Geothermal Energy Use, Country Update for Hungary

Annamária Nádor[1], Anikó N. Tóth[2], Attila Kujbus[3], Béla Ádam[4]

[1]Geological and Geophysical Institute of Hungary, H-1143 Budapest, Stefánia str. 14.

[2] University of Miskolc/Miskolc-Egyetemváros, H-3515 Hungary

[3] Geothermal Express Ltd, H-1223 Budapest, Hant str. 26/B

[4] Hidro-Geodrilling Ltd., H-1141 Budapest, Zsigárd str. 21.

nador.annamaria@mfgi.hu

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ABSTRACT

Hungary's excellent geothermal potential is well-known. Traditionally, the country's geothermal energy production that focuses mainly on the direct heat 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.

In 2011 595 active thermal water wells produced 68,5 million m^3 of thermal water in Hungary representing 695,48 MW_t / 10255TJ/y. The majority of the abstracted water was used for balneology (249 wells 36,8 million m^3 265 MW_t / 5285 TJ/year). In direct heat utilization the main sector was agriculture, where altogether 154 wells abstracted 9,34 million m^3 of thermal water, representing an installed capacity of 241,84 MW_t and an estimated use of 2800 TJ/y. Of this about 75% was used for heating of greenhouses and plastic tents, and the rest for animal husbandries (2011).

As of 2011, geothermal energy contributed to the heating of 19 settlements. At an additional 16 locations individual buildings were heated by thermal water. This altogether used 6,76 million m^3 of thermal water, which represent an estimated installed capacity of 132,97 MW_t and use of 1350 TJ/y. The reported industrial use was relatively low (8,3 MW_t / 170 TJ/y). In the "other" category (including public water supply – mainly for drinking water, sanitary water and some undefined utilization schemes) altogether 14, 1 million m^3 abstracted thermal water represents an installed capacity of 47,37 MW_t and an estimated use of 650 TJ/y.

Between 2007 and 2011 altogether 15 deep geothermal projects were supported with grants of 19,48 million euros. There are many current projects being prepared. These focus on geothermal power plant, CHP, district heating and GSHP incentives. Ongoing and increasing financial support, as well as simplified, transparent and reliable legislative frameworks is needed to reach the 2020 NREAP targets, which aim at establishing power production and increasing direct heat by 350%. The newly introduced concessional system targeting exploitation of reservoirs below -2500 m aroused much interest: altogether 16 proposals are waiting for the announcement of the first bids in 2013.

Hungary has traditionally had strong geothermal education, and in spite of the recession the courses are proceeding.

The key environmental issue in the Hungarian geothermal sector is still re-injection. At the moment only a minor part of the produced thermal water is re-injected.

1. INTRODUCTION

The financial crisis of 2008 deeply affected the county. This slowed down the geothermal sector, too. Nevertheless a few direct heat projects have been implemented every year. They represent an updated technology with re-injection, filter and pumping systems, with either cascade utilization and/or fully closed-loop system. The general goal is a zero emission operation.

The current report was based on the integrated evaluation of two datasets. The first is the National Geothermal Energy Register (maintained by the Hungarian Office for Mining and Geology), based on the self-declaration of users paying mining royalty, 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. From both databases data for 2011 were available, so all reported numbers refer to this year.

There were many discrepancies between the two databases, with several factors (i.e. seasonal operations, substantial differences between actual flow rates and reported well-data, lack of information on the real temperature gradients in many cases, etc.) impeding exact calculations. The reported numbers are the best expert estimates of the authors and show a realistic growth compared to the numbers of the previous country update reports (Árpási 2005, Tóth 2010).

2. GEOTHERMAL POTENTIAL OF HUNGARY

The geothermal potential of the Pannonian basin is outstanding in Europe, as it lies on a characteristic positive geothermal anomaly, with heat flow density ranging from 50 to 130 mW/m^2 with a mean value of 90-100 mW/m^2 and geothermal gradient of about 45 °C/km (Dövényi and Horváth 1988). This increased heat flux is related to the Early-Middle Miocene formation of the Pannonian Basin, when the lithosphere stretched and thinned (thus the crust is “only” 22-26 km thick) and the hot astenosphere got closer to the surface (Horváth and Royden 1981). During the continuing subsidence a large depression formed, occupied by a huge lake (Lake Pannon), which was gradually filled up by sediments transported by rivers, originating in the surrounding uplifting Alpine and Carpathian mountain belts (Bérczi and Phillips 1985, Magyar et al. 1999).

