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Hungary Country Update 2005-2009

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ABSTRACT

The utilization of geothermal energy has a long tradition in Hungary. When the present economic recession in the country ends in the near future, geothermal energy will surely play an increasing role in the energy supply. The paper shortly reviews the history of geothermal energy and discusses the present state of geothermal energy production and utilization in the country. There is a discrepancy between favorable natural conditions and the poor practice. Present state statistics as well as future plans are detailed.

1. INTRODUCTION

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 ^{o}C/m), and the vast expanses of deep aquifers form an important geothermal resource.

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. Based on data of 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 utilization. The peak of geothermal activity was at the late 70's: a total of 525 geothermal wells were registered, the best 30 of them had a production temperature of more than 90^{o}C. Total thermal power capacity of these wells was 1,540 MW, but utilization was seasonal and the efficiency was rather low.

The present state of geothermal energy production and utilization in Hungary has an ambivalent nature. The utilization of geothermal energy has decreased substantially because of the national and global recession while promising projects occur both in power generation and direct-uses.

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 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.

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, local recharge or discharge can slightly modify this pattern.

Another type of geothermal reservoirs are in the carbonate rocks of Triassic age having 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).

The existence of high enthalpy reservoirs was proven by a dramatic steam blowout from the well Fábiánsebestyén in the Southeast of Hungary in 1985. From an exploratory borehole over-pressured steam had blown out at a pressure of 360 bars and a temperature of 189^{o}C. The flow rate was approximately 8,400 m^3/day. The reservoir is a fractured dolomite formation at the depth of 3,800 m. 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 the 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 South-Eastern part of Hungary seems to be possible.

Many deep hydrocarbon exploratory wells were drilled in the South-Eastern of Hungary during the recent years. The high temperature of impermeable basement rock was proven during the exploration. The undisturbed temperature of the rock is obtained 252 ^{o}C at the depth of 6,000m. This area can be a promising target for the future EGS development projects.

3. PRODUCTION AND UTILIZATION

3.1 The Present Status

Most Hungarian geothermal wells produce hot water from the upper Pannonian reservoir system. A smaller part of them taps the deep karstic aquifer. At present (2009) 910 wells produce thermal water warmer than 30^{o}C. Out of this number, 184 wells are abandoned and 226 are temporarily closed.

