Geothermal Resources in Hungary

by Liz Battocletti,
Bob Lawrence & Associates, Inc.

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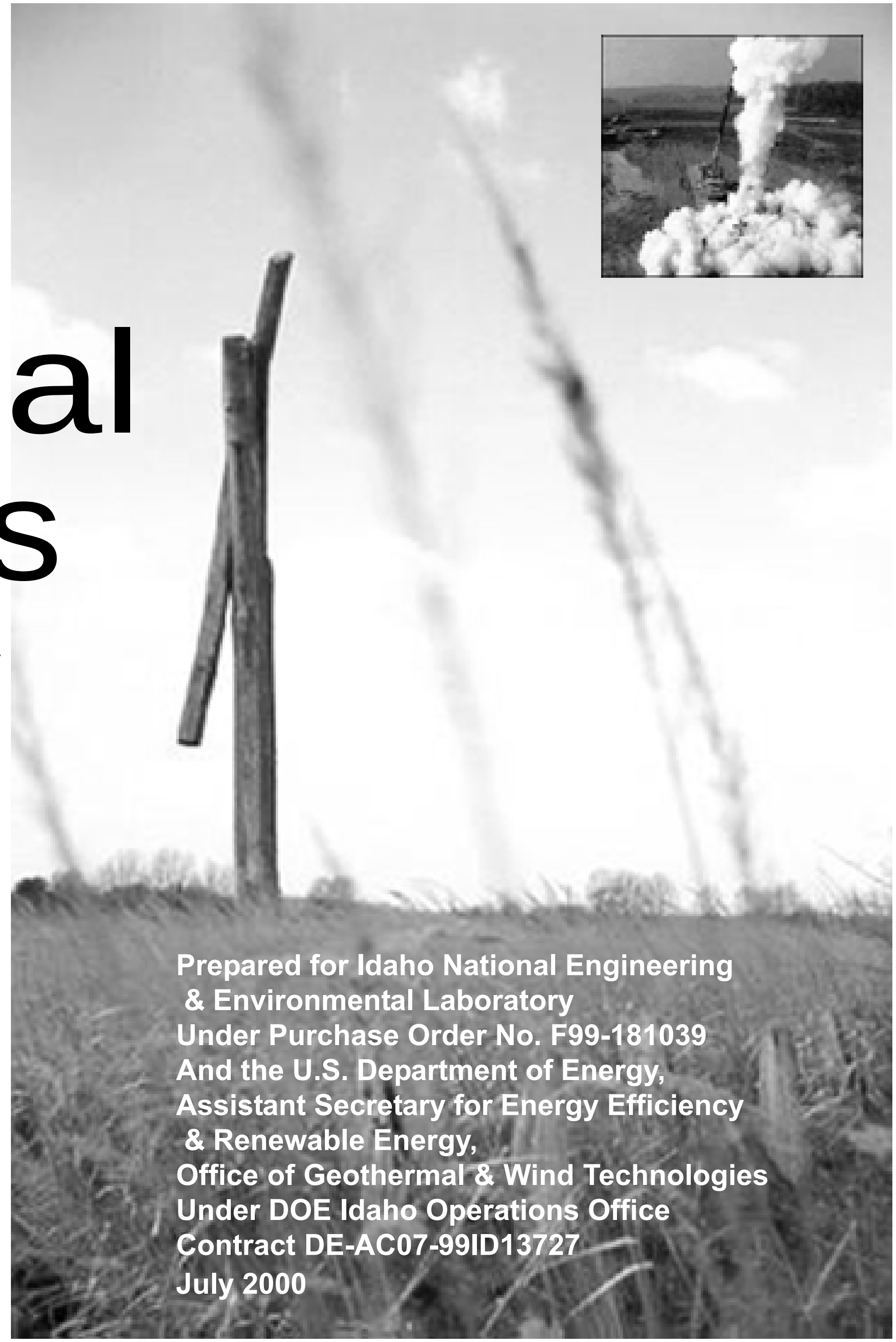

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Disclaimer

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Introduction

The **Database of Geothermal Resources in Hungary** contains information on 74 specific geothermal sites or projects. It was compiled using information collected in an extensive data and Internet search which accessed technical literature dating back to 1972 as well as numerous other U.S. and Hungarian sources.

Resource temperatures range from a low of 10ºC at Héviz to a high of 254ºC at Fábiánsebestyén (the bottomhole SiO_2 temperature of Fábiánsebestyén-4). Hungary has seven sites with a temperature of at least 100ºC as follows:

PROJECT NAME	TEMPERATURE (ºC)
Szentes	72-143
Szarvas	82-154
Álmosd	93-143
Mélykút-Pusztamérges	108-110
Oros	142-167
Nagyszénás-Fábiánsebestyén	150-254
Algyõ	156

For immediate dissemination to the industry, the report has been converted to a PDF file.[1]

The Database includes:

- Power Profile - basic information on Hungary, e.g., population, GDP, installed capacity, electricity prices, etc.;
- Power Summary - description of Hungary's power sector and privatization efforts;
- Government / Legislation - relevant Hungarian government agencies and laws; and
- Geothermal Sites / Projects - includes a Site Summary for each:

  1. Name
  2. Location
  3. Status

[1] PDF files can be read and printed using the free Adobe® Acrobat® Reader which can be downloaded at http://www.adobe.com/products/acrobat/readstep.html.

4. Temperature
5. Installed Capacity (MWe/MWt)
6. Potential (MWe/MWt)
7. Chronology
8. Notes

Dynamic Database

The Database was designed to be dynamic. Created using Microsoft® Access 2000, it can be easily updated or modified to include specific data which the industry would find most useful. In addition, the Database can be made more comprehensive by adding pertinent data, e.g., local population and market data, location of transmission lines and roads, etc., using the Geographic Information System (GIS), to the present structure. Finally, the Database could be adapted for posting on the World Wide Web and searched using a variety of variables such as country, desired temperature of resource, estimated power potential, and other parameters.

The **Database of Geothermal Resources in Hungary** was compiled and built by Liz Battocletti of Bob Lawrence & Associates, Inc. for Bechtel BWXT Idaho, L.L.C. (BBWI) under Purchase Order Number F99-181039, "Collection and Assembly of Published Data on Geothermal Potential."

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Special appreciation goes to Miklós Árpási, president of the Hungarian Geothermal Association; Ferenc J. Horváth, Acting CEO, Hungarian Energy Office; Sándor Geszti, Commercial Specialist for the U.S. Commercial Service, U.S. Embassy Budapest; and Paul Teleki, consultant to the World Bank.

Cover photographs are provided courtesy of Péter Csonka, "Gémeskút" (a well in Örség)[2], and the Hungarian Geothermal Association, "Gozkiaramlas."[3]

[2] Web site: http://www.uta.fi/~lopecs/photos/hungary/hungary.html.

[3] Web site: http://www.deltasoft.hu/mgte/indexa.htm.

Hungary

Hungary

Power Profile

Population (millions) - July 1999 estimated	10.19
Overall Electrification (% of population)	99%
GDP (billion US$) - 1998 estimated	$75.4
Real GDP Growth Rate - 1998 estimated	5.0%
Inflation Rate (CPI) - 1998 estimated	14.0%
Total Installed Capacity (MWe) - January 2000	7,903
Electricity Consumption per Capita (kWh) - 1999	3,303
Energy Demand Growth Rate	1.6%
Prices (US¢/kWh) -January 2000	
Average producers price	0.031
Average wholesale price	0.034
Average end-user price [a)]	0.053
Average residential tariff	0.060
Average non-residential tariff [b)]	0.051
[a)] Including supplementary fees	
[b)] Excluding supplementary fees	
Source: Hungarian Energy Office	

Geothermal Power Potential (MWe)	72

Power Summary

Located in the heart of Europe, the Republic of Hungary ("Hungary"), is strategically located astride main land routes between Western Europe and the Balkan Peninsula, and the Ukrainian and Mediterranean basins. Landlocked, it shares borders with Ukraine and Romania to the east, Slovenia and Austria to the west, the Slovak Republic to the north, and Croatia and Yugoslavia (Serbia) to the south.

Following the fall of the Berlin Wall in 1989 and the break-up of the Soviet Union in 1991, Hungary has developed increasingly close political and economic ties to the West.[4]

[4] Hungary's first free multi-party election was held in March 1990 after a peaceful transition in which the Hungarian Socialist Workers Party (as the Communist Party was then called) voluntarily abdicated its monopoly of political power, once Gorbachev let it be understood that the Soviet Union would not interfere. The election initiated the restoration of the country's market economy and West-European orientation (http://www.users.zetnet.co.uk/spalffy/h_hist.htm#c

Hungary joined the Organisation for Economic Cooperation and Development (OECD) in May 1996, became a member of the OECD's International Energy Agency (IEA) in 1997, joined the North Atlantic Treaty Organization (NATO) in March 1999, and is a founding member of the World Trade Organization.

In 1994, Hungary became the first former communist country to apply for full membership in the European Union (EU), and is on the accession fast track. While the country's exact accession date is uncertain, it most likely will be in 2003-2004.

Admission to the EU is a key driver behind the Government of Hungary's (GOH) 1999 National Energy Strategy, and affects the country's power generation system in two basic respects: compatibility in the field of environmental protection and compatibility of technical standards.

Air pollution is the most significant environmental issue facing the energy sector. Approximately 44% of the Hungarian population lives in areas that do not comply with national air quality standards. A significant contributor to air pollution is the abundant use of high sulfur, low calorific value, domestic coal and lignite, which are major source of sulfur dioxide (SO_2). Until the early 1980s, vast quantities of soot were poured into the atmosphere, but this was reduced by two-thirds as a result of extensive filter installations.

Hungary has signed a number of international agreements and accords on the environment, including the United Nation's Framework Convention on Climate Change, EU, and other agreements to control trans-boundary emissions. Under these agreements, Hungary must reduce its CO_2 emissions by 4 million metric tons per year (Bobok et al., 1998).

Presently, Hungary depends on traditional, non-renewable sources of energy for nearly all of its electrical power needs. All power plants are either fossil fuel or nuclear, with the exception of three small hydroelectric plants on the Tisza River in eastern Hungary. In addition to electric power generation, almost all Hungarian public power plants also supply heat, providing two-thirds of total heat demand of Hungary's district heating and industrial use needs.

As of January 2000, Hungary had an installed capacity of 7,903 MWe (up from 7,845 MWe in 1999). Approximately 7,300 MWe is generated by public power plants; the remainder by industrial power plants. Oil and gas accounted for 48% of total installed capacity, coal for 25%, nuclear for 24%, autoproducers for 2%, and hydro for a scant 1%.

The GOH privatized most of its generation capacity and local power distribution in the 1990s. A former

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monopoly, the state-owned Hungarian Power Companies, Ltd. (MVM Rt.) is responsible for the export, import, wholesale, high voltage transmission, and dispatching of electricity generated by independent power plants and the state-owned Paks Nuclear Power Plant. In the oil and gas sector, the 25% state-owned Hungarian Oil and Gas Company (MOL) has a monopoly on gas and oil exploration, transmission, stockpiling, and wholesale trade.