These several thousand meter thick multi-layered porous sediments (Upper Miocene-Pliocene “Pannonian sequene”) have low heat conductivity and are composed of successively clayey and sandy deposits. Within this basin-fill sequence the main thermal-water bearing sandy aquifers are those 100-300 m thick sand-prone units which are found in a depth interval of ca. 700-1800 m in the interior parts of the basin, where the temperature ranges from 60 to 90 °C. These are the main reservoirs, with bulk porosity of 20-30% and a permeability of 500-1500 mD, and with an almost uniform hydrostatic pressure, widely used for direct heat purposes as well as for balneology.

The karstified zones of the Palaeozoic-Mesozoic carbonates, as well as fractured zones in the crystalline rocks in the basement are also good thermal water reservoirs. They are characterized by high secondary porosity. At this depth (on average 2000 m or more) temperature can exceed 100-120 °C, and may provide favorable conditions for development of medium-enthalpy geothermal systems (e.g. CHP plants). Some high-enthalpy reservoirs also exist in Hungary, as was proven by a steam-blow-out at a pressure of 360 bars and 189 °C lasting for 47 days. It originated from a fractured dolomite reservoir at a depth of 3800 m in Fábiánsebestyén.

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 NaCl-type (fossil waters).

It has been demonstrated that the SSE-en 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 (≥ 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.

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 0-5 km depth 105 500 EJ, with probable reserves of 60PJ/y for the porous and 130 PJ/y for the basement reservoirs (supposing full re-injection) (Zilahi-Sebess et al. 2012).

3. NATIONAL GEOTHERMAL ENERGY POLICY AND LEGAL BACKGROUND

3.1 The position of the geothermal energy in the domestic energy policy

In addition to such global challenges as increasing energy demand, mitigating the effects of climate change via decreased greenhouse-gas emission and restricted reserves of fossil fuels, Hungary’s National Energy Strategy for 2011-2030 (Ministry of National Development, 2011) warns that energy-import dependency of Hungary (83% of hydrocarbons, about 20 billion m^3/year mainly from Russia) is serious supply-security problem. Therefore the Strategy statement focuses on the long-term sustainability, security, and economic competitiveness of energy supply. It also looks at how the country could use better its own resources. In this context the increased share of renewables is an important pillar.

3.2 The Hungarian Renewable Energy Action Plan (NREAP)

Although the RES Directive (2009/28/EC) prescribed a 13 % RES target for Hungary as a binding target by 2020, the Government did not consider it as an obligation, but as a possibility for economic growth. Therefore in the NREAP (Ministry of National Development 2010) Hungary targeted a 14,65% RES by 2020 referring to a share of geothermal in total RES from 9% to 17% (Table 1).

The NREAP numbers do not include balneology, therefore numbers reported in this study are much higher, as balneological utilization is included, too. (Table C).

NREAP targets	2010	2020
Renewable energy proportion of gross national energy consumption (%)	6.7	14.65
Renewable energy heating & cooling rate from national H&C (%)	9.0	18.9
Ground Source Heat Pump H&C production (PJ)	0.21	4.48
Direct Geothermal Uses (PJ)	4.23	16.43
Geothermal electricity capacity (MW_e)	0	57
Geothermal energy based electricity production (PJ)	0	1.476

Table 1: Growth of the Hungarian geothermal energy production, forecast of the NREAP (Kujbus 2012)

According to the present and forecasted positions, Hungary will remain among the leaders in deep geothermal among the EU 27 countries (Table 2).

Segments/ Ranking in EU27	2010	2020
Heat Pumps	~18-21	~8-11
Direct heat utilization	3	3
Electricity production	6-27	6

Table 2: Position of the forecasts of the NREAP (Kujbus 2012)

4. SHALLOW GEOTHERMAL

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.

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.

As regards heat pumps, the Hungarian NREAP targets show a considerable increase. Heat-pumps supplied 0.25 PJ in 2010 and are forecasted to provide as much as 5.99 PJ by 2020. Within the scope of heat-pumps, ground-source heat-pumps account for approximately three quarters of the heat quantity, 0.208 PJ in 2010, with the target for 2020 set at 4.48 PJ. Thus the expected growth is over twenty times high.

