GEOTHERMAL AGRICULTURE IN HUNGARY

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GEOLOGIC CONDITIONS

Hungary, a country of 36,000 square miles (93,000 sq km) or about the size of Indiana, is situated in Central-Europe in the Pannonian Basin. The Danube River cuts through the country separating it into two main parts: the Transdanubian Central Range with Lake Balaton in the northwest and the Great Hungarian Plain in the east and south.

In Hungary, there are two main hydrological systems that are associated with geothermal fluids. One, the more significant, is the Upper-Pannonian (Pliocene) series, and the other is in the fractured, carbonatic formations (Ottlik, 1989). The Upper-Pannonian series consists of clastic porous sedimentary rock, mainly sandstones. These porous and permeable sandstone strata contain immense quantities of water, oil and gas deposits of commercial value. The geothermal bearing portions of the formations have a maximum depth of more than 8,00 feet (2,500 m) in the Great Hungarian Plain. These calstic, porous formations are mainly confined aquifers without any recharge (Ferenc and Liebe, 1987). Overlying this formation are Pleistocene sediments nearly 3,300 feet (1,000 m) thick, containing cooler geothermal waters.

The carbonate formations consist of limestones, dolomites and marls of Mesozoic age, from which natural thermal springs issue along the border of the mountainous area (Figure 1). These thermal springs in the Transdanubin Central Range and in Budapest have a long historical record of use, especially for bathing and balneology. These springs have a temperature ranging from 86 to 140^{9}F (30 to 60ºC), yield from a few gallons per minute to 8,000 gallons per minute (500 l/s), have a total discharge estimated at 13,000 gallons per minute (830 l/s), and a total dissolved solid content usually less than 1,000 ppm (mg/l)(Ferenc and Liebe, 1987). They are also high in CO_2; thus, they are considered aggressive waters. Recharge for these aquifers is from precipitation in the karstic, mountainous area with an estimated residence time of thousands of years. The majority of these thermal reservoirs are confined since they are overlain by thick sediments. Where they are situated far from mountainous area, the NaCl content is nearly 50,000 ppm (mg/l). The high NaCl content and large depth to the formation (over 3,000 feet - 1,000 m), limit the utilization of this geothermal resource.

The average geothermal gradient is 3ºF/100 feet (50ºC/km) with a heat flow of 2.1 to 2.4 hfu (90 to 100 mW/m^2)(Horvath, et al., 1983). With the exception of the mountains, the average formation temperature at 3,300 feet (1,000 m) depth is 140ºF (60ºC) and at 6,600 feet (2,000 m) reaches 230ºF (110ºC).

Figure 1. Carbonate formation in Budapest with numerous hot springs.

HISTORY OF GEOTHERMAL DEVELOPMENT AND UTILIZATION

The earliest use of geothermal waters in Hungary was from the springs for bathing. This use dates back to the Roman and Turkish periods. Several famous hotels pools and Turkish baths are still popular in Budapest. Drilling for geothermal fluids started in the latter part of the last century, and in the 1920s, artesian wells of nearly 3,300 feet (1,000 m) depth were completed in the southeast (near Szeged) with flowing water temperatures from 140 to 158ºF (60 to 70ºC)(Ferenc and Liebe, 1987). Since this time, numerous "dry" oil exploration wells have been completed as geothermal producing wells. Approximately 1,000 of these "dry" wells are available; however, less than half are worth completing. By the early 1970s, there were 131 geothermal wells in Hungary, producing over 50,000 gallons per minute (3,300 l/s) with a peak load of 770 MW and an annual load of 260 MW (Boldisar, 1974).

Today, there are over 1,000 geothermal wells producing water above 86ºF (30ºC). A summary of these wells and their use is presented in Table 1 (Karai, et al., 1990), and a map of the utilization locations shown in Figure 2 (Ottlik, 1989).

The use of low-temperature geothermal water for drinking purposes occurs in areas where drinking water is not available at shallow depth. The most prevalent use is the balneological-therapeutical purposes in indoor and outdoor bath and swimming pools (Figure 3). A very important use is for agriculture and horticulture for the heating of greenhouses, plastic tents and tunnels, discussed in detail below. District and space heating is provided at several selected sites, such as Szeged and Budapest, where over 2,000 and 5,000 flats, respectively, are heated. In the past four years, the

