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Hungarian Country Update 2010-2014

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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. Many projects are currently being prepared. These focus on geothermal power-plant, CHP, district-heating and GSHP incentives. Hungary has traditionally had strong geothermal education, and many such courses are still being offered despite the recession. But ongoing and increasing financial support, as well as a simplified, transparent and reliable legislative framework is still needed.

Injection remains the key environmental issue in the Hungarian geothermal sector. Only a minor part of the produced thermal water is re-injected.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. In 2014, 672 active thermal water wells produced about 79.46 million m^3 of thermal water in Hungary, representing 863.58 MWt / 9,573 TJ/y. Most of the water thus produced was used for balneology where 295 wells provide 41.18 million m^3 and 352 MWt / 3,912 TJ/year in Bükkürdő, Hévíz, Harkány, Zalakaros, etc. As 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 306 MWt and an estimated use of 3,414 TJ/y. The major agricultural application was greenhouse and plastic-tent heating. The other applications are: fish farming, animal husbandry and agricultural drying. 23 locations use thermal water for individual space and district heating, as in Hódmezővásárhely, Miskolc, Szeged, Szentes, Szentlőrinc and Veresegyház etc. In 2013 a total of 11.67 million m^3 of thermal water was used for heating, which represents an estimated installed capacity of 186.58 MWt and use of 2,026 TJ/y. The industrial use was 19.00 MWt / 220 TJ.

Between 2010 and 2014, about 24 deep geothermal projects received support, with grants totaling 27.2 million Euros. The Szolnok hospital, the Szeged heating system, and the Gyopárosfürdõ Thermal Bath are three examples. In addition, two large district heating projects were begun in 2010 by Pannergy Ltd., in Szentlőrinc and in Miskolc, and finished in 2013. Many other projects are currently underway. These focus on geothermal power plant, CHP, district heating and GSHP incentives, for example in Mosonmagyaróvár, Szolnok and Győr.

The European Commission has awarded over 1.2 billion Euros to 23 highly innovative renewable energy projects, following the first call for proposals for the NER300 programme. In 2013, one of the projects selected was Hungary's first Enhanced Geothermal System (EGS), run by EU-FIRE and Mannvit Ltd. The project was awarded almost 40 million Euros of the NER300 funding, with a projected total investment cost of over €100 million. Other institutional and private investors will fund the project's remaining costs.

1. INTRODUCTION

The current report was based on the integrated evaluation of two datasets. The first is that of the Hungarian Office for Mining and Geology, 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), maintained by the National Institute for Environment, which contains data from all operating thermal wells.

There were many discrepancies between the two databases, with exact calculations impeded by such factors as fluctuations in seasonal operations, substantial differences between actual flow rates and reported well-data, and lack of information on the real temperature gradients in many cases. The reported numbers are the best expert estimates of the author and show a realistic growth, compared to the numbers given in previous country update reports (Tóth 2002, Arpasi 2005, Tóth 2010, Nador et al. 2013).

2. NATURAL CONDITION

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 the basin thus formed is filled by mostly tertiary sediments. 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, which is 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 large, 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, though local recharge or discharge can slightly modify this pattern.

Another type of geothermal reservoir is found in the carbonate rocks from the Triassic age, with a secondary porosity. These can be fractured or karstified rock masses with continuous recharge and important convection. About 20% of the Hungarian geothermal wells draw from such carbonate rock formations, mainly in the western part of the country. (Bobok, et al., 2007).

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^oC. Total thermal power capacity of these wells was 1,540 MWt, but utilization was seasonal and the efficiency was rather low (Tóth, 2010).

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^oC. 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^oC at a depth of 6,000 m. This area could be a promising target for future EGS development projects.

It has been demonstrated that the SSE part of the Pannonian basin is one of the most promising regions in Europe for EGS systems (Dövényi et al. 2005), with sufficiently high in-situ rock temperatures ($\geq$ 200^oC), 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 $NaHCO_3$ 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 10 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 (supposing full re-injection) (Zilahi-Sebess et al. 2012).

3. PRODUCTION AND UTILIZATION

3.1 The present status

Most Hungarian geothermal wells produce hot water from the upper Pannonian reservoir system. A smaller number of them tap the deep karstic aquifer. At present (2014) 672 wells produce thermal water warmer than 30^oC. Of these, 179 wells are abandoned and 220 are temporarily closed.

A typical geothermal well in Hungary might have a depth between 1,000 and 2,400 m. Well completion is typical. A 13-3/8 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 9-5/8 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 in a 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 manner that the casing-hole annulus is totally filled.