Given the country's geological conditions and the size of Hungary's existing heat market, these NREAP targets are likely to be attained.

Despite these ambitious targets, sales of heat-pumps in Hungary decreased in 2011 and 2012. 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, while 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).

The Hungarian heat-pump market has therefore stopped growing, after annual sales approximating 1000 units between 2008 and 2010.

Within the overall heat-pump market, air-source systems slightly increased their proportion. In 2011 sales of air-source heat pumps accounted for 57 % of total sales. 2012 and 2013 sales estimates show no signs of changing.

Many international companies operating in Hungary made significant investments in heat-pump systems in the recent years (e.g. Telenor and TESCO).

The National Environment and Energy Centre prepared an eight-years Action Plan to promote heat-pump investments to be implemented in operative programs to achieve its long term goals (NEEC-Kujbus 2012). The Action Plan includes recommendations for:

- an information and dissemination campaign,
- updating the relevant regulations,
- project supports
- training, education.

According to the current legislation, exploitation and utilization of geothermal energy above -2500 m without water abstraction (i.e. ground-source heat-pumps) is the responsibility of the Mining Inspectorate and require no licenses, although this does not free the entrepreneur from having to obtain other necessary (e.g. building) permits. This is one reason why data about ground-source heat-pumps and shallow geothermal energy use is inadequate, and mostly based on sales figures.

5. 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 that the NREAP forecasts.

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 2007 and 2011 altogether 15 projects were supported and 19,48 million euros was granted. This support ranged from 30 to 70% of the total budget. The Vácrátót Botanic Gardens and the Gyopárosfürdő Thermal Bath with "zero emission" technology went into operation in 2011. The Makó Thermal Bath, the Szolnok Hospital and the heating system for the town of Mezőberény were all commissioned in 2012. Preparation for two large successful district heating projects of 2010-2012, operated by Pannergy, were also co-finaced by the Environmental and Energy Operative Program.

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

The Miskolc-Mályi is the first "large-scale" project in Hungary, where geothermal-based district-heating system will feed several hundreds of flats 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 2305 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 re-injection wells were also established, as well as a 22 km pipeline. The planned heat capacity is 55 $MW_{t,}$ the heat demand is 695 000-1100 000GJ (Perlaky 2012).

In both projects Pannergy's contracted off-take partner is a city-owned company. The off-take contract is for 15+5 years.

5.1. Licensing of deep geothermal projects and legal barriers

The legal framework for geothermal energy use is rather complicated in Hungary; regulations and licensing procedures are shared by the mining-, energy-, environmental protection and water management sectors. Despite continuous efforts at legal harmonization, legal contradictions and time-consuming licensing processes still impede investment.

Hungary's two decisive legal parameters for geothermal utilization (including licensing) depend on: (1) whether groundwater is abstracted, and (2) whether the depth exceeds 2500 m. The exploration and exploitation of geothermal energy - if not connected with the abstraction of thermal groundwater – falls under the scope of the Mining Act. However, survey and abstraction of thermal groundwater yielding geothermal energy is regulated by environmental and water management legislation, and a water license is required. Utilization of thermal groundwater above -2500 m ("open area") is based on a water license and is considered as a license for prospection and exploitation of geothermal energy as well.

According to the amendment of the Mining Act in 2010, the exploration of geothermal energy from a depth below -2,500 m ("closed area") can take place only in the frame of a concessional system (with, or without groundwater abstraction), which is licensed by the Mining Inspectorate. In 2011-2012 altogether 16 proposal for geothermal concessions were submitted by different entrepreneurs. As a first step a preliminary complex vulnerability and impact assessment (CVIA) has to be prepared for the proposed areas, looking to determine those factors and areas within the planned concessional block, where future mining activity cannot be performed due to several restrictions (environmental- and nature protection, water management, protection of cultural heritage, agriculture, national defense, land-use, etc.). By the beginning of 2013, 10 out of the 16 proposals had completed studies and are now ready for a public tender. The first calls are expected to come out in the spring of 2013. The Minister will conclude a concessional contract with the winner of the public competition, which is valid for no more than 35 years, and can be extended once more by max. another 17,5 years. Within the period of the concession, exploration can last no longer than 4 years, to be extended twice more for an additional 2 years.