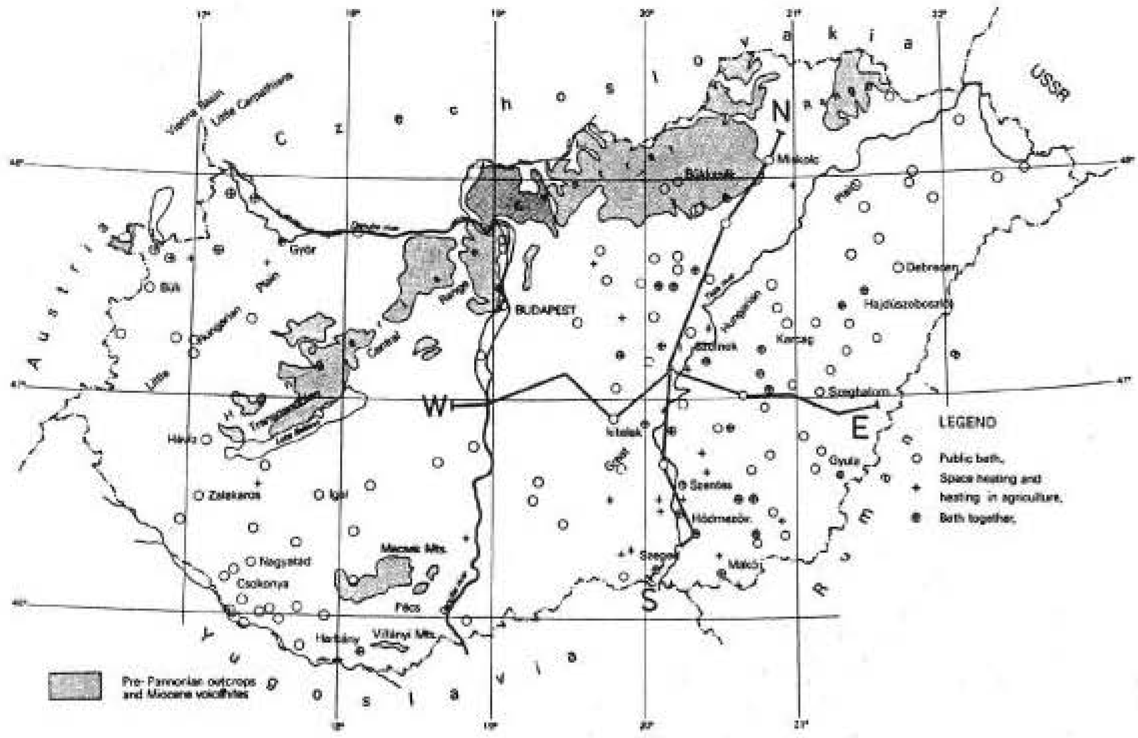

Figure 2a. Sketch map showing the utilization of geothermal water in Hungary in 1977-78.