Typical mass flow rates of the upper Pannonian wells can range between 10 and 30 kg/s. Truly exceptional are the Malyi wells, whose mass flow rate exceeds 100 kg/s and wellhead temperatures are up to 100°C.

Most Hungarian geothermal wells operate without any artificial production method. Reservoirs are driven by both compaction and dissolved gas producing an artesian flow. Submersible pumps are installed in wells whose reservoir pressure has been depleted substantially.

3.2 Deep geothermal

Deep geothermal exploration focuses on Pannonian sandstone thermal aquifers as well as reservoirs in the fractured-karstified basement rocks. Formerly deep geothermal sites emerged mainly from hydrocarbon exploration, or from drinking water/balneology projects. Deep geothermal exploration 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. The Miskolc-Mályi project is the first "large-scale" project in Hungary, where geothermal-based district-heating system will supply several thousand flats in the Avas housing estate in Miskolc, Hungary’s second largest city. As reported by the investment firm, the investment cost was 25 million EUR, of which the EU support was more than 5 million EUR.

A total of 5 wells were drilled. Two production wells went to a depth of 2,305 m and 1,514 m, yielding 6,600-9,000 l/min fluids with a temperature between 90 and 105°C from a karstified-fractured Triassic limestone reservoir. Three area-injection wells were also established, as well as a 22 km pipeline. The planned heat capacity is 55 MWt, the heat demand is 695,000-1,100,000 GJ. To use the run-off water in a future project, 10 hectares of greenhouse utilization is under development. Pannergy’s projects are contracted to an off-take partner, which is a city-owned company.

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

T_{WH}	S	A	C	I	MP	Σ
30-40	73	69	1	44	7	194
40-50	119	13	2	13	17	164
50-60	53	15	2	11	13	94
60-70	35	14	2	6	29	86
70-80	9	17	7	6	16	55
80-90	3	19	3	3	5	33
90-100	3	33	6	1	-	43
100<		1	1	-	1	3
Σ	295	181	24	84	88	672

Abbreviations: TWH Wellhead Temperature in ^{o}C, S-Spa, A-Agriculture, C-Communal, I-Industrial, MP-Multi Purpose, Σ-Production Well.

We can see that a great number of wells are utilized for water supply and balneology. It can be misleading to take into consideration the different well test data as the basis of thermal power assessment. Many thermal wells operate seasonally and there are substantial differences between the actual flow rates and well test data.

The theoretical total thermal power capacity of these wells is 1,845 MWt while the total mass flow rate as obtained is 6,661 kg/s. In spite of this, the Hungarian Office for Mining and Geology records 20,315,678 m^3/year thermal water production based on the self-declaration of the users. That is equal to the average mass flow rate 2,373 kg/s. It is obvious that the total available thermal capacity of Hungarian geothermal wells is substantially greater than the effective utilized geothermal energy. It can be estimated at a level of 863.58 MWt only. This produces an assumed load factor of 47 %.

Historically, balneology was the earliest application for thermal waters. Hungary has world-famous spas in Budapest, Bük, Hajdúszoboszló, Harkány, Hévíz, Sárvár, Zalakaros and many other nice places. Altogether 295 thermal wells and 132 natural springs produce water for sport and therapeutic purposes. The outflow temperature typically ranges between 30 and 50^{o}C. These wells mostly discharge the Miocene porous sandstone reservoirs between an average depth of 500-1500 m. About 50 wells had higher outflow temperature than 60^{o}C, many of them discharging the fractured-karstified basement aquifers. The hottest ones are at Zalakaros (SW-Transdanubia – 99^{o}C) and at Gyula (SE Hungary at the Romanian border – 91^{o}C). The estimated thermal power used for bathing and swimming is about 41.18 million m^3 352 MWt / 3,912 TJ/year.

Agricultural use is another major branch of geothermal energy utilization in Hungary. It involves 181 operating thermal wells, which produced 10.97 million m^3 of thermal water. In Hungary there are more than 70 hectares of greenhouses and more than 250 hectares of soil-heating plastic tents which use thermal water. There are more than 50 examples of chicken, turkey, calf, pig and snail farms which use thermal-water heating for their animal husbandry. In addition, there are fish ponds near Szarvas and Győr which use low-temperature geothermal water to heat their ponds. The 2013 total installed capacity in the agriculture sector was 306 MWt.. The estimated annual use in 2013 was 3.414 TJ. The major users are: Árpád-Agrár Zrt in Szentes and Flóratom; Bauforg Ltd-s. in Szeged; Bokrosi Ltd. in Csongrád and Primőr-Profit Ltd in Szegvár. There are many smaller users as well, especially in SE-Hungary.