The concession license also gives the entrepreneur an exclusive right to the designate the geothermal protection zone, only from that zone geothermal energy be exploited. The geothermal protection zone is a 3D „space" (subsurface "equivalent" of a mining plot) where recharge (heat and fluid) is sufficiently supplied for at least 25 years. This is outlined on the basis of complex flow- and heat transport models. Within the outlined geothermal protection zone any other pre-existing thermal water abstraction (based on previously issued water license) can be continued only upon agreement with the geothermal concession license holder. Without that, no new water permits are allowed.

The Hungarian legislation related to water management focuses on the long-term protection of (thermal) groundwater quality and quantity, in line with the Water Framework Directive, therefore does not promote the enhanced use of thermal waters for energetic purposes. During the preparation of River Basin Management Plan (RBMP) in 2009, several thermal groundwater bodies (especially the porous Pannonian aquifers in the central and S-ern part of the Great Hungarian Plain) got a bad quantity status assessment, as overexploitation had led to diminished groundwater level / hydraulic head at many places. Nevertheless much of the use was balneological.

The vigor of the water management policies clearly shows that the RBMP served as a basis for the regulation of re-injection. The Act on Water Management states that thermal water abstracted solely for geothermal energy utilization has to be re-injected to the same aquifer. An exemption can be applied for those users until December 22, 2014, who abstract thermal water from groundwater bodies which the RBMP has deemed to have poor quantity status. Recent legislation pushed this deadline up to June 30, 2015 for thermal waters users for direct heat purposes in the agriculture sector. In the currently planned amendment on the Water Act, which is going to being discussed by the Parliament in spring 2013, the formerly compulsory re-injection for energetic use would be discarded and become as optional. This would seriously threat the fulfillment of the NREAP targets, as well as the goals of the National Water Strategy in line with the requirements of the Water Framework Directive keeping groundwater resources in a good status.

Expenses to be paid after the abstraction and utilization of thermal waters include the mining royalty and the water resource fee. The mining royalty is 2 per cent of the value of the exploited geothermal energy gained from an energy carrier of a temperature higher than 30 °C, and is defined in a self-assessment. The water resource fee has to be paid after the amount of used water, based on the measured quantity by a certified water clock which has to be equipped at the well-head.

Thermal water used solely for energetic purposes have a multiple taxation (both a mining royalty and a water resource fee), while user-licensed abstraction for balneological purposes (even if the exploited thermal water is also used for a secondary purpose such as heating a spa) have to pay only the water resource fee.

5.2. Power generation

As the geothermal potential in Hungary is high enough, the deeper reservoirs can provide thermal heat to supply geothermal power plants. Several geothermal power plant models have been developed during the last few years, which show that it is technically possible to fulfil the objectives of NREAP (Table 3).

Plant model, (MW_{el})	Depth in Pannonian Basin (m)	Thermal water temp. range (°C)	Average electric power (MW_{el})	Number of estimated installed power plants	**Total power (MW_{el})**
5 - 12	> 4000	160 - 200	7	3	**21**
2 - 5	3000–4000	120 - 160	3	8	**24**
max. 2	< 3000	< 120	1.0	12	**12**
Total			2.7	21	**57**

Table 3: Technical opportunity to achieve the geothermal based electricity forecast of NREAP (Kujbus 2013)

The most significant Hungarian geothermal power plant concept is the Ferencszállás EGS Project, awarded in NER300 European Union First Bidding Round. The project site is in S-ern Hungary, not far from Szeged. Because of the region's excellent geothermal conditions the project looks to achieve more than 5 MW_e net electric capacity.

Presently there are two main barriers for Hungarian power plant projects; (1) the first geothermal concession tenders haven't been issued yet, and (2) the feed-in tariff system is under revision. The takeover price of the electricity produced from geothermal energy was about 10 €ct/kWh, but it is presently suspended.

