GEOTHERMAL RESOURCES OF HUNGARY AT A GLANCE

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SUMMARY

Hungary has some significant low-enthalpy geothermal resources. The success of geothermal development in Hungary is related to three market factors: the price of hydrocarbons, the country's accession to the European Union (EU), and the existence of private investment. However, due to the low cost of fossil fuels, especially natural gas, only the best geothermal resources are commercially competitive based on strict financial criteria. Commercial viability of power generation projects may be increased through the use of cascading.

1. INTRODUCTION

Hungary's most significant low-enthalpy geothermal resource is the Upper-Pannonian aquifer. It has an area of 40,000 km^2 and an average thickness of 200-300 m or more. Individual, horizontal, sandy layers are interbedded with clayey strata to form the aquifer. Most of the geothermal water-producing wells tap into 4 or 5 (sometimes more) separated sandy layers within a few hundred meters. The temperature difference between the lowest and the uppermost layers can exceed 20°C. These water streams have different flow rates and temperatures, and are mixed in the perforated section of the well.

The Republic of Hungary is located in the heart of Europe. 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. Hungary's first free multi-party election was held in March 1990 after a peaceful transition in which the Hungarian Socialist Workers Party (formerly the Communist Party) 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.

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 of the EU, and is on the accession fast track. While the country's exact accession date is uncertain, it is likely to be 2003 or 2004.

Admission to the EU is a key driving force behind the Government of Hungary's (GOH) 1999 National Energy Strategy. It affects the country's power generation system in two basic respects: compatibility in the field of environmental protection and compatibility with 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 sources 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, and European Union 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).

2. POWER PROFILE OF HUNGARY

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, most Hungarian public power plants also supply heat, providing two-thirds of the total domestic and industrial heating requirements. As of January 2000, Hungary had an installed capacity of 7,903 MWe (up from 7,845 MWe in 1999). Of this, approximately 7,300 MWe is generated by public power plants and 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%.

Nuclear power, produced by the Paks Nuclear Power Plant in southwestern Hungary, generates 40% of the country's electricity. Paks is state-owned and operated, and has four Soviet-designed vver-440/213 pressurized light-water reactors. These began operating between 1982 and 1987 and are designed to operate for 30 years. Currently, Paks is investigating a program that could extend the reactors' service life by another 10 years. 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 domestic heat and hot water) in contrast with a world average of 11%. Among the various renewable energy resources, geothermal and wind energy are considered to have the highest potential (Geszti., 2000).

Following EU directives, the country's share of renewable energy must be increased to 12% by 2010. However, Hungary's first priority is to modify and upgrade 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.

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 the 1997 levels, while the demand for natural gas is expected to increase by approximately 20%. Natural gas prices increased by 12% on 1 July 2000.

Hungary's energy intensity (the energy needed to produce US$1 GDP) is three times that of Japan and four times above 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 (Jaszay., 1997).

3. GEOTHERMAL SITES OF HUNGARY

As a result of the earth's thin crust in the Pannonian Basin, Hungary's geothermal gradient (increase in temperature per unit increase in depth) is higher than the world average, and reaches 58.9°C in some locations. In places where such high geothermal 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 Horvath., 1988; Arpasi and Szabo., 1999).

The main source of the geothermal energy in Hungary is the conductive heat flow which passes from magma through the overlying sediments to the surface. The average ground heat flow directed out from the earth's interior ranges between 80-100 mW/m²; twice as high as the continental average. The stratum temperature at a depth of 1,000 m reaches and exceeds 60°C (Andristyak et al., 1995; Árpási., 1995).

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. The Lower Pannonian sediments are impermeable; while the upper Pannonian and Quaternary formations contain vast, porous, permeable sand and sandstone beds forming the upper Pannonian aquifer — the most important geothermal water resource in Hungary (Bobok et al., 1998).