Early on, district and space heating by means of geothermal energy began near balneology centers. The first examples are some apartment houses and the Budapest Zoo, projects begun between the two World Wars. In the late 50’s district heating projects were started in Southeast Hungary, e.g. Hódmezővásárhely, Szeged, Szentes, Makó and Kistelek. The technical level of these geothermal heating systems can be very different. In some cases, there are well-designed and well-controlled sophisticated systems, where a dozen of geothermal wells supply a cascade of sub-systems -- with greenhouses, plastic tunnels and soil heating all connected in series (e.g. Hódmezővásárhely). In other cases, a single well provides thermal water directly to greenhouses. The discharged, still relatively hot water is then disposed of without providing additional benefit, sometimes causing environmental problems.

In 2013, individual space and district heating capacity was 186.58 MWt and actual use was 2,026 TJ/y, for all of Hungary. Hódmezővásárhely is the city with the most developed geothermal district heating system, with a capacity of 21MWt. For the last 60 years, injection into the region’s sedimentary reservoir has been problem-free.

Hungary's largest geothermal based district heating system is in Miskolc. The first phase of the system began operation in 2013, and is still being developed. Of special interest is the super well in Miskolc-Mályi, a PannErgy Plc project. The Miskolc-Mályi is the first "large-scale" project in Hungary, where geothermal-based district-heating system will feed several hundred apartments in the Avas housing estate in Miskolc, Hungary's second largest city. A total of 5 wells were drilled. Two production wells went to a depth of 2,305 m and 1,514 m, yielding 6,600-9,000 l/min fluids with a temperature between 90 and 105°C from a karstified-fractured Triassic limestone reservoir. Three reinjection wells were also established, as well as a 22 km pipeline. The Szentlőrinc project is another new project. The small town's heating system is based 100% on geothermal energy. In both projects Pannergy's contracted off-take partner is a city-owned company.

Some other private investment firms, such as CBA and EuFire, have become involved in geothermal energy production and utilization. Such firms have signed contracts with local governments, as in Mosonmagyaróvár, Kecskemét and Eger, so as to create geothermal district heating systems.

It is a little known fact that since 1969, thermal water has been used in 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. Another interesting application is that gathering pipes are heated by thermal water in the heavy oil producing oilfield Sávoly in the southwest of Hungary. For industrial purposes a total extraction of 1.54 million m^3 of thermal water, representing an installed capacity of 19 MWt and annual use of 220 TJ/y.

In the "other and multipurpose" category, 88 wells produced 14.1 million m^3 of thermal and drinking water. "Drinking thermal water" is an experience unique to Hungary, where 90% of the drinking water supply is provided from groundwater. Where the shallow aquifers are contaminated (e.g. natural high arsenic content in SE-Hungary) lukewarm thermal waters with low TDS from slightly deeper confined aquifers are used.

3.3 Geothermal heat pumps

Shallow geothermal heat utilization increased dynamically from 2000 to 2010, 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. As of 2013, anyone installing a heat pump no longer needs formal permission and is not even required to notify anyone before drilling – this means that geothermal heat-pump data can only be estimated!

The estimated installed capacity is about 40MWt. The actual number of installed units is more than 4,200, but the relevant data is incomplete. The average obtained COP is 4.0. The biggest Hungarian heat pump systems (around or over 1 MW capacity) are significant in the European market, but the technology has not really caught on yet. Many international companies operating in Hungary made significant investments in heat-pump systems in the recent years (e.g. Telenor and TESCO). The size of individual units ranges from 10 kW to 14 kW for residential use.

Despite these ambitious targets, sales of heat pumps in Hungary decreased in 2010 and 2014. 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 electric energy price is above the EU average).
- The favourable electricity tariff only applies to heat pumps used to heat during cold periods (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: reservoir pressure decrease, pollution of fresh groundwater and the waterways from surface geothermal effects, emission of dissolved gases, ground subsidence and noise.

Hungarian geothermal reservoirs may be sedimentary, sandy or karstified limestone aquifers. Reservoir pressure decrease occurs mainly in the sandstone aquifers. Some fields have been exploited for more than seventy years. As a result, the piezometric head of the reservoir has subsided almost 70 m in the Hajdúszoboszló field, where the production can be sustained by artificial lifting methods only. It seems that the supply of the carbonate aquifers in Western Hungary is not yet exhausted.