5.3. Direct heat utilization

There are two main types of ***"district heating"***. In Hungary there are 111 settlements where district heating systems now exist, but there are only 9 (Makó, Csongrád, Hódmezővásárhely, Nagyatád, Szeged, Szentes, Szigetvár, Vasvár and Szentlőrinc), where geothermal energy contributes to the district heating (operated otherwise by gas) and thermal water is supplied to the already existing systems. The only exception is Szentlőrinc, established in 2011, and completely based on geothermal. There are 3 towns where the district heating system is mostly supplied by geothermal: Szentes (97,4%), Csongrád (90%) and Hódmezővásárhely (80,4%). In the rest of the towns the contribution of geothermal energy is only about 10-30%. A major new geothermal-based district-heating system (Miskolc-Mályi) is under construction.

The number of such systems, which do not fall in the category of "district heating s.str, but can be called "geothermal-based town heating systems" is slightly higher (altogether 10 settlements: Kistelek, Veresegyház, Bóly, Mórahalom, Gárdony, Mezőberény, Szarvas, Szolnok, Cserkeszőlő, Újszilvás,). Another 3 town-heating projects are under construction (Törökszentmiklós, Barcs, Tamási). In these systems typically the gas-based heating of some public buildings (town hall, library, school, hospital, etc) is replaced by geothermal and other nearby buildings (private houses) may join the newly established thermal water pipelines. These systems are not connected to existing district heating systems, mainly because these facilities do not exist there. They supply heat only to a separate part of the settlement through a heat supply centre.

Due to the limitations of heat and yield, these systems cannot 100% fulfill the energy demand of the consumers, and therefore do not qualify as district-heating which requires a round-the-clock energy supply. Hence, users have to maintain heating systems suitable for additional (e.g. gas-based) supply, if needed. These local systems are commissioned on the basis of a water license and are often run by local municipalities. This contrasts with the district-heating systems, where heat is provided by a trading company on a contract basis, regulated by the Hungarian Energy Bureau).

The growing number of projects planned or under construction shows that municipal mayors in Hungary (e.g. Komárom, Kiskunhalas, Hajdúnánás, Erdőkertes, parts of Hódmezővásárhely) recognize the value of geothermal

In addition to the above 2 main categories of heating, wells provided thermal water for the heating of individual spa buildings at 16 locations.

In 2011 altogether 6,76 million m^3 of thermal water from 51 wells supplied all these different heating systems which represent an estimated installed capacity of 132,97 MW_t and an estimated annual use of 1350 TJ/year (Tables C, D).

The major sector for direct heat utilization is still the ***agriculture*** in Hungary. For the heating of greenhouses and plastic tents altogether 7,25 million m^3 thermal water was abstracted in 2011 from 86 wells, representing an installed capacity of 185,54 MW_t. For other energy purposes (e.g. animal husbandries) 2,09 million m^3 thermal water was abstracted from 68 wells, representing an installed capacity of 56,3 MW_t. Thus altogether the total installed capacity in the agriculture sector was 241,84 MW_t.. The estimated annual use in 2011 was 2800 TJ (Table C). 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.

For ***industrial purposes*** relatively small numbers were reported from 2011: a total abstraction of 1,44 million m^3 of thermal water from 15 wells, representing an installed capacity of 8,3 MW_t and annual use of 170 TJ/y (Table C).

For ***balneological purposes*** 249 wells produced thermal water with a total abstracted amount of 36,8 million m^3 (2011). The outflow temperature typically ranges between 30 and 50 °C. These wells mostly discharge the Miocene porous sandstone reservoirs between an average depth of 500-1500 m. About 45 wells had higher outflow temperature (60-80 °C), many of them discharge 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 installed capacity of the wells used for balneology is 265 MW_t with an annual use of 5285 TJ/year (2011) (Table C).

In the ***"other"*** category (also reported together with balneology - Table C) 3 main utilization groups were identified. 87 wells produced 10,8 million m^3 of thermal water for "public water supply", meaning for drinking water. "Drinking thermal water" is a country specific experience in Hungary, where 90% of the drinking water supply is provided from groundwater. On areas 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. This amount of thermal water altogether represents 25,56 MW_t capacity and about 350 TJ/y annual use.

22 wells produced 2,73 million m^3 of thermal water for "public water supply", meaning sanitary water, representing an installed capacity of 18,4 MW_t and annual use of cca 220 TJ/y.