Nuclear power, produced by the Paks Nuclear Power Plant in southwestern Hungary, generates 40% of the country's electricity.[5] Paks has four Soviet- designed vver-440/213 pressurized light-water reactors which were put into operation between 1982 and 1987 and are designed to operate for 30 years. Currently, Paks is looking into a program that could extend the reactors' service life by 10 years. Paks is state-owned and operated.

The remaining 60% of Hungary's electricity is produced by coal, oil, or gas-fired power plants.

Renewable energy resources currently supply only 3.6% of Hungary's primary energy needs (which includes district heat and hot water) in contrast with a world average of 11%. Among renewable energy resources, the geothermal and wind energy sectors' potential are considered the highest (Geszti, 2000)

Following EU directives, the country's share of renewable energy must be increased to 12% by 2010. Hungary is first concentrating, however, on modifying and upgrading existing technologies; either making them clean enough to meet EU standards or replacing them with cleaner, existing energy technologies. With the exception of one coal-fired plant in northern Hungary, all coal plants will be converted to gas or shut down.[6]

Natural gas reserves are about 3.4 trillion cubic feet (TCF). In 1997, natural gas production was 155 billion cubic feet (BCF). To meet the domestic demand of approximately 431 BCF, Hungary imports 85% of its natural gas from the Russian Gazprom consortium. The bulk of the natural gas in Hungary is typically piped straight into homes and businesses for heating. It is estimated that natural gas production in 2010 will decline approximately 30% from 1997 levels, while natural gas demand is expected to increase by approximately 20%. Natural gas prices increased by 12% on 1 July 2000.

5 EU safety experts have indicated that Paks is as safe as western nuclear power plants and will comply with EU standards by 2002. Paks has had an excellent safety record and has been ranked in the top 10% of reactors worldwide.

6 It is estimated that converting a 200 MWe coal to gas turbines takes two years at a cost of $60-$80 million for the equipment (U.S. Department of Energy, Office of Fossil Energy).

Hungary's energy intensity (the energy needed to produce US$1 GDP) is three times that of Japan and four times the EU average. The high energy-to-income ratio and 50% import dependence make the country vulnerable to any energy price shocks.   Restructuring the product mix, increasing the share of high added value items in industrial production, and increasing the share of the service sector may improve Hungary's energy intensity indicator (Jászay, 1997).

Energy consumption in Hungary peaked in the late 1980s, at 30 Mtoe/year, almost equal to the per capita demand of Japan. After several years of decline, electricity consumption increased in 1995, by 2.5%, but this trend is very modest.

According to an MVM Rt. forecast based on micro-economic studies for the period 1996-2010, the average gross electricity demand will increase by 1.6% annually in the next 15 years. Forecasted gross electricity consumption rates by 2015 range from 45 to 50 TWh.

Hungary's power stations have 38.5% excess capacity (Ministry of Economic Affairs). The average age of power generation equipment and installations in Hungary is over 20 years. One-third of the present generating capacity will be replaced in the next 10-15 years at a total cost of $5 billion (U.S. Department of Commerce, 1999). Most of the currently tendered projects will come on-line between 2002 and 2006; 12 projects totaling 1,696 MWe are underway, mostly to replace retired units.

Hungary and the United States have close economic and political ties. The U.S. is Hungary's fifth largest trade partner with more than $1 billion in U.S. exports annually.

U.S. products are considered to be of high quality, but expensive. The main competitors to U.S. companies are European, especially German suppliers, which often offer better prices, credit, and financing terms. Once Hungary enters the EU, all power generating equipment imported from EU countries will enter Hungary duty free; U.S. exports will face an average of 5-10% duty (Geszti, 1996).

The U.S. Government has many programs designed to promote the development of Hungary as a market for U.S. goods and services.

Last December, the U.S. Department of Commerce led a power generation trade mission to Hungary, Poland, and the Czech Republic. A follow-up clean energy trade mission, was planned for the same three countries 28 September-5 October 2000. Due to unforseen circumstances involving return on investment for electric power in Hungary, however, the mission was limited to Poland and the Czech Republic.[7]

The Export Import Bank of the United States (Ex-Im Bank) and Overseas Private Investment Corporation (OPIC) offer financing and insurance in Hungary. As in other European countries, the "Build, Operate, Own and Transfer" (BOOT) financing structure is accepted. Also, the U.S. Trade and Development Agency (TDA) can provide feasibility study grants for potential renewable energy projects.

Economic prosperity has not reached areas in Eastern Hungary. The U.S.-Eastern Hungary Partnership is intended to draw the attention of U.S. companies and entrepreneurs to Eastern Hungary's skilled workforce, attractive manufacturing sites, and proximity to neighboring countries. Offices are open in Debrecen, Nyiregyhaza, and Miskolc to coordinate the effort.

Under the South-East Europe Reconstruction Credit Initiative signed in May 2000, Ex-Im Bank and the Hungarian Export-Import Bank are working together to provide low-cost financing to U.S., Hungarian, and Southern European businesses. The agreement specifically targets efforts to promote environmentally beneficial projects and financing for small and medium-sized businesses.

Under the terms of the Credit Initiative, the banks will work together to identify projects for joint support. Financing enhancements under the program include:

- The maximum allowable OECD repayment terms,
- Capitalization of interest during construction, and
- Local cost coverage equal to 15% of the U.S. contract price.

Another USG program is EcoLinks. Funded by the U.S. Agency for International Development (USAID), EcoLinks seeks practical, market-based solutions to industrial and urban environmental problems in Central and Eastern Europe and the New Independent States (CEE/NIS) by promoting partnerships and issuing grants.

EcoLinks Partnership Grants are competitively awarded, cost-sharing grants which support both short-term and long-term partnerships among businesses, local governments and associations to solve urban and industrial environmental problems in CEE/NIS. The grants must be jointly managed by partners from the US and CEE/NIS, or within the CEE/NIS itself.

7 The Hungarian Government decided to maximize the wholesale price increase of natural gas and electricity in order to keep inflation down. This decision goes against current energy legislation which guarantees an 8% return on invested assets to foreign investors in the sector (Andrew Collier, U.S. Department of Commerce).

Challenge Grants of up to $50,000 support one-year partnership projects or activities that address specific urban and industrial environmental problems. Twinning Grants of up to $250,000 support two-year cooperative projects that address environmental problems and also lead to lasting partnerships. These grants will be introduced at the end of 2000.

In addition to the grants, EcoLinks also offers Quick Response Awards (QRAs) of up to $5,000. QRAs are designed to meet the immediate and small-scale needs of organizations exploring potential partnerships within the framework of EcoLinks. Activities must either facilitate the matchmaking of potential partners or promote environmental trade and investment.

Finally, Hungary is a member of the European Bank for Reconstruction and Development (EBRD). The GOH no longer requires financial assistance from the International Monetary Fund (IMF), and has repaid its IMF debt. Hungary's borrowing from the World Bank has been conservative, primarily to support the country's pension and higher education reform projects.

Government / Legislation

Hungary has a well-developed and partially privatized energy system, and an energy policy which is focused on achieving EU accession. The previously centrally controlled, vertically integrated electricity sector has been reorganized into a three-tier structure with generation, transmission, and distribution activities separate.

From 1963-1991, electric power generation in Hungary was controlled by the State through the monopolistic MVM Rt. which directed all activities related to the generation, wholesale and retail trade, transmission, and distribution of electricity.

In 1992, MVM Rt. was reorganized into a two-tier company structure. The upper tier, which remained MVM Rt, manages all electricity trade, and owns and operates the high voltage transmission grid and dispatching center. It purchases power from electricity generating companies and sells it to smaller distribution companies.

The second tier of the utility system includes eight generating companies, six regional distribution companies; and the National Power Line Company Ltd. ("Országos Villamostávvezeték Rt." [OVIT]). With the exception of the Paks Nuclear Power Plant and OVIT, which remain majority-owned by MVM Rt., generating and distribution companies have been privatized.

Adopted by the Hungarian National Assembly in 1993, the primary objectives of the country's energy policy are to:

- develop diverse energy supplies and eliminate dependency on imports from the former Soviet Union,

- improve environmental protection,
- increase energy efficiency through modernization of supply structures and better management of electricity consumption, and
- attract foreign capital for investment in capital-intensive energy projects.

The policy also provides for the gradual contraction of the coal mining industry by merging coal mines that supply coal to power companies.[8]

The next step in Hungry's restructuring of the electricity sector is the establishment of a free market-based energy system which will:

- increase the choice of suppliers;
- intensify competition for consumers;
- relieve the present system's upward pressure on prices, and in the long run to achieve a reduction of the prices and thus enhance the competitiveness of the economy;

[8] The Hungarian coal industry has opposed the GOH's plan to phase out coal power plants. In December 1999, over 2,000 coal miners gathered in Budapest to protest the plan.

- enhance the security of supply through the connection to the single European energy market;
- reduce suppliers' and service providers' present monopolies to the level of natural/technical monopolies; and
- introduce free market trading, based on business considerations, in energy without any governmental guarantees.

Beginning 1 January 2001, an experimental market opening of about 10% will be introduced in Hungary's domestic electricity market. Opening up the market will allow eligible consumers to choose their supplier, i.e. they will be able to purchase electric energy or natural gas directly from any producer or trader.[9] Liberalization of import and export rights is planned to take place simultaneously with the country's accession to the EU.

Also on 1 January 2001, the National Transmission Line Company ("Nemzeti Távvezeték Társaság"), incorporating the present transmission network and OVIT, will be established.

[9] Hungary's gas industry, due to its significant dependence on imports and the rapid increase of gas consumption, will only be fully opened up to market forces at the time of accession to the EU.

Lastly, an Independent System Operator (ISO) will be created by merging the National Load Distribution Center and the Regional Dispatching Services into a non-profit company under the direction of the Ministry of Economic Affairs. The ISO will exercise technical control of the electrical power system. The legal status, financing, and asset ownership of this organization remain to be clarified.

Currently, the Ministry of Economic Affairs (GM), the Hungarian Energy Office (MEH), and the Hungarian Power Companies, Ltd. (MVM Rt.) are the key organizations responsible for the planning and development of electric power projects in Hungary.

Brief descriptions are also included on the Ministry of Agriculture and Food, the Hungarian Oil and Gas Company (MOL Rt.), the Investment and Trade Development Agency (ITDH), and the Water Resources Research Center (VITUKI).

A brief listing of the relevant legislation and regulations regarding Hungary's electric sector in general and geothermal resource development in particular is also included in the following section.

<u>Ministry of Economic Affairs (Magyar Köztársaság Gazdasági Minisztériuma [GM])</u>

The Ministry of Economic Affairs oversees the Hungarian Energy Office, which was established by the Electricity Act of 1994 to regulate Hungary's energy market. The Ministry has full control over electricity and gas prices and determines the least quantity of the types of energy to be stockpiled by power plants with an installed capacity of 50 MWe or more.

The first stop for a foreign investor in renewable energy is the GM's Energy Affairs Department which is in charge of energy policy and can give a broad overview of the development of the sector (Geszti, 2000).

GM Decree 74/1999 outlines "Purchase Obligation Regarding Electricity Produced with Geothermal Energy."