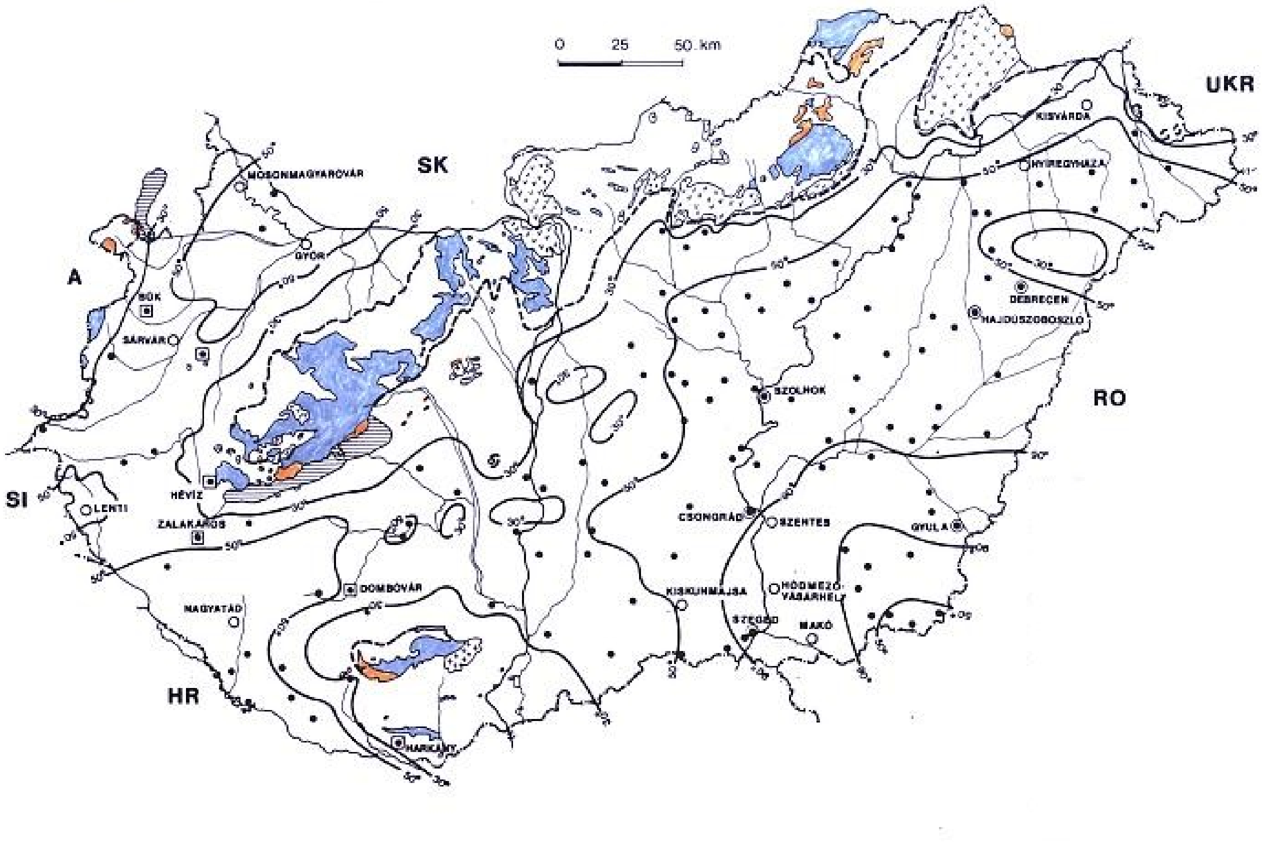

Figure 1: Regional distribution of accessible wellhead temperatures

A typical geothermal well in Hungary might have a depth between 1,000 and 2,100 m. The 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. It 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. The production temperatures vary regionally as shown in Fig.1. Undoubtedly, the best area is in the Southeast of Hungary near the cities Szeged, Szentes and Hódmezővásárhely.

Most Hungarian geothermal wells operate without any artificial production method. Reservoirs are driven by both compaction and dissolved gas. Submersible pumps are installed to that wells, in which the reservoir pressure has been depleted substantially.

It can be seen 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 base of thermal power assessment. Many thermal wells operate seasonally and there are a substantial difference between the actual flow rates and well test data.

Table 1: Number of geothermal wells based on wellhead temperature and type of utilization Abbreviations: T_{WH} Wellhead Temperature in ^oC, W Water Supply, S Spa, A Agliculture, C Communal, I Industrial, MP Multi Purpose, Σ Production Well.

T_{WH}	W	S	A	C	I	MP	Σ
30-40	203	73	73	1	44	6	400
40-50	30	118	17	2	13	17	197
50-60	7	50	15	2	11	13	98
60-70	-	33	17	1	6	29	86
70-80	-	9	17	5	6	16	53
80-90	-	3	20	1	3	5	32
90-100	-	3	33	5	1	-	42
100<	-	-	1	-	-	1	2
Σ	240	289	193	17	84	87	910

A theoretical thermal capacity is calculated taken the well test data for the different wellhead temperature range in Table 2.

Table 2: Theoretical thermal power capacities. Abbreviations: T_{WH} Wellhead Temperature in ^oC, Σm Total Flow Rate, m_{av} Flow Rate per Well, ΣP Total Thermal Power, P_{av} Thermal Power per Well.

T_{WH}	Σm [kg/s]	m_a $[kg/s]_v$	ΣP $[MW_t]$	P_{av} $[MW_t]$
50-60	1,662	16.96	306	3.12
60-70	1,418	16.49	327	3.80
70-80	1,065	20.09	290	5.47
80-90	659	21.26	207	6.07
90-100	1,012	24.09	360	8.57
100<	62	31.00	23	11.50

The theoretical total thermal power capacity of these wells is 1,513MW_t while the total mass flow rate is obtained as 5,878kg/s. In spite of these the Hungarian Office for Mining and Geology records 14,015,418 m^3/year thermal water production based on the self-declaration of the users. It's equal to the average mass flow rate 444.4 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 654,6 MW_t only. This obtains an assumed load factor of 44 %.

Balneology use was the earliest way to utilize thermal waters. Worldwide-known spas are in Budapest, Bük, Hajdúszoboszló, Harkány, Hévíz, Sárvár, Zalakaros and many other places. Altogether 289 thermal wells and 120 natural springs produce water for sport and therapeutically purposes. The estimated thermal power applied in the field of bathing and swimming utilization is about 272 MW_t 5356 TJ/year.

Agricultural use is an important branch of geothermal energy utilization in Hungary. It means 193 operating thermal wells. Greenhouses of more than 67 Ha, and plastic tents and soil heating supplied with the heat of thermal water more than 232 Ha.