Finally there were another 17 active wells which produced 0,57 million m^3 of thermal water with unidentified purposes representing an installed capacity of 5,41 MW_t and an estimated annual use of 80 TJ/y.

6. EDUCATION, TRAINING

Geothermal education has a long tradition in Hungary. The petroleum engineering education at the University of Miskolc, Faculty of Earth Science started in the early 60'. 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 are 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), Geothermal Environmental Impacts (5).

In 2012 an EU co-funeded 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).

7. ENVIRONMENTAL ASPECTS

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.

The most problematic question of the Hungarian geothermal sector from environmental point of view is re-injection. There are 595 wells producing thermal water and only 34 wells are (partly) operating for re-injection, so only a minor part of the produced thermal water is re-injected.

Re-injection is relatively simple into fractured-karstified carbonate reservoirs, and there are some successful examples on this in the western Hungary. It is a more complex procedure, however, when applied to sandstone reservoirs, where the necessary injection pressure can substantially increase within a relatively short time. This is especially relevant for the Upper Miocene (Pannonian) sandstone reservoirs, mostly fine-grained, with a highly hetereogenous lithology (silt, clay intercalations) and high clay content. Therefore, the most common problem is the plugging of screens (perforation) in the well and pore throats of the reservoir formation. That leads to the decrease of permeability due to clay swelling, pore-space blocking by fine particles, or precipitation of dissolved solids due to the mixing of injected and formation water. The precise mechanisms which determine injectivity are site specific and processes are not entirely understood yet, although several local experiments including theoretical analyses, numerical simulations, laboratory and in-situ experiments were carried out in SE – Hungary (Hódmezővásárhely, Szeged and Szentes areas - Szanyi and Kovács 2010, Bálint et al. 2010, Barcza et al. 2011).

The main lessons learned from these studies are that long-term sustainable injection is possible, but instead of ad hoc approaches, scientifically sound solutions must be found. That means selecting the right injection well (location and depth), creating and executing a good design, achieving good hydraulic performance, and ensuring a very slow transient performance process (pressure, temperature, flow rate). Special research is needed as early as the drilling phase to determine permeability, conductivity, rock-mechanical characteristics, pressure, geothermal properties of the reservoir and the hydrogeochemistry of the formation fluids. These studies also revealed that the main reason for the initial failure was that early projects tried to transform existing abstraction wells into re-injection wells, not paying attention to micro-filtration prior to re-injection.

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, which means that due to the lack of own 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 the current legislation (which might change in 2013 by deleting compulsory re-injection) new geothermal energy production capacities may be installed only if they involve re-injection, otherwise no project can receive any support or subsidy.

The chemistry of the Hungarian thermal waters shows a great variety. Although some of the dissolved elements make thermal waters valuable as medicinal waters in balneology, the high total dissolved content may cause scaling problems. The environmental impact of the thermal waters with high TDS released to the surface can be serious, e.g. the wells of Bükkszék spa produce more than 1 m^3/min of very saline water with dissolved solids at 24.000 mg/l (Tóth 2010).

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 H_2S 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 H_2S is present only in a few Hungarian geothermal wells (e.g. Mezőkövesd).

Some Hungarian thermal water contains toxic materials: arsenic, beryllium, chromium, organic materials (pesticides) and pathogenic organisms, bacteria. If released to the natural waterways, toxic materials may endanger the ecosystem.

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 encompass 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. There is a variety of chemicals that are toxic e.g. chromates. During the well completion operations acid jobs can be hazardous.

A blow out can be also a significant environmental hazard during drilling operations. The most serious blow out of a geothermal well occurred in Fábiánsebestyén, E-ern Hungary in 1985. The noise level during the outburst reached 125 dB.

Another important environmental concern is the integrated management of hydrogeothermal reservoirs with the overlying freshwater aquifers. It was demonstrated that these two systems are in hydrodynamic connection and cold-water abstractions from the shallow aquifers can have a serious impact on the pressure and yield conditions of the underlying reservoirs (Nádor et al. 2012).

Due to the special geological/geographical setting of the Pannonian Basin, it is extremely important to pay attention to transboundary issues. Thermal water extraction from the same geothermal reservoir shared by neighboring countries at a national level may cause negative impacts, such as drops in pressure and temperature, which might impact the bordering countries. The sustainable utilization of transboundary geothermal reservoirs therefore should count on joint management strategies (Nádor et al. 2011).