<u>Hungarian Energy Office ("Magyar Energia Hivatal" [MEH])</u>

The Hungarian Energy Office is responsible for licensing electric production, transport, and supply facilities; satisfying customer demands; and ensuring standards of service. MEH is in charge of permits for all power projects over 50 MWe. Application for preliminary licensing may be submitted exclusively on the basis of a feasibility study. Public power plants with an installed capacity of 20 MWe or less do not require operating licenses.

The Energy Office develops the detailed rules of price setting and price application. Prices are determined and promulgated by decree by the Minister of Economic Affairs. The Energy Office reviews the price level and the price upon the request of any concerned party and publishes the results of the procedure.[10] The price of steam sold by an electric plant not generating electricity committed for public utility purposes is set by representatives of the relevant municipality rather than the MEH.

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Hungarian Power Companies, Ltd. ("Magyar Villamos Müvek Reszvenytarsag" [MVM Rt.])

It is MVM Rt.'s responsibility to ensure the optimal utilization of power plants and the national grid at the least cost. Electric utilities are allowed to buy power directly from power generators but only with the approval of the Hungarian Energy Office and notification of MVM Rt.
Because MVM Rt. buys electricity from generating companies at different prices that reflect generating costs, the low-cost nuclear power generated at the Paks Power Station subsidizes most other generating plants (U.S. Department of Energy, Office of Fossil Energy, 2000).

Equipment vendors can obtain information about the status of projects and contact potential investors through MVM Rt.

Ministry of Agriculture and Food

The Ministry of Agriculture and Food is responsible for the agricultural utilization of geothermal resources. In addition, the Ministry of Agriculture plans to dedicate a $2 million fund from the central budget to subsidize new renewable energy projects. This subsidy system, considered meager by some Hungarian experts, aims to help fund projects in the coming years by way of preferential loans (Geszti, 2000).

[10] During the period of centralized planning, Hungary's energy prices were controlled and relatively very low. The consumer price of electricity in Hungary is still much lower than the European and global average, between ⅓ and ½ of the prices in EU countries. According to the Ministry of Economic Affairs, Hungary's energy prices will be roughly equivalent to those in Germany by 2005.

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Hungarian Oil and Gas Company (MOL Rt.)

MOL Rt. manages the exploration, production, and utilization of hydrocarbons in Hungary, and is one of the most aggressive and competitive firms in the country's energy sector. Although its monopoly is being challenged by new foreign-owned energy firms, MOL still handles 66% of all energy resources used in Hungary. After MOL's privatization in 1995, the company positioned itself to remain Hungary's main petroleum supplier, and maintains all the country's oil and natural gas pipelines. In addition to dominating the retail fuel market, MOL supplies all gas- and oil-fired power generators in Hungary.

MOL's Geothermy Project (1995-1999) was created to determine whether the company's more than 2,000 abandoned oil and gas wells are suitable for thermal water production and reinjection. MOL completed pre-feasibility studies for three pilot geothermal projects. (Additional information is included in the "Geothermal Sites / Projects" section of this report.)

Investment and Trade Development Agency (ITDH)

ITDH was established by the Ministry of Economic Affairs in 1993 to promote international economic relations and business endeavors which have a direct impact on the development of the Hungarian economy. ITDH's targeted investment programs currently focus on greenfield investments with special regard to electronics and software, automotive parts, and tourism.

The Hungarian government guarantees the repatriation of all profits in U.S. dollars.

Water Resources Research Center (VITUKI)

VITUKI (as a successor of the Hydrographic Department established in 1886) was founded in 1952 to perform basic and applied research and studies related to the development, conservation, and sound management of Hungary's water resources. Supported by hydraulic, hydromachinery, hydrochemical, hydrobiological, wastewater technological and soil mechanical laboratories, equipment, instrumentation, computer facilities and library, VITUKI has emerged as one of the most complex water-oriented full-service professional organizations of Europe, and is also engaged in the transformation of

Hungarian standards and directives related to the water sector to EU standards.

Electricity Act of 1994 (Act XLVIII of 1994) on the Production, Transport, and Supply of Electric Energy

Under the 1994 Electricity Act, power plants sell electricity to MVM Rt. under long-term contracts. MVM, with due regard to consumer demand and the necessary reserves, commissions the capacity of the power stations, thus paying them a capacity fee for fixed costs and profits. These capacity commissioning agreements do not make allowances for any cheaper generating capacity or cheaper energy that might emerge in the Hungarian or European markets during the long contract periods.

The Electricity Act of 1994 does not apply to power plants of less than 50 MWe which produce electricity exclusively for meeting their own demands.

Section 34 of the 1994 Electricity Act

Section 34 states that, "The establishment of the small power plant (less than 50 MWe) and of the direct line is not an activity subject to licensing. At least one year prior to the envisaged commissioning of the small power plant of a capacity of more than 1 MWe, the operator shall notify the Energy Office of the commissioning and, when connected to the cooperating electricity system, also the transmission licence holder, the regionally competent distribution licence holder and the system operator."

Section 43 of the 1994 Electricity Act

Section 43 states that, "Purchase of power generated by use of renewable energy, as well as power generated in designated power plants may not be refused if its transfer capacity exceeds 0.1 MWe, if the technical conditions in uploading are met, and if the price does not exceed the level determined by the pricing authority."

1999-2000 Draft Electricity Act

A new Electricity Act was drafted in 1999 to establish the legal framework for the country's new free market-based electricity model. Originally expected to be enacted in 1999, the draft bill was withdrawn for further modifications. It is scheduled to be considered by the National Assembly in the Fall 2000 session.

Act XVI of 1991 on Concessions

Under the Concession Act, the exploitation of natural wealth owned by the Hungarian State may be carried out as a concession. Concession bids are evaluated on an individual basis, and the best bidder receives the concession rights. Concession contracts may be concluded for up to 35 years. Although not regulated by the Act, any new geothermal project must include total water reinjection (Szita, 1995).

The Concession Act covers national regional public utility systems, the operation of local public utilities, and "mining research and exploitation, and related secondary mining activities."

Act LVII of 1995 on Water Management

The utilization of thermal water is regulated by the Water Authority through a permit. Any person may obtain a permit; thermal water wells can be privately owned. Oil and gas wells, however, are state-owned. The permits issued by the water authorities provide directions on how thermal wells are to be drilled and operated, including what depth-interval is permitted and waste water disposal. Well logging techniques are also regulated by law since all data must be comparable (Ottlik, 1988).

The Water Management Act does not include the utilization of geothermal water for energy generation purposes, and does not deal with the energy content of the geothermal fluids (Árpási and Szabó, 2000).

Environment Act of 1995

A part of the Hungarian legal reform program, a new Environment Act was passed in December 1995. The Act requires disassembling heavy polluting plants after a moratorium of eight years and making power generating companies responsible for providing environmental information to the public. From 1 January 2004, the new environmental regulations will also be applied to operating equipment. Until that date, however, only new projects have to adhere to the new Act.

Geothermal Law

Hungary has no geothermal law. The use of geothermal resources for power generation has no legal basis but rather a "legal, unregulated status" (Árpási and Szabó, 2000). The GOH discourages geothermal energy use through "triple taxation" which is imposed on users of geothermal energy (Árpási and Szabó, 2000).

Hungary's current legislation is unclear and contradictory regarding the development of the country's geothermal resources:

- The Water Management Act (Act LVII of 1995) does not include the utilization of thermal waters to produce energy, or deal with the energy content of thermal waters in any way.

- The Mining Code (Act XII of 1997) excludes the exploration and production of subsurface waters which carry geothermal energy.

- The Mining Code (Act XII of 1997) contradicts the Concession Act (Act XVI of 1991) stating that a mining concession tender cannot be issued for the exploration of geothermal energy and its production for power engineering purposes if the project also involves the production of thermal water.

- The amendment comprising Act XII of 1997 of Act XLVIII of 1993 (Mining Code) is totally irrelevant from the point of view of developing geothermal resources for energy production.

The expedient enactment of an independent Geothermal Act which provides the legal basis for utilizing geothermal resources for energy, protects water reserves, and does not pollute the environment is urgently required. Additionally, the Concession Act should be modified to include the development of geothermal resources (Árpási and Szabó, 2000).

Finally, current electricity prices serve as limiting factors in the further development of geothermal power plants. Government subsidies are needed to promote the development of geothermal resources for power generation. Since the apparent cost of electricity from renewable energy sources lies somewhere between two to five times more than base load coal-generated power, the GOH's goal of increasing the share of renewables will require significant subsidies. Currently, renewable power costs 50% more than the average wholesale price of electricity. Further development of the renewable energy market depends on pricing and subsidies provided by the central government or local municipalities. This is not unprecedented in Western Europe, where a certain share of the power sold by distributors has to be "green" power by law (Geszti, 2000).

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Hungary
International boundary
County (megye) boundary
National capital
County (megye) capital
Railroad
Expressway
Road
Kaposvár City with county status (megyei város)
Pest County is administered from Budapest. Budapest has county status.
0 25 50 Kilometers
0 25 50 Miles
Lambert Conformal Conic Projection, SP 49N/56N
CZECH REPUBLIC
SLOVAKIA
UKRAINE
AUSTRIA
ROMANIA
SLOVENIA
CROATIA
BOSNIA AND HERZEGOVINA
Serbia
Vojvodina (autonomous province)
Pol.
Budapest
Vienna
Bratislava
Zagreb
Belgrade
Miskolc
Debrecen
Szeged
Pécs
Győr
Kecskemét
Szolnok
Danube
Balaton
Tisza
Base 802212 (R01145) 11-94

Source: Zentai László, http://lazarus.elte.hu/gb/maps/moteljes.htm

Geothermal Sites / Projects

For the most part, Central Europe has only low-enthalpy geothermal resources. Hungary, however, due to its unique geological position astride the Pannonian Basin, a "geothermal hot spot," is the exception to the rule.[11] While all of the country's geothermal resources developed to date are low- and medium-enthalpy[12], a few high-enthalpy resources have been discovered. As yet, they remain undeveloped.

Encircled by the Alps, the Carpathians, and the Dinarides, the Pannonian Basin extends across nearly all of Hungary and beyond to the Czech Republic, Slovakia, Austria, Romania, Croatia, and Yugoslavia (Serbia). The earth's crust in this region, and particularly under Hungarian territory, is thinner than average (~25 km) due to sub-crustal erosion.[13]

As a result of the earth's thin crust, Hungary's geothermal gradient (increase in temperature per unit increase in depth) is higher than the world average, and reaches as high as 58.9ºC in some spots.[14] In places where such high gradients are present, so-called abnormal or geopressured reservoir conditions exist (Spencer et al., 1994) accompanied by high-temperature steam/water phase brines, analogous to occurrences in the Gulf of Mexico (Dövényi and Horváth, 1988; Árpási and Szabó, 1999).

The main source of the geothermal energy in Hungary is the conductive heat flow which passes from magma through the sediments to the surface. The average ground heat flow directed out from the earth's interior ranges from 80-100 mW/m^2; two times higher than the continental average. Stratum temperature at a depth of 1,000 m reaches and exceeds 60ºC (Andristyák et al., 1995; Árpási, 1995).

