into the aquifer. The reinjection is very useful for other reasons, too: it re-pressurizes the reservoir, makes the enthalpy of the rock matrix exploitable, and helps prevent ground subsidence on the surface.

Reinjection is a routine technology in the petroleum industry, but of Hungary's 672 thermal-water production wells only 34 wells even use partial re-injection, so only a small part of the total produced thermal water is re-injected. It is relatively simple to inject hydraulically into karstic carbonate aquifers, but short circuiting the injected fluid to the production wells introduces a serious risk. With a sandstone reservoir the procedure is more complex, as the necessary injection pressure can substantially increase within a relatively short time. The permeability decreases because of damage to the formation. That can occur because of clay swelling, pore space blocking by fine particles, or the precipitation of dissolved solids due to the mixing of injected water and the formation water or due to temperature changes.

Many efforts are underway to solve these problems: theoretical analyses, numerical simulation, laboratory and in-situ experiments. Successful industrial experiments were carried out in the city of *Hódmezővárhely.* Based on that experience, the most important elements of a successful re-injection are: a suitable location and depth for the injection well; a good, well-executed design; good hydraulic performance; and very slow transient performance processes (pressure, temperature, flow rate). In Hungary the average re-injection wells is fairly new, with even the oldest -- in Hódmezővásárhely -- only having been in operation for 16 years.

Right now there is neither EU-sourced nor national support for drilling purpose-built injection wells, which means that Hungary's underfunded municipalities and agricultural entrepreneurs cannot invest into re-injection. Furthermore, there are no available R&D funds for additional pilot studies. According to current legislation, new geothermal energy production capacities may be installed only if they involve re-injection. There is a chance that future legislation may eliminate that requirement, but failing that, there will be no government support or subsidy for those projects that don't use re-injection.

Some Hungarian thermal water contains toxic materials: arsenic, beryllium, chromium, organic materials (pesticides) and pathogenic organisms, bacteria. If released to the natural waterways, such toxic materials can harm the wildlife of these waterways. In addition to releasing various dissolved 'natural' thermal-water components to the surface, an important environmental concern is the heat-load: when the used thermal waters are not cooled down sufficiently, the warm waters can seriously impact the ecosystems.

Freshwater aquifers are located above the geothermal reservoir, so drilling operations can also present environmental hazards. During normal drilling situations, downhole drilling fluids are usually the greatest potential threat to the environment. In the case of oil-based mud the cuttings may also cause difficulties. Some of the chemicals used are extremely toxic, e.g., chromates. During well completion operations, acid jobs can present an additional hazard. Lastly, a blow-out during drilling operations -- like the one that occurred in 1985 in Fábiánsebestyén -- can of course cause very significant environmental damage.

Another important environmental concern is the integrated management of hydrogeothermal reservoirs with the overlying freshwater aquifers. It has been demonstrated that these two systems are hydrodynamically connected, so cold-water withdrawals from the shallow aquifers can have a serious impact on the pressure and yield conditions of the underlying geothermal reservoirs (Nádor et al. 2013).

5. Energy Policy Legal and Regulatory Aspect

To progress, the Hungarian geothermal sector needs a well-considered energy policy, along with clear-cut legal and financial regulations. It is necessary to elaborate the framework which can accommodate the relevant legislative, environmental, planning and financial considerations. Unfortunately, Hungary currently has insufficient operating regulations.

One of the biggest problems is uncertainty over geothermal-resource ownership. Landowners don't own the geothermal resources beneath their property, as these are owned by the Hungarian state. The well, on the other hand, is owned by the developer who has drilled it, and the produced geothermal energy is the property of the mining contractor. All these conflicting and confused matters of legal ownership must be regulated in a new, single Geothermal Act. That is a prerequisite for the successful development and regulation of the Hungarian geothermal industry.

Another source of confusion is that the licensing system is currently is overseen by too many different authorities. The relevant administrative procedures must be simplified.

Currently, there is no national geothermal authority responsible for promoting geothermal energy production and utilization.

There is no integrated database for the geothermal sector.

National taxation law does not promote increased capital investment in geothermal energy (e.g., no renewable tax incentives, preferential VAT rates, etc.).

National regional and local government authorities should promote deep geothermal energy projects, and grants or other financial support schemes for commercial and residential sector systems should be available. Inventories of the geothermal resources are rather weak. Over the last five years, all such support totaled about 10,5M USD.

A geothermal insurance and risk fund, particularly for deep exploratory drilling, requires that financial tools be made available based on substituting clean energy for fossil fuel and on the potential for national CO2 emission savings.

Finally, innovative applications of geothermal-energy research and development activity should benefit from specific discounts.

6. Education, Training

Geothermal education has a long tradition in Hungary. The petroleum engineering education at the University of Miskolc, in the Faculty of Earth Science, started in the early 60s. From there, geothermal education has progressed to the point of being able to offer degrees at BSc, MSc, and PhD levels.

The four-semester Postgraduate Certificate in Geothermal Energy Technology was created in 2008. The topics for which credits (numbers in brackets) are given are: Renewable Energy (5), Advanced Geology (6), Advanced Geophysics (6), Fluid Dynamics (6), Hydrogeology (5), Drilling Well Design (6), Geothermal Reservoirs (5), Geothermal Water Production (5), Geoinformatics (5), Geothermal Chemistry (5), Geothermal Heat-Transfer Systems (5), Geothermal Power Production (5), Geothermal Direct Uses (5), Geothermal Heat Pumps (5), and Geothermal Environmental Impacts (5).

In 2012 an EU co-funded project started between the University of Miskolc and the University of Colorado (USA), with the purpose of developing online (e-learning) postgraduate geothermal education.

In addition, the Hungarian Engineering Chamber began working with the University of Miskolc to organize several geothermal short courses dealing with shallow and deep geothermal direct uses (Tóth 2013).

7. Conclusions

Hungary has favorable natural conditions for geothermal energy production. In spite of this, production and utilization is stagnating -- contrary to general tendencies worldwide. The global recession of 2008 weakened the entire nation, and the Hungarian geothermal sector is no exception. Nevertheless, there are promising elements. The country's first geothermal pilot power plant was begun, and even though the first project was not successful, preparation is underway for a second attempt. A few up-to-date cascade systems were implemented for direct use, with successful re-injection being carried out. The use of ground-source heat pumps has started to accelerate in recent years. Some non-trivial industrial applications are also close to completion. If a well-considered energy policy is devised, together with supporting legal and financial conditions, the Hungarian geothermal industry could start to make real progress.

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