Animal husbandries are heated by thermal water in more than 52 cases at chicken, turkey, calf, pig and snail farms. Low-temperature released waters supply fish ponds near Szarvas and Győr.

The estimated thermal power applied in the field of agricultural utilization is about 212 MW_t 2,572 TJ/year.

District and space heating by geothermal energy was started near balneology centers. The first examples are some apartment houses and the Budapest Zoo in between the two World Wars. In the late 50's district heating projects were started in Southeast Hungary e.g. Hódmezővásárhely, Szeged, Szentes, Makó, Kistelek. At the present 40 townships more than 9,000 flats are heated by thermal water, the estimated total thermal power is more than 118,6MW_t 1162 TJ/year. From these figures is assumed to be for district heating about 80% and 20% for individual heating.

Technical level of these geothermal heating systems can be very different. There are well designed and controlled sophisticated systems, where a dozen of geothermal wells supply a cascade of sub-systems: greenhouses, plastic tunnels and soil heating are connected in series (e.g. Hódmezővásárhely). In other cases a single well provides thermal water directly to greenhouses, and the discharged, still relatively hot water causes a low efficiency and sometimes environmental problems.

It is a little known fact that since 1969, thermal water is used in the secondary oil production technology in the Algyő oilfield. Presently 5,400 m^3/s of hot water is reinjected to the oil reservoir for oil displacement. The utilized geothermal power during this secondary oil recovery technology is 12 MW_t .

Another application is that gathering pipes are heated by thermal water in the heavy oil producing oilfield Sávoly in the Southwest of Hungary.

Geothermal heat pumps have had the largest growth in Hungary since 2005. The installed capacity is about 40MW_t. The actual number of installed units is more than 4,000 however data is incomplete for this number. The average COP is obtained as 4.0. The size of individual units ranges from 10kW for residential use to large units of 1,000kW, with 180 BHE. This latter is recently installed in the official building of Pannon GSM Budapest.

3.2 The New Developments

As it is known, there is no electricity production on a geothermal base in Hungary until now. The Hungarian Petroleum Company, MOL Plc. decided to implement Hungary's first geothermal pilot power plant. It seemed to be a suitable idea to choose a small, binary cycle power plant based on the Kalina cycle. The project seemed to be to less expensive using two dry holes as a doublet. After a pre-selection of these wells 60 candidates remained for a more detailed investigation. The main criteria, that needs consideration for successful selection are the reservoir temperature (> 125 ^oC), the productivity (> 15 kg/s) the chemical composition of the reservoir fluid (TDS < 15 g/l) and the distance between the two wells (< 3,5 km). Finally the Ortaháza field was chosen. It is a fractured limestone aquifer having a temperature of 145 ^oC a depth of 3,000 m a TDS of 5 g/l, and a distance between the wells of 1,000 m. The two wells were deepened to further 300m. The drilling and well completion works were done at the best technical level. Flow curves were obtained from the production and injection tests. The flow rates of the wells were determined based on flow curves. Since the built in position of the submersible pump was determined by the well completion, the flowing borehole pressure can be at most 22 MPa. In this case the accessible flow rate is obtained as 619 m^3/d only. Even reservoir temperature was satisfactory the flow rate was lower than the necessary expected value. This was a typical case of an unpredictable geological risk. Finally the project became temporarily suspended.

Based on the pilot tests MOL Plc. and its partners decided to enter the Hungarian geothermal business. In 2008 they established Central European Geothermal Energy Production Limited (CEGE) in order to operate this activity. CEGE reviewed the project opportunities concerning the deep structures and launched its first geothermal power plant project in 2010.

There is an interesting momentum, MOL Plc. decided to apply geothermal energy for industrial heating at own gas pressure reduction stations. It means more than 400 gas pressure reduction stations. Their capacities fall in a wide range. The pre-heating of the gas in these stations needs thermal power from 20 kW to 1 MW. A new project starts to replace the gas fired boilers by geothermal heat pumps. The total built-in boiler capacity of the pressure reduction stations is 76.45 MW_t. Naturally the effective thermal power is less, because of the seasonal change of the gas consumption. Thus the self-consumption of the stations is also changes. Its yearly average is 49.6 MW_t only. Assuming an average COP of the heat pumps is 4.5, the electric power consumption of the station is 11.02 MW.