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11 There is no volcanic activity in Hungary; the country is not part of a geothermally anomalous zone of volcanic origin. The most recent volcanic activity in the Carpathian basin ended in the late Pliocene and early Pleistocene (Korim, 1972).

12 Hungary has the largest underground thermal water reserves and geothermal energy potential of low- and medium-enthalpy in Europe (Boldizsár, 1967; Bobok, 1988).

13 The thin crust has sunken isostatically, forming a basin which is filled primarily by tertiary sediments. Pannonian sediments are multilayered and composed of sand, shale, and silt beds. Lower Pannonian sediments are impermeable; the upper Pannonian and Quaternary formations contain vast porous, permeable sand and sandstone beds formed by the upper Pannonian aquifer — the most important thermal water resource in Hungary (Bobok et al., 1998).

14 The average geothermal gradient is 0.042-0.066ºC/m in Hungary compared to 0.020-0.033ºC/m on the earth in general (Andristyák et al., 1995; Árpási, 1995).

Two primary types of thermal water reservoirs exist in Hungary: the Pannonian and the Triassic.

The Pannonian Basin's largest thermal water resources are located in the sand and sandstone formations of the Pliocene age. The individual sandy layers of the upper Pannonian Basin have thicknesses of 1-30 m. Their horizontal extension is not too large, but the sand lenses are interconnected and form an hydraulically unified system. This upper part of the 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 Pannonian hot water reservoir has an almost uniform hydrostatic pressure distribution; local recharge or discharge slightly modifies this pattern. The lower Pannonian strata mainly include marls, clay marls, and relatively solid sandstones. Their porosity and permeability are relatively low. The upper Pannonian strata consist of sandstone-clay marl groups with high porosity (20-30%) and significant permeability . About 80% of the country's geothermal wells produce from the upper Pannonian reservoir system (Horváth, 1986; Bobok et al., 1998).

The flow rate of the thermal water wells producing from Upper Pannonian aquifers ranges from a few hundred to 3,000 l/min. Temperature of the water at the wellhead reaches 100ºC. The majority of thermal waters are usually of good quality and of a relatively low concentration. The average value of the total dissolved solids within the main thermal water horizon is about 1,500-2,500 ppm. The chloride ion content is very low, generally less than 100 ppm. These waters represent an alkaline-bicarbonate type (Korim, 1972).

The geothermal energy reserves of the Upper Pannonian reservoir are estimated to be 1,835.1 KJ (Bobok et al., 1984).

Upper Pannonian formations occur in 40-50% of the country's territory, but are covered by younger formations, consequently, the thermal water reserves in them are only accessible by deep drilling. Unlike the Triassic carbonate thermal water reservoir, most of the upper Pannonian thermal water reserves are non-renewing.

The Triassic age geothermal reservoir is composed of carbonate rocks consisting of fractured, cavernous, partly karstic carbonate rocks located in the area of the Central Transdanubian Mountains, covering approximately 13,000 km^2, or 14% of Hungary's territory. About 20% of the country's geothermal wells produce from this type of carbonate rock formation.

Under natural conditions, rainwater infiltrated into the reservoir and partially exited to the surface through springs and marshes. (Such hot water springs supply hot water to Lake Héviz and Lake Harkány.) The dynamic equilibrium was changed by human intervention through water supply and mining activities (Horváth, 1986; Bobok et al., 1998).

The salt content of thermal waters varies from place to place; on average it is 3,000 mg/l (Horváth, 1986). The chemical composition of the thermal waters coming from aquifers of Pannonian age is mainly of the alkaline-carbonate type; these waters also contain methane and carbon dioxide. Salt content is on average 3,000-5,000 mg l-1; gas content varies over a wide range. Due to the methane, explosions have occurred on several occasions (Ottlik, 1988).

The only recharge to aquifers near the surface is the infiltration of precipitation. Hungary averages 400-800 mm/year of precipitation, a low amount. With few exceptions, reinjection has not been used in Hungary due to high investment costs (Ottlik, 1990).

Hungary has five primary geothermal regions:

1. the Great Hungarian Plain,
2. the Little Hungarian Plain,
3. the Mountainous Border,
4. the South Transdanubia, and
5. the Basement.

Thermal water temperature is defined by the local value of the geothermal gradient. The mean values are as follows:

50ºC/km	in the greatest part of the Great Hungarian Plain;
45ºC/km	in the southern part of the Great Hungarian Plain (partly convectionally cooled area);
55-60ºC/km	in the eastern part of the Great Hungarian Plain;
40ºC/km	in the Little Hungarian Plain; and
50-60ºC/km	in most parts of the Transdanubia.

There are some local anomalies within the above mentioned regions (Ferenc and Liebe, 1985).

Measured temperatures are highest in the Great Hungarian Plain (30-100ºC) and Basement (30-100ºC). The highest surface temperature thermal water measured in Hungary is 97ºC. The highest temperature measured in geothermal brine from a geopressured reservoir is 171ºC (at Nagyszénás-Fábiánsebestyén). The highest aquifer temperature registered is 140ºC. The highest geopressured reservoir temperature is 220ºC (Árpási, 1995).

Geopressured reservoirs have been found in the basement of the Great Hungarian Plain. These systems are characterized by high reservoir pressures and temperatures, as well as the presence of dissolved natural gas (3-12 grams per liter in the liquid phase).

Geothermal surface manifestations across Hungary have been known since ancient times. Thermal springs in Budapest were used during the Roman Empire and later in medieval times. Legendary drilling engineer, V. Zsigmondy, drilled Europe's then-deepest well (971 m) in Budapest in 1877.

In the early 1900s, interest in geothermal exploration waned. Between the two World Wars, in the process of looking for oil and gas, huge thermal water reservoirs were discovered. The majority of Hungary's more than 10,000 drill holes have been drilled since the 1930s, primarily as exploration wells for oil and gas. After World War II, geothermal development, primarily for space heating, became a national priority and resulted in the installation of several district heating and water systems.

In the 1950s and '60s, hundreds of geothermal wells were drilled, primarily for agricultural use. Tibor Boldizsár constructed the first regional heat flow map of Hungary in the late 1950s, and conducted the first geothermal resource assessment of Hungary in 1978.[15]

[15] The extractable amount of energy was determined by the volume method. Thermal energy stored in the upper three kilometers of the Pannonian Basin was obtained by Boldizsár to be equal to 5.5 x 10 KJ (Bobok et al., 1984).

During this time, the GOH supported the development of geothermal energy under the National Energy Program. Geothermal activity's peak occurred in the late '70s when 525 new geothermal wells were registered; the best 30 had temperatures of over 90ºC.

In the 1980s, two problems emerged: decreasing yields in wells, many which had been used without reinjection for over 20 years, and scaling which damaged equipment and required expensive maintenance (Szita, 1995).

Most Hungarian geothermal waters are subject to scaling; only a few cases of corrosive water occur. Scaling arises from the CO_2 equilibrium being through free and dissolved gases including CO_2, coming to the surface. Since the mid 1980s, chemical water treatment has been used to prevent scaling.

Since 1990, however, as Hungary moved away from communism and a centrally-controlled economy, and towards a free-market economy, the GOH has ceased all support to geothermal development. The last state-funded geothermal project, a space heating project covering 4,000 dwellings, was completed in 1987 (Szita, 1995).

The water fee to use geothermal water has increased substantially, becoming a significant operating cost. Proliferation of water and energy saving operations will be one of the most important challenges of the near future in Hungary. Interest-free subsidies, low interest long-term credits, or subsidies for experimental and R&D projects (e.g., reinjection) are needed (Szita, 1995).

Although no comprehensive estimates are available for the total economically exploitable geothermal resources in Hungary, it is tentatively estimated that some 10-12% of the heating needs of Hungary's urban population could economically be met with geothermal energy (Jónatansson, 1993).

As for power generation, considering wells with an outflow temperature of 80ºC or more and non-productive hydrocarbon wells, the estimated power potential of Hungary's existing wells is 25-70 MWe (Andristyák et al., 1995; Árpási, 1995; Geszti, 2000).

Direct Use

The proportion of geothermal energy utilization in the energy balance of Hungary, despite the significant proven resources, is low (0.16%) (Árpási and Szabó, 2000).

The Romans used hot springs to supply baths and heat the associated buildings. The remains of these facilities can still be seen in Budapest, in the area of the Roman Aquincum town (Horváth, 1986). Balneological and therapeutic uses of the geothermal waters remain very popular in Hungary with world-renown spas located in Budapest, Bük, Debrecen, Gyula, Hajduszoboszló, Harkány, Héviz, and Zalakaros. As of 1 January 2000, Hungary used geothermal water for 61 medicinal baths, 350 public baths, and 1,200 swimming pools (Árpási and Szabó, 2000).

Developing additional hot springs resorts and spas to attract tourists is an important objective of Hungary's National Development Plan (Széchenyi Plan). Tourism is Hungary's second-largest industry, after agriculture, and accounts for 9% of GDP (Ministry of Economic Affairs).

Direct uses were mainly agricultural, e.g., greenhouses, poultry breeding farms, driers, etc., and primarily in the southeastern part of the country.

Agriculture had an installed capacity of 120.43 MWt; district heating, sanitary hot water (SHW), and industrial applications 58.7 MWt; and bathing and balneology 187.3 MWt for a total of 366.5 MWt as of 1 January 2000 (Árpási and Szabó, 2000).

Power Generation

Hungary has no geothermal power generation facilities. This is not due to a lack of suitable, high-enthalpy resources, however: the existence of high-enthalpy resources in Hungary was dramatically proven by a steam blow out from Fábiánsebestyén-4 in 1985-1986.

The best high-enthalpy geothermal area is the southeastern corner of Hungary, near the cities of Szeged, Szentes, and Hödmezõvásárhely. Wellhead temperatures in this area are 80-90ºC.

The mean temperature in the Pannonian Basin is estimated to be 165ºC at 3 km (Ottlik et al., 1981), indicating that electric generation temperatures may well be found at 4-5 km depths (Lawrence and Stoyanov, 1996).

The three most promising geothermal sites, in terms of power generation potential, and the subjects of the MOL Geothermy Project (1995-1999) are:

1. Andráshida-Nagylengye,
2. Mélykút, and
3. Nagyszénás-Fábiánsebestyén.

Following pre-feasibility studies, MOL concluded that Andráshida-Nagylengyel could produce 108,000 GJ of heat per year; Mélykút-Pusztamérges 234,700 GJ; and Nagyszénás-Fábiánsebestyén 1,312,410 GJ (Árpási, 1997; Árpási and Szabó, 1999). Mélykút-Pusztamérges, has an estimated power generation potential of 1-2 MWe.

Two small-scale, modular electric power generation plants using the Organic Rankine Cycle (ORC) with 100ºC water, were planned. In order to make the projects economically feasible, however, in addition to generating power, the resources would also be used for direct applications, e.g., district heating and greenhouses.

The capital cost of geothermal electric power generation (assuming binary power generation using the ORC) is $1,000-2,850/kW, depending on the temperature of the resource. The investment cost of a 140ºC resource is $1,348; of a 80ºC resource, $2,805/kW.[16] Electric power generation using geothermal resources is cheaper than imported power (Andristyák et al., 1995).