The freshwater aquifers are located above the geothermal reservoirs. Thus the drilling operations can be hazardous. 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 also present a problem. There are a variety of toxic chemicals to beware of, e.g. chromates. During well completion operations, acid jobs can be hazardous.

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 contains mainly sodium chloride. The environmental impact of the released thermal waters can therefore be serious. The wells of the Bükkszék spa produce more than 1 m^3/min of very saline water, with 24,000 mg/l of solved solids. This means that 14,000 t/year are polluting the small Tarna River.

Most problems of environmental pollution can be avoided by means of reinjection of the heat-depleted thermal water to the aquifer. The reinjection is very useful for some other reasons too. The pressure support for the reservoir can be provided, the enthalpy of the rock matrix becomes exploitable and the surface ground subsidence can also be avoided.

Although reinjection is a routine technology in the petroleum industry, there are in Hungary 672 wells producing thermal water and only 34 wells are (partly) performing re-injection, so only a minor 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. Reinjection is a more complex procedure when it goes into a sandstone reservoir, as the necessary injection pressure can substantially increase within a relatively short time. The permeability is decreased because of formation damage. It can occur because of clay swelling, pore space blocking by fine particles or precipitation of dissolved solids due to the mixing of injected water and the formation water or due to temperature changes. There are many efforts ongoing to solve these problems: theoretical analyses, numerical simulation, laboratory and in-situ experiments. Successful industrial experiments were carried out in the city of Hódmezővasarhely. Experience shows that the following is the most important: an injection well of suitable location and depth, correct design and completion of the well, good hydraulic performance, and very slow transient performance processes (pressure, temperature, flow rate). The average age of the re-injection wells is low. Even the oldest, in Hódmezővásárhely, has only been operating for 16 years.

Right now there is neither EU-sourced nor national support for drilling only an injection well. This means that due to the lack of local or regional resources neither municipalities nor agricultural entrepreneurs can invest into re-injection. Furthermore, there are no available R&D funds for additional pilot studies. According to current legislation (which might change in 2013 if the compulsory re-injection is scrapped) new geothermal energy production capacities may be installed only if they involve re-injection -- otherwise, no project can receive any support or subsidy.

Some Hungarian thermal water contains toxic materials: arsenic, beryllium, chromium, organic materials (pesticides) and pathogenic organisms, and harmful bacteria. If released to the natural waterways, toxic materials and the relative warm waste waters could harm the wildlife of these waters.

Thermal waters also contain dissolved gases, mainly methane, nitrogen, carbon dioxide and hydrogen sulphide. Methane is separated from the water and utilized in auxiliary equipment. The H2S is more harmful because of its acid, corrosive nature. This may lead to perforation of the casing and damaging of the cement sheet as well. Fortunately H2S is present only in a few Hungarian geothermal wells (e.g. Mezőkövesd).

In addition to releasing various dissolved “natural” components of thermal waters to the surface, an important environmental pressure is the heat-load: in many cases the used thermal waters are not cooled down sufficiently and the warm waters can seriously impact the ecosystems.

Drilling operations also involve 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. Blow-outs can also cause significant environmental hazards during drilling operations.

5. ENERGY POLICY LEGAL AND REGULATORY ASPECT

Progress in the Hungarian geothermal sector requires a well-considered energy policy, clear-cut legal and financial regulations. It is necessary to elaborate on the framework which can accommodate the legislative, environmental, planning and financial considerations. Hungary currently has poor operating regulations.

There has been no suitable clarification of geothermal resource ownership. Currently, geothermal resources don't belong to the owner of the land containing the resource. The well is owned by the developer who has drilled it. The produced geothermal energy is the property of the mining contractor. These and other conflicting ownership questions must be regulated in a new, single Geothermal Act -- a primary requirement if Hungary is to develop and regulate its geothermal industry.

The licensing system currently is shared among too many authorities, and relevant administrative procedures should be simplified.

The following points should be addressed on a national level:

- There is no national geothermal authority responsible for promoting geothermal energy production and utilization.
- The geothermal sector has no access to an integrated, comprehensive national database containing precise, reliable, independently verified and regularly updated information.
- National taxation law does not promote increased capital investment in geothermal energy (e.g., renewable tax incentives, preferential VAT rates).
- A geothermal insurance and risk fund, particularly for deep exploratory drilling, requires that financial tools be made available, to help replace fossil-fuel use and reduce the country's CO2 emission savings.
- 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. Petroleum engineering education at the University of Miskolc, in the Faculty of Earth Science, started in the early 60's. From that beginning, 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 about shallow and deep geothermal direct uses (Tóth 2013).