Even it is a small scale of use geothermal energy is utilized in the nuclear industry too. The National Nuclear Waste Storage is established in an underground granite block. The storage chambers open into the two main shafts of 1860 m length. Their slope is 8%. Icing can occur in the pavement of the entrance section of 200 m if the intake air temperature is lower than -5 ^{o}C. The safety of the traffic of the heavy trucks in the slick pavement makes necessary the de-icing. For this purpose the pavement is heated in cold weather. The heat supply is partly from the enthalpy of the inflowing water through the walls (500 m^3/day), and partly the warmed up air in the out-take tunnel applying an air-water heat pump of 104 kW.

A new investor firm PannErgy Plc. has occurred in the geothermal energy production and utilization. A number of contracts has been bonded with local governments in order to implement geothermal district heating systems. Their first production well is drilled in Szentlőrinc with a depth of 1790 m.

4. ENVIRONMENTAL IMPACT

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 on the surface thermal effects, emission of dissolved gases, ground subsidence and noise.

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

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

Nevertheless a blow out can be the greatest environmental hazard while drilling. The most serious blow out of a geothermal well occurred in Fabiánsebestyén, Eastern Hungary in 1985. The mass flow rate was 92 kg/s having an extreme high salinity and the small creek Kórógy lost all kinds of life. The noise level during the outburst reached 125 dB.

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 be serious. The wells of Bükkszék spa produce more than 1 m^3/min of very saline water, its solved solids are 24.000 mg/l. This means that 14.000 t/year are 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 damaging of the cement sheet as well. Fortunately H_2S is present only in a few Hungarian geothermal wells (e.g. Mezőkövesd).

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 of the reservoir can be provided, the enthalpy of the rock matrix becomes exploitable and the surface ground subsidence can also be avoided.

Reinjection is a routine technology in the petroleum industry. 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. It is a more complex procedure 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 Hódmezővárhely. The most important experiences are: a suitable choice of place and depth of the injection well, correctly designed and completed well, good hydraulic performance, very slow transient performance processes (pressure, temperature, flow rate).

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 and the relative warm waste waters harm the wildlife of these waters.

5. ENERGY POLICY LEGAL AND REGULATORY ASPECT

Progression of Hungarian geothermal sector needs a well-considered energy policy, clear-cut legal and financial regulations. It is necessary elaborate the framework which can accomodate the legislative, environmental, planning and financial considerations. Hungary currently has poor operating regulations.

There is no suitable clarification of geothermal resource ownership. The ownership of geothermal resources doesn't belong to the owner of the land containing the resource. As any natural resources obviously geothermal resources are owned by the state in Hungary. The well is owned by the developer who has been drilled it. The produced geothermal energy is the property of the mining contractor. These must be regulated in a new, single Geothermal Act. It is a primary requirement to develop and regulate the Hungarian geothermal industry.

The licensing system currently is shared among too many authorities. The administrative procedures need a substantial simplification. Administrative procedures should be as simple as possible.

There is no a national geothermal authority that has the responsibility to promote the geothermal energy production and utilization.

There is no any integrated database for the geothermal sector.

National taxation law is not encouraged to promote increased capital investment in geothermal energy (eg: renewable tax incentives, preferential VAT rates).

Deep geothermal energy projects should be promoted by national regional and local government authorities. Grants or other financial support schemes for both commercial and residential sector systems should be available. Inventories of the geothermal resources are rather weak. During the last five years the sum of all supports was about 10,5M USD.

A geothermal insurance and risk fund, particularly for deep exploratory drilling needs financial tools to be made available based on the substitution for fossil fuel use and on the potential for national CO2 emission savings.

Innovative applications of geothermal energy research and development activity should benefit from specific discount.

6. CONCLUSIONS

Hungary has favorable natural conditions for geothermal energy production. In spite of this production and utilization is stagnating contrary to the general tendencies worldwide. The Hungarian geothermal sector is in serious troubles because the weakened economy of the country is overtaken by the global recession. Nevertheless there are promising elements. The implementation of the first geothermal pilot power plant has been decided. Even as the first project was not successful preparation is continuous for the second attempt. A few up to date cascade system was implemented for direct use with successful injection practice. Spreading of ground source heat pumps is accelerated in the recent years. Some non-trivial industrial applications are also close to completion. Progression of Hungarian geothermal industry needs a well-considered energy policy together with supporting legal and financial conditions.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)			Total	
	Capac-ity	Gross Prod.	Capac-ity	Gross Prod.	Capac-ity	Gross Prod.	Capac-ity	Gross Prod.	Capac-ity		Gross Prod.	Capac-ity	Gross Prod.
	MWe	GWh/yr	MWe	GWh/yr	MWe	GWh/yr	MWe	GWh/yr	MWe		GWh/yr	MWe	GWh/yr
In operation in December 2009			6381	21336	50,5	250	2000	14500	175 323,2 20	wind biomass biogas	224 1660 33	8950	38103
Under construction in December 2009			635	3100	2,22	7,5						637	3108
Funds committed, but not yet under construction in December 2009													
Total projected use by 2015	4	28	7300	26000	58	270	2600	19000	440 450 80	wind biomass biogas	600 2100 120	10932	48118