A preliminary analysis established that the electric power generation by ORC and other methods could produce 25 MWe; generate 215 GWh of power annually; save 500,000 tons of crude oil per year at a cost of $50 million a year; and offset the annual emissions of 810,000 tons of CO_2, 1,100 tons of NOx, and 3,500 tons of CO (Árpási, 1995).

Nagyszénás-Fábiánsebestyén, where MOL found extremely high-pressure hot steam instead of oil, has the strongest potential for a future 60-70 MWe geothermal power plant project. If the GOH were to guarantee a 50% higher than average subsidized wholesale purchase price for geothermal electricity, production would be feasible. Such an intervention is currently against the law, which states that MVM Rt. must always buy the lowest-cost power available from the generators and resell it to regional electricity distributors (Geszti, 2000).

The Database of Geothermal Resources contains data on 74 geothermal sites or projects which are listed in the table on the following page, and summarized below.

[16] For comparison's sake, lignite electric power plants stations cost US$1,600/kW; coal, US$1,300/kW; nuclear, power US$1,900/kW; and combined cycle gas, US$750/kW (Andristyák et al., 1995).

GEOTHERMAL SITES / PROJECTS IN HUNGARY

SITE / PROJECT NAME	COUNTY	STATUS	TEMP. (ºC)
Algyõ	Csongrád	Direct use -- developed	156
Álmosd	Hajdú-Bihar	Well(s) or hole(s) drilled	93-143
Andráshida-Nagylengyel ("AN Project")	Zala	Prefeasibility study	93
Apátfalva	Csongrád	Direct use -- developed	86
Békés	Békés	Direct use -- developed	N/A
Békésscsaba	Békés	Direct use -- developed	N/A
Buda	Pest	Direct use -- developed	N/A
Budapest	Pest	Direct use -- developed	74-100
Bük	Vas	Direct use -- developed	58
Bükkszék	Heves	Direct use -- developed	39-40
Cegléd	Pest	Well(s) or hole(s) drilled	54
Csengele	Csongrád	Well(s) or hole(s) drilled	77
Cserkeszollo	Jász-Nagykun-Szolnok	Direct use -- developed	83
Csongrád	Csongrád	Direct use -- developed	58
Csorna	Gyõr-Moson-Sopron	Direct use -- developed	67
Debrecen	Hajdú-Bihar	Direct use -- developed	50-71
Egerszalók	Heves	Well(s) or hole(s) drilled	65
Esztergom	Komárom-Esztergom	Direct use -- developed	N/A
Fejér	Fejér	Direct use -- developed	N/A
Felgyõ	Csongrád	Well(s) or hole(s) drilled	84
Gyõr-Sopron	Gyõr-Moson-Sopron	Direct use -- developed	N/A
Gyula	Békés	Direct use -- developed	93
Hajduszoboszló	Hajdú-Bihar	Direct use -- developed	60-70
Harkány	Baranya	Direct use -- developed	61

SITE / PROJECT NAME	COUNTY	STATUS	TEMP. (ºC)
Heves	Heves	Direct use -- developed	N/A
Héviz	Zala	Direct use -- developed	10-50
Hödmezõvásárhely	Csongrád	Direct use -- developed	N/A
Igal	Somogy	Direct use -- developed	76
Kapuvár	Gyõr-Moson-Sopron	Direct use -- developed	62-66
Karcag	Jász-Nagykun-Szolnok	Direct use -- developed	75
Kecskemét	Bács-Kiskun	Direct use -- developed	51
Komárom	Komárom-Esztergom	Direct use -- developed	N/A
Lipót	Gyõr-Moson-Sopron	Direct use -- developed	64
Makó	Csongrád	Direct use -- developed	89-95
Margitsziget (Margaret Island of the Danube)	Pest	Well(s) or hole(s) drilled	44-69
Martfú	Jász-Nagykun-Szolnok	Well(s) or hole(s) drilled	62
Mélykút-Pusztamérges	Bács-Kiskun	Prefeasibility study	108-110
Mezokövesd	Borsod-Abaúj-Zemplén	Direct use -- developed	64-71
Mindszent	Csongrád	Direct use -- developed	93
Mosonmagyaróvár	Gyõr-Moson-Sopron	Direct use -- developed	75-78
Nagyatád	Somogy	Well(s) or hole(s) drilled	32
Nagybánhegyes	Csongrád	Direct use -- developed	72
Nagylengyel	Zala	Direct use -- developed	N/A
Nagymágocs	Csongrád	Direct use -- developed	96
Nagyszénás-Fábiánsebestyén	Békés	Prefeasibility study	150-254
Nógrád	Nógrád	Direct use -- developed	N/A
Nyirád	Zala	Direct use -- developed	N/A
Nyíregyháza	Szabolcs-Szatmár-Bereg	Direct use -- developed	N/A
Oros	Szabolcs-Szatmár-Bereg	Well(s) or hole(s) drilled	142-167
Orosháza	Békés	Direct use -- developed	95-97
Pitvaros	Csongrád	Direct use -- developed	78
Rábasõmjén	Vas	Direct use -- developed	83

SITE / PROJECT NAME	COUNTY	STATUS	TEMP. (ºC)
Recsk	Heves	Direct use -- developed	39
Rõszke	Csongrád	Direct use -- developed	82
Ruzsa	Csongrád	Well(s) or hole(s) drilled	61
Sajóhidvég	Borsod-Abaúj-Zemplén	Direct use -- developed	95
Sarvar	Vas	Direct use -- developed	N/A
Sávoly	Somogy	Direct use -- developed	N/A
Szabolcs-Szatmár	Szabolcs-Szatmár-Bereg	Direct use -- developed	N/A
Szanda-Tiszaliget	Jász-Nagykun-Szolnok	Direct use -- developed	54-55
Szarvas	Békés	Direct use -- developed	82-154
Szeged	Csongrád	Direct use -- developed	60-91
Szegvár	Csongrád	Direct use -- developed	93
Szentes	Csongrád	Direct use -- developed	72-143
Szolnok	Jász-Nagykun-Szolnok	Direct use -- developed	56-70
Táska	Somogy	Direct use -- developed	68-75
Tiszakécske	Bács-Kiskun	Direct use -- developed	42
Tolna	Tolna	Direct use -- developed	N/A
Toserdo	Bács-Kiskun	Well(s) or hole(s) drilled	41
Tótkomlós	Békés	Direct use -- developed	87
Vas	Vas	Direct use -- developed	N/A
Veszprém	Veszprém	Direct use -- developed	N/A
Zalakaros	Zala	Direct use -- developed	95-99
Zsóri	Borsod-Abaúj-Zemplén	Direct use -- developed	65

Algyõ

LOCATION In southeastern Hungary; on the Tisza River; in Csongrád County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	156
INSTALLED CAPACITY (MWt)	15
POTENTIAL (MWt)	15
CHRONOLOGY Since 1969 - Geothermal water has been used in the secondary oil production technology in Hungary's largest oilfield; 7,000 m³/d of hot water is reinjected into the oil reservoir to displace oil. The utilized geothermal power is 15 MWt (Bobok et al., 1998).	
NOTES Oil and gas prospecting well, Algyõ-1, was drilled to 3209.6 m and encountered a rock temperature of 156ºC (Boldizsár, 1975).	

Álmosd

LOCATION In Hajdú-Bihar County	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	93-143
INSTALLED CAPACITY	—
POTENTIAL	—
CHRONOLOGY 1981 - Álmosd-13 well drilled; entered a tectonic zone in the metamorphic rocks at 3,278-3,280 m. Well produced 93ºC water at rate of 360 m³/d and some gaseous steam. Production pressure was 12,9 MPa; reservoir pressure was 48.035 MPa. During production, the temperature of the fluid was 143ºC at 2,500 m (Árpási et al., 2000).	
NOTES	

Andráshida-Nagylengyel

LOCATION In the central western part of Hungary; in the town of Zalaegerszeg (population 60,000); in Zala County	
STATUS Prefeasibility study	
TEMPERATURE (°C)	93
INSTALLED CAPACITY (MWt)	—

POTENTIAL (MWt)	21.4

CHRONOLOGY
1940s - Geological and geophysical research began, leading to the opening of the most significant oilfield in Hungary at that time.

1952 to 1954 - Five (5) wells were drilled; no oil or gas found; wells were abandoned.

1989 - Wells A-1 and A-2 were selected for flow testing.

NOTES
As part of the Geothermy Project, the Hungarian Oil and Gas Company (MOL) conducted a prefeasibility study of the abandoned production well. The well, which must be pumped, is low-enthalpy. It has a wellhead temperature of 92-93ºC and a flow rate of over 30 l/s (Árpási and Cohut, 2000).

The production well has a potential heat capacity of 241 TJ/year (Árpási and Szabó, 1999). The technical feasibility study concluded that the geothermal resource could provide heat to Landorhegy, the largest housing estate in Zalaegerszeg. It could also be used for a new greenhouse complex as well as cascaded uses. The total thermal capacity of the three-tiered proposed system is 21.4 MWt (Árpási, 1997).

Of the three MOL pilot projects, Andráshida-Nagylengyel, or the "AN Project." has the highest estimated geological-technical feasibility at 95% (Árpási and Szabó, 2000).

Apátfalva

LOCATION
In Csongrád County

STATUS
Direct use -- developed

TEMPERATURE (°C)	86
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES
Well (2200 m, 86ºC) has a problem with scaling (Bélteky, 1975).

Békés

LOCATION
In southeastern Hungary, near the Romanian border; in Békés County

STATUS
Direct use -- developed

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	
CHRONOLOGY	
NOTES Geothermal resource used for balneology, district heating, greenhouses, and fish and other animal farming.	

Békésscsaba

LOCATION In southeastern Hungary, near the Romanian border; in Békés County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology.	

A prospecting well penetrated thermal water-bearing horizons below 2000 m (Bélteky, 1972).

Buda

LOCATION In Pest County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 16th and 17th Centuries - Baths developed during the Turkish occupation.	
NOTES Geothermal resource used for balneology.	

Budapest

LOCATION The capital of Hungary, located in the north-central part of the country; in Pest County	
STATUS	

Direct use -- developed	
TEMPERATURE (°C)	74-100
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

During the Roman Empire - Hot springs used for bathing and space heating.

1868 to 1877 - First thermal water well in the country drilled to 970 m at Városliget, Budapest; triassic dolomite formation; flow rate of 350-500 l/min; thermal water used for heating and domestic hot water supply and supplies water to nearby Széchenyi bath (Horváth, 1986).

1953 - Geothermal hot water used to supply hot water and heat to 16,000 homes and several hospitals.

1980 - Well drilled to 1,000 m in permian limestone produced water of 100ºC (Lawrence & Stoyanov, 1996).

NOTES

Geothermal resource used for balneology, district heating, and greenhouses.

Gellert and Jozsef Hills in Budapest have flow rates of 2-4 l/min and 3-7 l/min respectively; both springs contain SO_3, Cl, and HCO_3 ions in significant amounts (Lawrence & Stoyanov, 1996).

Area is overlain by Eocene limestones (Ferenc and Liebe, 1985).