Two primary types of geothermal water reservoir exist in Hungary: the Pannonian and the Triassic. The Pannonian Basin's largest geothermal water resources are located in Pliocene sand and sandstone formations. The individual sandy layers of the Upper Pannonian strata have thicknesses between 1-30 m. Their horizontal extension is not large, but the sand lenses are interconnected to form a hydraulically unified system. This Upper Pannonian aquifer has an area of 40,000 km², 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; but local recharge or discharge slightly modifies this pattern. The Lower Pannonian strata mainly include marls, clay marls, and relatively compacted sandstones. Their porosity and permeability are relatively low. The Upper Pannonian strata consist of sandstone-clay marl groups with a high porosity (20-30%) and significant permeability. About 80% of the country's geothermal wells are located in the Upper Pannonian reservoir system (Horváth., 1986; Bobok., 1998).

The flow rate of the geothermal water wells in Upper Pannonian aquifers ranges fiom a few hundred to 3,000 l/min. The temperature of the water at the wellhead reaches 100°C. The majority of the geothermal waters are usually of good quality with a relatively low concentration of dissolved solids. The average concentration within the main geothermal water horizon is about 1,500-2,500 ppm. The chloride ion content is very low, generally less than 100 ppm. They are alkaline-bicarbonate waters (Korim., 1972). The geothermal energy reserve of the Upper Pannonian reservoir is estimated at 1,835.1 KJ (Bobok et al., 1984).

Upper Pannonian formations occur over 40-50% of Hungary, but are covered by younger formations; consequently, the geothermal water reserves in them are accessible only by deep drilling. Unlike the Triassic carbonate geothermal water reservoir, most of the Upper Pannonian geothermal water reserves are not recharging.

The Triassic geothermal reservoir is composed of carbonate rocks sometimes exhibiting karst topography (fkactured, cavernous rocks) located in the Central Transdanubian Mountains, and covering approximately 13,000 km^2, or about 14% of Hungary's territory. About 20% of the country's geothermal wells are sourced fiom this carbonate rock formation. Under natural conditions, rainwater infiltrates into the reservoir and there is some surface discharge through springs and marshes. (Lake Heviz and Lake Harkány receive hot water fiom such springs.) The dynamic equilibrium has been changed by human intervention, through water use and mining activities (Horvath., 1986; Bobok., 1998).

The salt content of geothermal waters varies fiom place to place; on average it is 3,000 mg/l (Horvath., 1986). The chemical composition of the geothermal waters coming fiom the Pannonian aquifers is mainly alkaline carbonate; these waters also contain methane and carbon dioxide. The salt content is on average 3,000-5,000 mg/l; gas content varies widely. Due to the methane, explosions have occurred on several occasions (Ottlik., 1988).

The only recharge to aquifers near the surface is through infiltration fiom precipitation. Hungary averages 400-800 mm/year of precipitation, a low amount. With a few exceptions, re-injection 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,
5. The Basement.

Geothermal water temperature is defined by the local geothermal gradient. The mean values are as follows: 50°C/km in the majority of the Great Hungarian Plain; 45°C/km in the southern part of the Great Hungarian Plain (this area is partly cooled by convection); 55-60°C/km in the eastern part of the Great Hungarian Plain; 40°C/km in the Little Hungarian Plain; and 50-60°C/km in most parts of the Direct Use. Despite the significant proven resources, geothermal energy provides only 0.16% of Hungary's primary energy requirements (Árpási and Szabo., 2000).

The Romans used hot springs to supply baths and to heat the associated buildings. The remains of these facilities can still be seen in Budapest, in the Roman Aquincum town (Horvath., 1986). Balneological and therapeutic uses of the geothermal waters remain very popular in Hungary, with world-renowned spas located in Budapest, Bük, Debrecen, Gyula, Hajduszoboszlo, Harkány, Heviz, 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 Szabo., 2000). The development of additional hot spring resorts and spas to attract tourists is an important objective of Hungary's National Development Plan (The 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 farms, driers, etc. and located primarily in the southeastern part of the country. From a total of 366.5 MWt, agriculture had an installed capacity of 120.43 MWt; domestic heating, sanitary hot water (SHW) and industrial applications 58.7 MWt; and bathing and balneology 187.3 MWt as of 1 January 2000 (Árpási and Szabo., 2000).

Hungary has no geothermal power generation facilities yet, but a high-temperature (170°C) overpressured reservoir (700 bar) was identified in 1983. The geothermal brine is extremely saline but industrial utilization can be achieved in the future.

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