6. 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 Hungarian geothermal sector is in serious trouble because of the weakened economy of the country, which was overtaken by the global recession. Nevertheless, there are promising signs. The implementation of the first geothermal pilot power plant has been given the go-ahead. Even though the first project was not successful, preparations are underway for a second attempt. A few up-to-date cascade systems were implemented for direct use, with successful injection practices. The popularity of ground source heat pumps has accelerated in recent years. Some non-trivial industrial applications are also close to completion. But for the Hungarian geothermal industry to progress, it needs a well-considered energy policy together with a framework of supportive legal and financial conditions.

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (wind, solar)		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 2014			7016	24436	50	250	2000	14500	518	**2102**	9500	
Under construction in December 2014							1000	7250				
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020	4	28	7300	26000	60	290	3000	21750	700	2800	11064	50868

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

Locality	Type[1)]	Maximum Utilization					Capacity	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy (kJ/kg)			Ave. Flow	Energy	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Boly	D,H	16.2	80	25			3.73	10.25	74.36	0.63
Cserkeszőlő	H,B	7.08	86	45			1.21	4.20	22.71	0.59
Csongrád	D,A,B,G	66.57	65	34			8.63	31.00	126.76	0.47
Felgyő	D,A,B,G	40.11	84	33			8.56	17.10	115.03	0.43
Gárdony	B,H	8.12	48	25			0.78	5.02	15.23	0.62
Hódmezővásárhely	D,A,G,B	76.11	90	23			21.34	39.20	346.42	0.51
Kistelek	D,A,B,G,I	22.57	72	35			3.49	10.50	51.24	0.47
Makó	D,A,B,G	47.87	85	40			9.01	21.50	127.61	0.45
Mórahalom	H,B	16.66	70	48			1.53	8.10	23.50	0.49
Miskolc	D,A,	150	103	50			33.26	50.80	355.13	0.34
Szarvas	D,A,B,G,F	43.5	92	32			10.92	20.20	159.86	0.46
Szeged	D,A,B,G,I	116.3	72	35			18.00	41.50	202.53	0.36
Szegvár	D,A,B,G,I	113	86	35			24.11	39.60	266.39	0.35
Szentes	D,A,B,G,I	285.9	85	40			53.83	136.10	807.82	0.48
Szentlőrinc	D	25	86	53			3.45	13.20	57.46	0.53
Veresegyház	H,B	36.11	67	35			4.83	18.20	76.82	0.50
Others	D,A,B,G,I,F	6045	62	35			656.87	1921.00	6841.26	0.33
TOTAL		7116.1					863.58	2373.02	9573.06	0.47

I = Industrial process heat; H = Individual space heating (other than heat pumps); 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

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2014

Locality	Ground or Water Temp. (°C)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type	COP	Heating Equivalent Full Load Hr/Year	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Budapest and the countryside	15	10	4200	V	4	5200	695	132
TOTAL	15	10	4200		4	5200	695	132

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr = 10^{12} J/yr)	Capacity Factor
Individual Space Heating[1)]	33.02	326.05	0.31
District Heating [1)]	153.56	1700.26	0.35
Air Conditioning (Cooling)			
Greenhouse Heating	271.00	3024.12	0.35
Fish Farming	6.00	61.51	0.33
Animal Farming	4.00	31.34	0.25
Agricultural Drying[2)]	25.00	297.13	0.38
Industrial Process Heat[3)]	19.00	220.62	0.37
Snow Melting			
Bathing and Swimming[4)]	352.00	3912.03	0.35
Other Uses (specify)			
Subtotal	863.58	9573.06	0.35
Geothermal Heat Pumps	42.00	695.00	0.52
TOTAL	905.58	10268.06	0.36

1) Other than heat pumps; 2) Includes drying or dehydration of grains, fruits and vegetables; 3) Excludes agricultural drying and dehydration; 4) Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)		14			15.6
Production	>150° C					
	150-100° C		3			6100
	<100° C		15			26.34
Injection	(all)		4			6.3
Total			36			6148.24

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	3	18	7	3	0	28
2011	3	19	7	4	0	32
2012	4	19	9	4	0	35
2013	5	21	11	7	0	44
2014	5	21	11	7	0	44
Total	20	98	45	25	0	183

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

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) 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	0.1		0	40	60
2000-2004	0.3	0.15		0	80	20
2005-2009	3.7	2.8		0	90	10
2010-2014	3.8	4.8	28.7	0	90	10