Bük

LOCATION

In western Hungary; in Vas County

STATUS

Direct use -- developed

TEMPERATURE (°C)	58
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES

Geothermal resource used for balneology.

Well (1010 m, 58ºC) has a problem with scaling (Bélteky, 1975).

Bükkszék

LOCATION

In Heves County

STATUS Direct use -- developed	
TEMPERATURE (°C)	39-40
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Wells (517 m, 39ºC and 550 m, 40ºC) have problems with scaling (Bélteky, 1975).	

Cegléd

LOCATION Southeast of Budapest; in Pest County	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	54
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1987 - Production, pumped well drilled to 1093 m; maximum temperature of 54ºC, flowing enthalpy of 226 kJ/kg, and flow rate of 21 kg/s (Ottlik, 1990).	

NOTES

Csengele

LOCATION In Csongrád County	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	77
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1986 - Production, pumped well drilled to 1569 m; maximum temperature of 77ºC, flowing enthalpy of 322 kJ/kg, and flow rate of 22 kg/s (Ottlik, 1990).	
NOTES	

Cserkeszollo

LOCATION In northeastern corner of Hungary; in Jász-Nagykun-Szolnok County
STATUS Direct use -- developed

TEMPERATURE (°C)	83
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Well (2311 m, 83ºC) has a problem with scaling (Bélteky, 1975).	

Csongrád

LOCATION In southeastern Hungary; northwest of Szentes; in Csongrád County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	58
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1985 - Production, pumped well drilled to 1549 m; maximum temperature of 58ºC, flowing enthalpy of 243 kJ/kg, and flow rate of 17 kg/s (Ottlik, 1990). 1986 - Geothermal district heat system for 654 dwellings began operation.	
NOTES Geothermal resource used for balneology, district heating, greenhouses, and fish and other animal farming.	

Csorna

LOCATION In northwestern Hungary; in Győr-Moson-Sopron County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	67
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY December 1970 - Well drilled to 1800 m; acid treatment carried out to 50 m depth and repeated weekly. 1971 - Scaling existed even below 50 m; scales consisting of calcium and magnesium bicarbonate were removed by drilling but drill cuttings dropped to the bottom, filling up the lower part of the well. 1971 to 1972 - Acid treatment carried out; water-yield	

decreased, indicating scaling even below 80 m (Bélteky, 1975).

NOTES
Well (1800 m, 67ºC) has a problem with scaling (Bélteky, 1975).

Debrecen

LOCATION
In central-eastern Hungary, south of Nyiregyhaza; in Hajdú-Bihar County

STATUS
Direct use -- developed

TEMPERATURE (°C)	50-71
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1972 - Gas production which accompanied the thermal water withdrawal was collected and introduced into the city's gas supply system (Bélteky, 1972).

1984 - The water level of the thermal wells fell radically after several years of production (Bobok et al., 1984).

1985 -Two production, pumped wells drilled to 750 m and 871 m; encountered maximum temperatures of 50ºC and 71ºC, flowing enthalpies of 209 and 297 kJ/kg, and flow rates of 14 and 13 kg/s, respectively (Ottlik, 1990).

NOTES
Geothermal resource used for balneology.

Egerszalók

LOCATION
In Heves County

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	65
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES
Well (407 m, 65ºC) has a problem with scaling (Bélteky, 1975).

Esztergom

LOCATION

In northern Hungary, near the border with Slovakia; in Komárom-Esztergom County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology.	

Fejér	
LOCATION In Fejér County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology and greenhouses.	

Felgyõ	
LOCATION In Csongrád County	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	84
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1985 - Production, pumped well drilled to 2500 m; maximum temperature of 84ºC, flowing enthalpy of 353 kJ/kg, and flow rate of 49 kg/s (Ottlik, 1990).	
NOTES	

Gyõr-Sopron
LOCATION In northwest Hungary; southeast of Mosonmagyaróvár; in Gyõr-Moson-Sopron County
STATUS Direct use -- developed

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology, district heating, and greenhouses.	

Gyula

LOCATION In southeastern Hungary, near the Romanian border, east of Békésscsaba; in Békés County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	93
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1972 - Well drilled to 2500 m yielded 712 l/m of 93°C water (Bélteky, 1972).	
NOTES Geothermal resource used for balneology.	

Hajduszoboszló

LOCATION In eastern Hungary, southwest of Debrecen; in Hajdú-Bihar County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	60-70
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1925 - First thermal water well established in the course of oil and gas exploration; well is still functioning (Horváth, 1986). The water level of the thermal wells has fallen radically after several years of production (Bobok et al., 1984). 1986 - Production, pumped well drilled to 900 m; maximum temperature of 60ºC, flowing enthalpy of 251 kJ/kg, and flow rate of 15 kg/s (Ottlik, 1990).	
NOTES Geothermal resource used for balneology. The considerable gas content of the produced thermal water was used, in the beginning, for local electric power generation and for lighting in railway coaches (Bélteky, 1972).	

Well (1091 m, 70ºC) has a problem with scaling (Bélteky, 1975). Artesian water well of nearly 1,000 m encountered water of 60-70ºC (Ferenc and Liebe, 1985).

Harkány	
LOCATION In south-central Hungary, north of the border with Croatia; in Baranya County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	61
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1866 - Well drilled to 37.7 m in triassic limestone formation (Lawrence & Stoyanov, 1996).	
NOTES Geothermal resource used for balneology.	

Heves	
LOCATION In Heves County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology, district heating, and greenhouses.	

Héviz	
LOCATION In western Hungary, near Lake Héviz; in Zala County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	10-50
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1970s - Natural water influx into Lake Héviz was 450 l/s.

1980s - Natural water influx into Lake Héviz decreased to 300 l/s.

1995 - Since mining activity was stopped at Nyirád in the early 1990s, a slow rise in the natural springs' flow rates has been observed; flow rate is now over 370 l/s (Farkas, 1995). The spring contains SO_3, Cl, and HCO_3 ions in significant amounts (Lawrence & Stoyanov, 1996).

NOTES
Lake Héviz is the most famous thermal lake in Hungary. The lake's water supply comes from different temperature springs of a huge karstic fractured reservoir. Temperature distribution in the Pannonian layer ranges from 10ºC east and northeast of the lake to 50ºC northwest of the lake (Farkas, 1995).

Geothermal resource used for balneology.

Hödmezõvásárhely

LOCATION
In southern Hungary, south of Szentes; in Csongrád County

STATUS
Direct use -- developed

TEMPERATURE (°C)	217
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1985 to 1987 - Reinjection experiments carried out.

1987 - Geothermal district heat system for 570 dwellings began operation. Geothermal resource used to heat Hödmezõvásárhely Hospital and ceramic plant.

NOTES
Oil and gas prospecting well, Hödmezõvásárhely-1, was drilled to 5750 m and encountered a rock temperature of 217ºC (Boldizsár, 1975).

Igal

LOCATION
In Somogy County

STATUS
Direct use -- developed

TEMPERATURE (°C)	76
INSTALLED CAPACITY (MWt)	—

POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Well (651 m, 76ºC) has a problem with scaling (Bélteky, 1975).	

Kapuvár	
LOCATION In the northwest corner of Hungary; in Gyõr-Moson-Sopron County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	62-66
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1986 - Production, pumped well drilled to 1800 m; maximum temperature of 62ºC, flowing enthalpy of 260 kJ/kg, and flow rate of 12 kg/s (Ottlik, 1990). 1986 - Geothermal district heat system for 230 dwellings began operation.	
NOTES Geothermal resource used for balneology.	

Well (1801 m, 66ºC) has a problem with scaling (Bélteky, 1975).

Karcag	
LOCATION In Jász-Nagykun-Szolnok County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	75
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Well (1497 m, 75°C) has a problem with scaling (Bélteky, 1975).	

Kecskemét	
LOCATION In Bács-Kiskun County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	51

INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology, district heating, and greenhouses.	

Komárom	
LOCATION In northern Hungary near the border with Slovakia; in Komárom-Esztergom County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology and greenhouses.	

Lipót	
LOCATION In northwest Hungary on the Little Hungarian Plain; in Gyõr-Moson-Sopron County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	64
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Wells yield water at 64ºC; resource is used for greenhouses, to heat the soil, irrigation, and for balneology.	

Makó	
LOCATION In southeastern Hungary, near the borders with Romania and Serbia; in Csongrád County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	89-95

INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1986 - Production, pumped well drilled to 2299 m; maximum temperature of 94ºC, flowing enthalpy of 394 kJ/kg, and flow rate of 23 kg/s (Ottlik, 1990). Geothermal district heat system for 1,170 dwellings, including Makó Hospital, began operation.

NOTES
Geothermal resource used for district heating.

Wells (2067, 95°C and 2105 m, 89°C) have a problem with scaling (Bélteky, 1975).

Margitsziget (Margaret Island of the Danube)

LOCATION
In Budapest; in Pest County

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	44-69
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1866 - Well drilled to 118.5 m in eocene marl formation; flow rate of 6,200 l/m (Lawrence & Stoyanov, 1996).

1952 to 1954 - Largest thermal water supply system in Europe, at that time, was built at Margitsziget. Thermal water of 69ºC with a flow rate of 1,000 l/m was piped across the bridge to supply hot water to more than 5,600 dwellings in 250 buildings in the Pest district. Some parts of this system are still in operation (Horváth, 1986).

NOTES
Geothermal resource used for district heating.

Martfú

LOCATION
In central Hungary; north of Csongrád; in Jász-Nagykun-Szolnok County

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	62
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1988 - Production, pumped well drilled to 1100 m; maximum temperature of 62ºC, flowing enthalpy of 260

kJ/kg, and flow rate of 33 kg/s (Ottlik, 1990).

NOTES

Mélykút-Pusztamérges

LOCATION
In south-central Hungary; southwest of Nagyszénás-Fábiánsebestyén; near the Serbian border; in Bács-Kikun County

STATUS
Prefeasibility study

TEMPERATURE (°C)	108-110
INSTALLED CAPACITY (MWe)	—
POTENTIAL (MWe)	1-2

CHRONOLOGY
1976 to 1985 - Extensive seismological data collected during exploration for oil in Bács-Kikun county; well clusters are on the Pannonian plain close to the Serbian border.

NOTES
As part of the Geothermy Project, Hungarian Oil and Gas Company (MOL) conducted a prefeasibility study of the well. The well is artesian, low-to medium-enthalpy. It has a wellhead temperature of 108-110ºC, a flow rate of 31 l/s (Árpási and Cohut, 2000), and wellhead pressure of 1-5 bar. The production well has a potential heat capacity of 289 TJ/year and a potential installed capacity of 1-2 MWe (Árpási and Szabó, 2000).

Three apparently independent hydrodynamic units were identified: Block 1 containing wells M-3, M-6, and M-7; Block 2 containing wells M-2 and M-1; and Block 3 containing well P-3 (no interference or injection test results are available to support or refute this conclusion). The prevailing temperatures are 101ºC (109ºC at depth) in Block 1, 155ºC (170ºC at depth) in Block 2, and 130ºC (140ºC at depth) in Block 3. The flow rate for Blocks 2 and 3 is 30 l/s (Árpási et al., 1997).