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2009 (other than heat pumps)

1) I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting

H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

Locality	Type[1)]	Maximum Utilization Flow Rate (kg/s)	Temperature (°C) Inlet	Temperature (°C) Outlet	Enthalpy[2)] (kJ/kg) Inlet	Enthalpy[2)] (kJ/kg) Outlet	Capacity[3)] (MWt)	Annual Utilization Ave. Flow (kg/s)	Annual Utilization Energy[4)] (TJ/yr)	Capacity Factor[5)]
Csongrád	D,A,B,G	66,57	65	35			8,35	31	122,67	0,47
Fábiánsebestyén	D,A,B,G	37,9	84	39			7,135	15	89,03	0,40
Felgyő	A,G	40,11	84	33			8,56	17,1	115,03	0,43
Hódmezővásárhely	D,A,I,B,G	76,11	80	48			10,19	39,2	165,46	0,51
Kistelek	D,A,B,G	22,57	72,00	36,00			3,39	10,50	49,86	0,47
Makó	D,A,B,G	47,87	85,00	40,00			9,01	21,50	127,61	0,45
Szarvas	G,D,A,F,B	43,50	92,00	30,00			11,28	20,20	165,19	0,46
Szeged	D,A,B,I,G	116,30	72,00	34,00			18,49	41,50	208,01	0,36
Szegvár	G,D,A,B,I	113,00	86,00	35,00			24,21	39,60	266,39	0,35
Szentes (all)	G,D,A,B,I	285,90	85,00	35,00			59,81	136,10	897,58	0,48
Others	A,B,G,I,D,F	5028,00	54,00	36,00			475,00	1921,00	4560,84	0,30
TOTAL		5877,83	78,09	36,45			635,43	2292,70	6767,66	0,42

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2009

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

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

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

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

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

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

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Budapest and the countyside	15	10	4000	V	4	4800	946	118
TOTAL	15	10	0 4000	0	4	4800	518	118

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

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

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

[3)] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3)]
Individual Space Heating[4)]	23,7	232	0,31041
District Heating [4)]	94,9	930	0,310751
Air Conditioning (Cooling)	0		
Greenhouse Heating	196	2388	0,386344
Fish Farming	4	44	0,34881
Animal Farming	2	17	0,269535
Agricultural Drying[5)]	10	123	0,390033
Industrial Process Heat[6)]	12	159	0,420158
Snow Melting	0		
Bathing and Swimming[7)]	272	5356	0,624407
Other Uses (specify)	0		
Subtotal	614,6	9249	0,477198
Geothermal Heat Pumps	40	518	0,410645
TOTAL	654,6	9767	0,473131
Average			0,443921

[4)] Other than heat pumps
[5)] Includes drying or dehydration of grains, fruits and vegetables
[6)] Excludes agricultural drying and dehydration
[7)] Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2005 TO DECEMBER 31, 2009 (excluding heat pump wells)

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

Purpose	Wellhead Temperature	Number of Wells Drilled: Electric Power	Direct Use	Combined	Other (specify)	Total Depth (km)
Exploration[1)]	(all)		12			12,5
Production	>150°C					
	150-100° C		2			6,18
	<100°C		12			21,20
Injection	(all)		3			5,80
Total		0	29			45,68

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

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

Year	Professional Person-Years of Effort (1)	(2)	(3)	(4)	(5)	(6)
2005	4	12	5	3	0	22
2006	3	13	5	2	0	24
2007	4	15	6	1	0	23
2008	4	16	6	2	0	25
2009	3	18	7	3	0	28
Total	18	74	29	11	0	122

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization: Direct Million US$	Utilization: Electrical Million US$	Funding Type: Private %	Funding Type: Public %
1995-1999	0,25	0,1	0,15	0	40	60
2000-2004	0,30,	0,15	0,21	0	80	20
2005-2009	3,7	2,8	4	0	90	10