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Tables A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2012	-	-	6348	36146	-	-
Under construction end of 2012	-	-	100	600	-	-
Total projected by 2015	3.5	24	6500	40000	0.054	0.06

Table B: Existing geothermal power plants, individual sites*

*Geothermal power plants are not yet available in the country.

Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers

	Geothermal DH Plants		Geothermal heat in agriculture and industry		Geothermal heat in balneology and other	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2012*	132,97	375,03	250,14	825,066	312,37	1648,743
Under construction end of 2012	10	32	3	11	4	13
Total projected by 2015	178	515	264	867	325	1688

*2011 data

Table D: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name*	Year com-mission	Is the heat from geo-thermal CHP?	Is cooling provided from geo-thermal?	Installed geotherm. capacity (MW_{th})	Total installed capacity (MW_{th})	2012 geo-thermal heat prod. (GWh_{th}/y)	Geother. share in total prod. (%)
Bóly	TH	2002	No	No	2.5	2,5	7,55	100
Cserkeszőlő	TH	2001	No	Yes	1.2	1,2	4,78	100
Csongrád	DH	2012	No	No	4.3	4.78	15,28	90
Hódmező-vásárhely	DH	1994	No	No	15.0	18.66	45,96	80.4
Kistelek	TH	2005	No	No	3.39	3,39	13,85	100
Gárdony	TH	2010	No	No	1.5	1,5	5,33	100
Makó	DH	2012	No	No	5,0	no updated data		
Mórahalom	TH	2004	No	No	1.5	1,5	5,36	100
Nagyatád	DH		No	No	2	6,25	7,1	32.2
Szarvas	TH		No	No	11.28	11,28	50,88	100
Szeged	DH		No	No	18.49	1087.65	69,81	1.7
Szentes	DH	1958	No	No	52,29	53,9	69,22	97.4
Szentlőrinc	DH	2009	No	No	3.1	3.1	6,66	100.0
Szigetvár	DH		No	No	3	27,27	11,2	11.0
Szolnok	TH	2012	No	No	1.2	1,2	5,7	100
Újszilvás	GSHP	2010	No	Yes	0,46	0,46	0,07	100
Vasvár	DH		No	No	1,76	14,67	6,4	12,9
Veresegyház	TH	1993	No	No	5.0	5.0	14,5	100
Total					**132,97**		**339,65**	

*TH= town-heating, DH= district-heating, for discussion see the text

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New GSHP in 2012		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2012	5 000	55	110	300	4	50
Projected by 2015	7 000	75	150			

Table F: Investment and Employment in geothermal energy

	in 2012		Expected in 2015	
	Investment (million €)	Personnel (number)	Investment (million €)	Personnel (number)
Geothermal electric power	0.5	5	20	80
Geothermal direct uses	5	50	25	180
Shallow geothermal	5	200	21	800
total	**10.5**	**255**	**66**	**1060**

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	DIS	DIS	no
Financial Incentives – Investment	DIS, FIT (suspended)	DIS	yes, for enterprises, budgetary/governmental and non-profit organizations (there is no incentive for individuals)
Financial Incentives – Operation/Production	no	no	Reduced electricity price for GSHPs. Its rate is depending on electricity supplying regional companies (geo-tariff)
Information activities – promotion for the public	yes	yes in frame of ongoing projects	A shallow geothermal utilization campaign of the Energy and Environment Centre
Information activities – geological information	yes on the website of the Geological and Geophysical Institute of Hungary (www.mfgi.hu)	yes	Under development
Education/Training – Academic	yes	yes	Academic engineering education at the University of Miskolc
Education/Training – Vocational	Yes Hungarian Engineering Chamber in collaboration with University of Miskolc held several courses	Yes Hungarian Engineering Chamber in collaboration with University of Miskolc held several courses	Hungarian Engineering Chamber in collaboration with University of Miskolc held several courses. EUCERT and Geotrainet will be started by the Hungarian Heat Pump Association

Key for financial incentives:					
DIS	Direct investment support	RC	Risk coverage	FIP	Feed-in premium
LIL	Low-interest loans	FIT	Feed-in tariff	REQ	Renewable Energy Quota