The geothermal field contains significant amounts of gas and is prone to calcite scaling. The chloride content is high (6,600 ppm) and some corrosion likely (Árpási et al., 1997).

Using an Organic Rankine Cycle, production of electricity is technically feasible. ORMAT and Turboden estimated the potentials of M-2/M-1 and P-3/Pl-1 doublets at 735 kWe and 1,130 kWe respectively (Árpási et al., 1997).

Due to relatively low yields and the high GWR, electricity production alone is not economically feasible. Developing the resource for cascading uses, e.g., power production, hot water supply, and a greenhouse complex, is more profitable and would provide employment and other community benefits (Árpási et al., 1997).

Mélykút-Pusztamérges's estimated geological-technical feasibility is 80% (Árpási and Szabó, 2000).

Mezokövesd	
LOCATION Northeast of Budapest; in Borsod-Abaúj-Zemplén County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	64-71
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology. Wells (875 m, 71ºC, and 972 m, 64ºC) have problems with scaling (Bélteky, 1975).	

Mindszent	
LOCATION In Csongrád County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	93
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Well (2555 m, 93ºC) has a problem with scaling (Bélteky, 1975).	

Mosonmagyaróvár	
LOCATION In the northwest corner of Hungary; in Gyõr-Moson-Sopron County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	75-78
INSTALLED CAPACITY (MWt)	—

POTENTIAL (MWt)	—
CHRONOLOGY 1987 - Production, pumped well drilled to 1995 m; maximum temperature of 78ºC, flowing enthalpy of 326 kJ/kg, and flow rate of 43 kg/s (Ottlik, 1990). Geothermal district heat system for 350 dwellings began operation.	
NOTES Geothermal resource used for balneology and district heating. Well (1996 m, 75ºC) has a problem with scaling (Bélteky, 1975).	

Nagyatád

LOCATION South of Lake Balaton; in Somogy County	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	32
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY 1911 - Well drilled to 413 m in pannonian sediments; flow rate of 900 l/min (Lawrence & Stoyanov, 1996).	
NOTES	

Nagybánhegyes

LOCATION In Csongrád County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	72
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Well (1248m, 72ºC) has a problem with scaling (Bélteky, 1975).	

Nagylengyel

LOCATION In Zala County	
STATUS Direct use -- developed	

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource is used in oil production. Natural gas, with a high content of CO_2 (~81%) is produced, transported, and reinjected to form an artificial gas cap above the depleted part of the oil reservoir. The technology operates without compressors; compressor power is provided by the thermal lift between the production and the reinjection wells. The higher the extracted geothermal heat from the produced gas, the stronger the thermal lift and the higher the gas mass flow rate. In this case, the fluid carrying the geothermal energy is CO_2 gas (Bobok et al., 1998).	

Nagymágocs	
LOCATION In Csongrád County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	96
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Well (2004 m, 96ºC) has a problem with scaling (Bélteky, 1975).	

Nagyszénás-Fábiánsebestyén	
LOCATION In the southeastern part of the country; Nagyszénás-3 is about 12 km from Fábiánsebestyén-4; in Békés County	
STATUS Prefeasibility study	
TEMPERATURE (°C)	150-254
INSTALLED CAPACITY (MWe)	—
POTENTIAL (MWe)	60-70
CHRONOLOGY 1985 to 1986 - Fábiánsebestyén-4 well drilled near a major tectonic zone. During the drilling, steam blew out from the opened section (3,698-4,239 m) on 16 December 1985. The blow out lasted 47 days, continuing until 31 January 1986; the wellhead pressure and flow rate remained constant. The well was finally killed and the borehole cemented.	

The blowout produced hot water (161ºC) with steam (20%). The amount of fluid was 5,000-8,500 m^3/d; production pressure at the surface was 36.0-37.5 MPa, and occasionally up to 40.0 MPa. The estimated pressure at the bottom of the well was 76.3 MPa; the reservoir temperature 200-210ºC. The mass flow rate was approximately 80 kg/s; salt content is 27.2 g/l. The bottomhole temperature at 4,239 m is 202ºC; the SiO_2 temperature is 254ºC (Árpási et al. 2000).

Nagyszénás-Fábiánsebestyén was one of three pilot projects under the Hungarian Oil and Gas Company (MOL) Geothermy Project. The first high pressure, high temperature thermal water found in Hungary was in Fábiánsebestyén-4.

NOTES

Nagyszénás-Fábiánsebestyén has the strongest potential for a future 60-70 MWe geothermal power plant project. If the government were to guarantee a 50% higher than average subsidized wholesale purchase price for geothermal electricity, production would be feasible. Such an intervention is currently against the law, which states that MVM Rt. must always buy the lowest-cost power available from the generators and resell it to regional electricity distributors. Therefore, any price subsidy would require the amendment of current energy legislation (Geszti, 2000).

Nagyszénás-Fábiánsebestyén is a reservoir with carbonate rocks (dolmite) quartz porphyry (Árpási and Szabó, 2000).

Magnetotelluric measurements proved the existence of geothermal reservoirs which are connected to tectonic zones and go down 9-10 km (Árpási et al., 2000).

Nagyszénás-2 has a temperature of 165ºC and a geothermal gradient of 53.3ºC/km at 2,911 m, and belongs to the Pannonian age.

Nagyszénás-3 (3,165-4,034 m deep) is a medium- to high-enthalpy geopressured, artesian well. It has a wellhead temperature of 171ºC (the highest water-steam mixture temperature measured in Hungary), a flow rate of 1,891 m^3/day, a geothermal gradient of 49.7ºC/km at 3,200 m, production wellhead pressure of 450 bar, and belongs to the Lower Triassic age. At 3,500 m, the temperature is 176ºC, the geothermal gradient 47.4ºC/km, and belongs to the Permian age. The production well has a potential heat capacity of 575 TJ/year and 64 MWe (Árpási and Szabó, 2000; (Árpási et al., 2000).

During the well test, it was found that the extremely good inflow is a considerably fractured reservoir, within a 400-m radius of the well, with a permeability of 11.28x10-3 2. During the production test, the best volume rate of the water was 1,891 m^3/d and 10.060 m^3/d for the gas. The wellhead temperature was 171ºC; the highest temperature (185.47ºC) was measured at 3,006 m. When shut-on, the temperature decreased to

177.79ºC and then to 169ºC. On the basis of these data, the temperature is 190ºC at 3,165 m and the pressure is 63.8 MPa. The SiO_2 temperature is 193-199ºC (Árpási et al., 2000).

Fábiánsebestyén-2 has a temperature of 162ºC and a geothermal gradient of 46.6ºC/km at 3,259 m, and belongs to the Miocene age.

Fábiánsebestyén-3, oil and gas prospecting well, was drilled to 2,980 m and encountered a rock temperature of 150ºC (Boldizsár, 1975).

Fábiánsebestyén-4 has a temperature of 166.4ºC and a geothermal gradient of 49.5ºC/km at 3,160 m, and belongs to the Upper Cretaceous age. At 3,864.5 m, the temperature is 190.5ºC, the geothermal gradient 46.7ºC/km, and the age Middle Triassic (Árpási et al., 2000).

Technical problems — high pressure (360 bars) and strongly saline water — appear to be serious (Bobok et al., 1998).

Nógrád

LOCATION
In Nógrád County

STATUS
Direct use -- developed

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES

Nyirád

LOCATION
25 km northeast of Héviz; in Zala County

STATUS
Direct use -- developed

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1980s - About 13 million m³/month of water had to be produced from the extended Transdanubian karstic reservoir to ensure bauxite mining (Farkas, 1995).

Early 1990s - Mining activity stopped due to environmental damage.

NOTES Geothermal resource was used in mining.

Nyíregyháza

LOCATION In northeastern Hungary, north of Debrecen; in Szabolcs-Szatmár-Bereg County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology.	

Oros

LOCATION In the Nagyszénás-Fábiánsebestyén region; in Szabolcs-Szatmár-Bereg County	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	142.2-167
INSTALLED CAPACITY (MWe)	—
POTENTIAL (MWe)	—
CHRONOLOGY	
NOTES Oros-1 has a temperature of 142.2ºC and a geothermal gradient of 50.6ºC/km at 2,610 m, and is of the Pannonian age. At 2,800 m, the temperature is 149ºC, the geothermal gradient 49.6ºC/km and the age Precambrian. Oros-2 has a temperature of 162ºC and a geothermal gradient of 54.1ºC/km at 2,610 m, and is of the Miocene age. Oros-3 has a temperature of 160ºC and a geothermal gradient of 54.2ºC/km at 2,771 m, and is of the Pannonian age. At 2,942 m, the temperature is 167ºC, the geothermal gradient 53.4ºC/km and the age Precambrian (Árpási et al., 2000).	

Orosháza

LOCATION In Békés County
STATUS Direct use -- developed

TEMPERATURE (°C)	95-97
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Two wells (1700 m, 97ºC and 1610 m, 95ºC) have problems with scaling (Bélteky, 1975).	

Pitvaros

LOCATION In Csongrád County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	78
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Well (1700 m, 78ºC) has a problem with scaling (Bélteky, 1975).	

Rábasõmjén

LOCATION In Vas County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	83
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Well (1943 m, 83ºC) has a problem with scaling (Bélteky, 1975).	

Recsk

LOCATION In Heves County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	39
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	

NOTES
Well (998 m, 39ºC) has a problem with scaling (Bélteky, 1975).

Rõszke

LOCATION
In Csongrád County

STATUS
Direct use -- developed

TEMPERATURE (°C)	82
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES
Well (2000 m, 82ºC) has a problem with scaling (Bélteky, 1975).

Ruzsa

LOCATION
In Csongrád County

STATUS
Well(s) or hole(s) drilled

TEMPERATURE (°C)	61
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1986 - Production, pumped well drilled to 1135 m; maximum temperature of 61ºC, flowing enthalpy of 255 kJ/kg, and flow rate of 42 kg/s (Ottlik, 1990).

NOTES

Sajóhidvég

LOCATION
In Borsod-Abaúj-Zemplén County

STATUS
Direct use -- developed

TEMPERATURE (°C)	95
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES
Well (1880 m, 95ºC) has a problem with scaling (Bélteky, 1975).

Sarvar	
LOCATION In northwestern Hungary; in Vas County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology.	

Sávoly	
LOCATION In southwestern Hungary; in Somogy County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource heats gathering pipes in a heavily producing oilfield (Bobok, et al., 1998).	

Szabolcs-Szatmár	
LOCATION In Szabolcs-Szatmár-Bereg County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology and greenhouses.	

Szanda-Tiszaliget
LOCATION In Jász-Nagykun-Szolnok County
STATUS Direct use -- developed

TEMPERATURE (°C)	54-55
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	

NOTES
Wells (1013 m, 55ºC; and 1443 m, 54ºC) have problems with scaling (Bélteky, 1975).

Szarvas

LOCATION
In the heart of the Hungarian Plain; on the banks of the Körös dead channel; population 18,000; in Békés County

STATUS
Direct use -- developed

TEMPERATURE (°C)	82-154
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1965 - First geothermal well drilled at Dósza Agricultural Cooperative; 3 additional wells developed for agricultural purposes.

1985 - Space heating using geothermal energy became popular as a national program to replace fossil fuels with renewable energy began. The town council applied for a grant from the government to develop a geothermal heating system.

1986 -Two new production and reinjection wells were drilled to 1790 m (artesian) and 1501 m; maximum temperatures of 97ºC and 82ºC, flowing enthalpy of 406 and 343 kJ/kg, and flow rates of 25 and 18 kg/s, respectively. The artesian well's production rate is 65 m^3/h (at 6 m wellhead pressure); outflow temperature at maximum flow rate is 98ºC; GWR is 0.83; CH_4, CO_2, and N_2 are present in the water. Surface equipment, pipelines, and heat exchangers were installed.

Geothermal district heat system for 480 dwellings began operation at the end of the year with only three consumers and using only 20% of the wells' capacity. Construction of an immense health center with a spa hotel and thermal baths promised by the town council for political reasons was abandoned.

Wells were placed rather far away from the city's large heat consumers. Also, to make matters worse, the camp ground, the largest heat consumer, disconnected itself from the geothermal system and began using natural gas boilers (Szita and Kocsis, 2000).

1988 - Reinjection test caused wellhead pressure in the well to rise unexpectedly and rapidly.

1993 - Local government, through its limited liability company, M. Thermal Ltd., finalized contracts with Porció Ltd. to implement a geothermal heating system using the well owned by the town (free of charge for 10 years), and to supply three public buildings with heat. The heat supplied by the geothermal resource will be 5-15% cheaper (average 10%) than that provided by fossil fuel.

1994 - Implementation began; more than 4 km of transmission and distribution double pipelines were laid for 17 geothermal substations. Operation began 1 November.

1995 - Second stage became operational in January. Geothermal resource used for balneology and space heating, providing 16 consumers 6,150 kW of heat to 200,800 m^3 (Szita and Kocsis, 2000).

Oil and gas prospecting well, Szarvas-DNy-1, was drilled to 3020 m and encountered a rock temperature of 154ºC (Boldizsár, 1975).

NOTES
Geothermal resource is used for district heating.

Cooled geothermal water is sent to a cooling pool and then discharged into the Körös River. Reinjection is not used because of 1988 test results but may soon be mandatory due to stricter regulations from water authorities (Szita and Kocsis, 2000).

The geothermal system could be expanded to provide heat to several additional buildings. Also, the used geothermal water could be used in a greenhouse, extracting an additional 1 MWt in capacity. Financing has been an insoluble problem (Szita and Kocsis, 2000).

Szeged

LOCATION
In southeastern Hungary on the southern Great Hungarian Plain; south of Szentes; near the Serbian border; in Csongrád County

STATUS
Direct use -- developed

TEMPERATURE (°C)	60-91
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1920s - Artesian water well of nearly 1,000 m completed; encountered water of 60-70ºC (Ferenc and Liebe, 1985).

1962 - District heating project, comprising 1,000 flats in Szeged was started; used thermal water of 89ºC coming from a nearby well drilled to 1,900 meters (Ottlik et al., 1981). The University at Szeged was subsequently added to the system (Lawrence & Stoyanov, 1996).

1983 to 1985 - Reinjection experiments carried out; two-well system established did not function due to a series of machine breakdowns (Horváth, 1986).

1987 - Production, pumped well drilled to 1552 m; maximum temperature of 70ºC, flowing enthalpy of 293 kJ/kg, and flow rate of 33 kg/s (Ottlik, 1990).

1990 to 1992 - With PHARE's (European Community) support, a geothermal project was launched; a slanted pair of unused geothermal wells were operated as a doublet. Production and reinjection test conducted on the pair of wells in late 1992 by Porcio, Ltd. At the end of the 20-day experiment, well head pressure associated with a maximum water drain of 45 m^3/h was stabilized at 10.5 bar. As a result of the project, a contract was issued to Porcio, Ltd. to implement the project (Szita, 1995).

NOTES
Geothermal resource used for balneology and space heating.

At the Szeged Clinic, the production level and water quality dropped dramatically over 15 years of use. Despite ceasing production, the level did not recover (Szita, 1995).

Wells (1800-2000 m, 83-91ºC) have problems with scaling (Bélteky, 1975).

Permeability is 7-846 x 10-3 ^{2}; the mean value on the basis of hydrodynamic measurements in 10 wells is 261x10-3 ^{2}. (Árpási et al., 2000).

Szegvár

LOCATION
In Csongrád County

STATUS
Direct use -- developed

TEMPERATURE (°C)	93
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY
1988 - Production, pumped well drilled to 2485 m; maximum temperature of 93ºC, flowing enthalpy of 389 kJ/kg, and flow rate of 28 kg/s (Ottlik, 1990).

NOTES
Geothermal resource used for agricultural purposes.

Szentes

LOCATION
In southeastern Hungary on the Great Hungarian Plain; in Csongrád County

STATUS Direct use -- developed	
TEMPERATURE (°C)	72-143
INSTALLED CAPACITY (MWt) POTENTIAL (MWt)	— —

CHRONOLOGY

1957 - Development of a geothermal heating system began.

1959 - Municipal hospital of Szentes supplied by thermal water; water used to heat the hospital wards and other rooms.

1960s - First thermal well drilled to heat greenhouses (Farkas, 1995). Well 2000-2500 m deep yielded 1500-2000 l/min of 90-95°C water (Bélteky, 1972).

1986 and 1987 - Two production, pumped wells drilled to 1997 m and 2345 m; encountered maximum temperatures of 72°C and 96°C, flowing enthalpy of 301 and 402 kJ/kg, and flow rates of 12 and 25 kg/s, respectively (Ottlik, 1990). Geothermal district heat system for 1,487 dwellings began operation.

End of the 1980s - Number of wells increased to 40; average flow rate decreased from 600,000 to 300,000 m^3/yr. Model showed that injection could partially reduce the decline in pressure (Farkas, 1995).

1985 to 1987 - Reinjection experiments carried out.

NOTES

Geothermal resource used for balneology, space heating, greenhouses, and soil heating.

The six month winter season represents the main utilization period. In the summer, the majority of the thermal wells are shut down (Korim, 1972).

Szentes-ÉK-1 has a temperature of 143.4ºC and a geothermal gradient of 44.8ºC/km at 2,975 m, and is of the Pannonian age. At 3,400 m, the temperature is 160ºC, the geothermal gradient 44.1ºC/km and the age Upper Cretaceous (Árpási et al., 2000).

Szolnok

LOCATION

Southeast of Budapest; in Jász-Nagykun-Szolnok County

STATUS Direct use -- developed	
TEMPERATURE (°C)	56-70
INSTALLED CAPACITY (MWt) POTENTIAL (MWt)	— —

CHRONOLOGY

1920s - Artesian water well of nearly 1,000 m completed; encountered water of 60-70ºC (Ferenc and Liebe, 1985).

NOTES
Geothermal resource used for balneology, district heating, greenhouses, and fish and other animal farming. Wells (1001-1687 m, 56-62ºC) have problems with scaling (Bélteky, 1975).

The water level of the thermal wells has fallen radically after several years of production (Bobok et al., 1984).

Táska

LOCATION
In Somogy County

STATUS
Direct use -- developed

TEMPERATURE (°C)	68-75
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES
Wells (691-942 m, 68-75ºC) have problems with scaling (Bélteky, 1975).

Tiszakécske

LOCATION
South of Szolnok; in Bács-Kiskun County

STATUS
Direct use -- developed

TEMPERATURE (°C)	42
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—

CHRONOLOGY

NOTES
Geothermal resource used for balneology.

Water of 42º at 220 m was found; flow rate of 1500 l/min (Bélteky, 1972).

Tolna	
LOCATION In south-central Hungary; in Tolna County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology.	

Toserdo	
LOCATION In Bács-Kiskun County	
STATUS Well(s) or hole(s) drilled	
TEMPERATURE (°C)	41
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Water of 41º at 1050 m was found; flow rate of 1500 l/min (Bélteky, 1972).	

Tótkomlós	
LOCATION In Békés County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	87
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Well (1460 m, 87ºC) has a problem with scaling (Bélteky, 1975).	

Vas	
LOCATION In Vas County	
STATUS Direct use -- developed	

TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology, district heating, greenhouses, fish and other animal farming, and agricultural drying.	

Veszprém

LOCATION In Veszprém County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	—
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology.	

Zalakaros

LOCATION In western Hungary, south of Héviz; in Zala County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	95-99
INSTALLED CAPACITY (MWt)	—
POTENTIAL (MWt)	—
CHRONOLOGY	
NOTES Geothermal resource used for balneology. Wells (2307 m, 99ºC and 2752 m, 95ºC) have problems with scaling (Bélteky, 1975).	

Zsóri

LOCATION In northeastern Hungary; in Borsod-Abaúj-Zemplén County	
STATUS Direct use -- developed	
TEMPERATURE (°C)	65
INSTALLED CAPACITY (MWt)	—

POTENTIAL (MWt)	—

CHRONOLOGY

1968 - Regular acid treatment began, eliminating the need for removal of scaling by drill (Bélteky, 1972).

NOTES

Geothermal resource is used for balneology.

The 850 m deep well at the Zsóri spa has the most intense precipitation in Hungary — 1-1.3 mm per day. Corrosion has been controlled by a Dutch inhibiting agent (Servo CK 821) which is added to the thermal water at 65ºC. Operation of the bathing facilities is not hindered by the cleaning process which is done overnight and usually takes only 2.5 hours (Bélteky, 1972).

Conclusion

Hungary has a handful of high-enthalpy geothermal resources which may be suitable for power generation. First and foremost is Nagyszénás-Fábiánsebestyén with a potential of 60-70 MWe. Despite this potential, however, development is unlikely in the near future.

The success of geothermal development in Hungary is connected with three factors: the price of hydrocarbons, the country's accession to the EU, and the existence of private investment. When the price of oil is high, geothermal and other renewable technologies become increasingly attractive (Árpási and Szabó, 1999). Due to the low cost of fossil fuels, especially natural gas, however, only the best geothermal resources are commercially competitive based on a strict financial comparison. Commercial viability of power generation projects may be increased through the use of cascading.

Additionally, Hungary's energy policy is focused on EU accession. The GOH will promote alternative energy sources as long as they are economically viable in a free market-based electricity system. It may offer support or subsidies to geothermal development after EU accession, particularly to achieve the EU's goal of having 12% of its member-countries' total inland energy generated by renewable energy sources.

U.S. companies considering bidding on future renewable energy projects in Hungary should be prepared for three to four years of project development, according to the U.S. Foreign Commercial Service in Budapest. In this long process, local joint-venture partners may play an important role. The GOH, in general, is encouraging foreign investors to invest in power generation projects. Renewable energy has an important role in this process (Geszti, 2000).

The short-term outlook is brighter regarding Hungary's direct use potential, particularly in district heating. According to a recent EU report, opportunities both to extend existing usage and to develop related businesses are rife in Eastern European, including Hungary, where large centralized district heating systems using conventional fuels could be converted to geothermal (European Union, 1999).

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