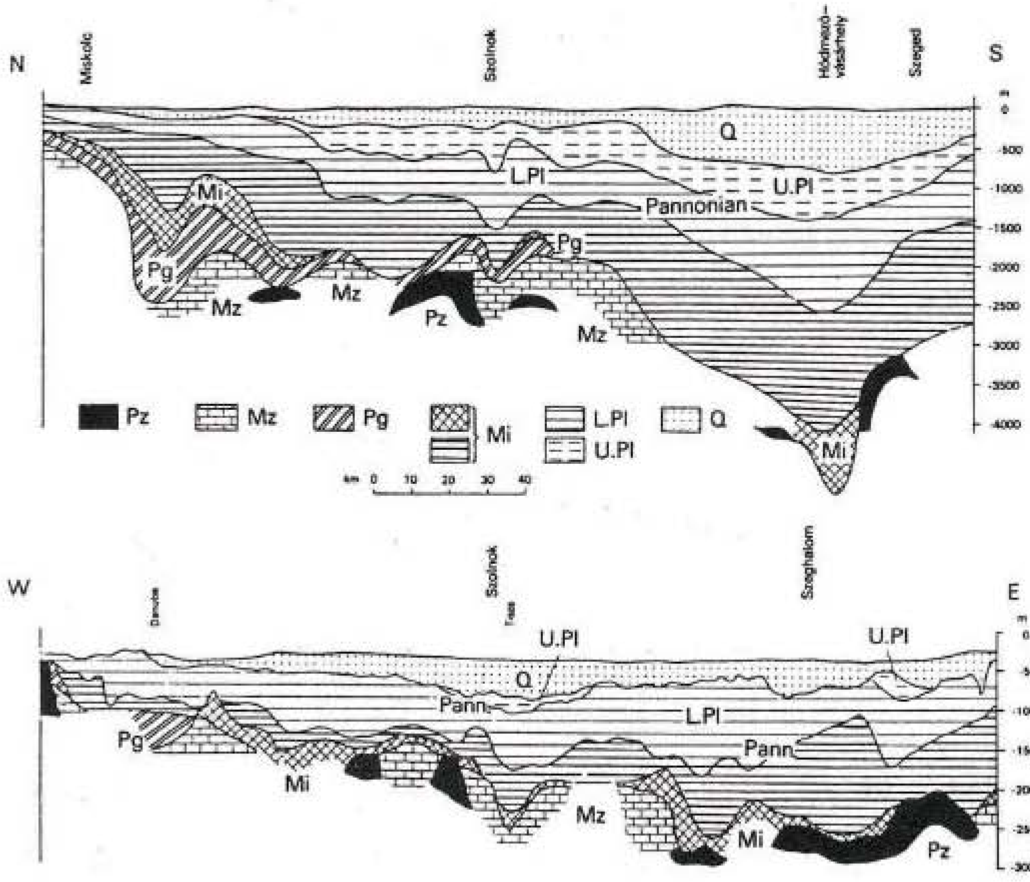

Figure 2b. Geological profiles of strike directions N–S and E-W across the Great Hungarian Plain. Pz: Paleozoic, MZ: Mesozoic, PG: Paleogene, Mi: Miocene, Pl: Pilocene, Q: Quateruary.

Table 1. Thermal Wells in Hungary 1987.01.01

			Utilization						
Temp. 20°C	Number of Wells	Flowrate m^3/min	Drinking	Balneo.	Agriculture	Space Heating	Industry	Other	Closed
30-39.9	516	348.00	211	74	109	1	36	73	12
40-49.9	209	190.11	28	98	25	2	12	39	5
50-59.9	105	96.99	5	44	20	2	12	15	7
60-69.9	92	100.67	1	43	25	3	6	11	3
70-79.9	59	67.39	0	24	23	4	2	3	3
80-89.9	46	62.33	0	5	35	1	1	1	3
90-	40	63.27	0	5	27	4	2	1	1
Total	1067	928.76	245	293	264	17	71	143	34

Figure 3. Geothermal pool at Hotel Gillieret in Budapest.

Geothermal Technical Development Cooperative has converted 5,000 flats in six towns to geothermal heating from oil and gas. The cooperative believes an additional 20,000 to 30,000 flats could be converted.

GEOTHERMAL UTILIZATION IN GREENHOUSES

Approximately 420 acres (200 ha) of glass and plastic covered greenhouses are heated with geothermal energy. In addition, 2,500 acres (1,000 ha) of temporarily covered plastic tents of "tunnels" are also heated (Ottlik, personal communication, 1989). Vegetables are grown in about 25% of the greenhouses covered by glass and in 95% of those covered with plastic. The most important vegetables grown are peppers, tomatoes and cucumbers. The remaining greenhouses are used for nursery stock, ornamental and cut flowers. Of the 8.5 x 10^{12} Btu per year (9 X 10^{12} kJ/year) used in horticulture for heating purposes, 72% (161 million TOE) is recovered from geothermal fluids (Karai, et al., 1990). Including all energy use, geothermal fluids provide over 80% of the energy demand at vegetable farms.

Besides greenhouse heating, geothermal waters are used at animal farms, for space heating and hot water supply (approximately 5 to 8% of the greenhouse heating load). Geothermal waters are used for heating purposes at 50% of the farms, where the heat is cascaded for all of the above purposes (Karai, et al., 1990). "Dry" petroleum wells are made available to farmers at a low price, making the capital cost very attractive. New wells are amortized in 5 to 6 years, based on fossil fuel savings. Commercial vegetable farms in Hungary are at least 25 to 30 acres (10 to 12 ha) in size, while ornamentals require at least 15 to 20 acres (6 to 8 ha) to be profitable.

The most common greenhouse in use is one constructed of galvanized steel and glass mounted on a 10-in (25-cm) high concrete strip foundation. The floor space of the Hungarian manufactured greenhouses are 10.5 x 21 feet (3.2 x 6.4 m) modulus with an eave height of 9 feet (2.7 m) (Figure 4). The plastic tents are usually constructed of bent-to-shape plastic or galvanized steel pipes with spacing of 5 feet (1.5 m), which are either anchored directly in the ground or on concrete strip foundations. The width varies from 15 to 25 feet (4.5 to 7.5 m), with the latter most common. The height is around 6 feet (2 m) and they can be up to 330 feet (100 m) long (Figure 5).

Figure 4. Glass greenhouses at Szentes.

A typical greenhouse and plastic tent geothermal heating system is illustrated in Figure 6 (Karai, et al., 1990). Water is produced by deep-well pumps and discharge into a degassing tank. The water then flows by gravity to a collection tank and then circulated by pumps to the greenhouse heating system. The greenhouse supply temperature is 176°F (80°C) and exit temperature is 104°F (40°C). The waste water is then combined with geothermal water at 180°F (82°C) to produce 140°F (60°C) fluid for cascading to the plastic tents. The final effluent, at 77°F (25°C) is then stored for future use, such as irrigation. Ice and snow on the roof or in the down spouts can also be melted.

Figure 5. **Plastic tents for growing vegetables in Szentes.**

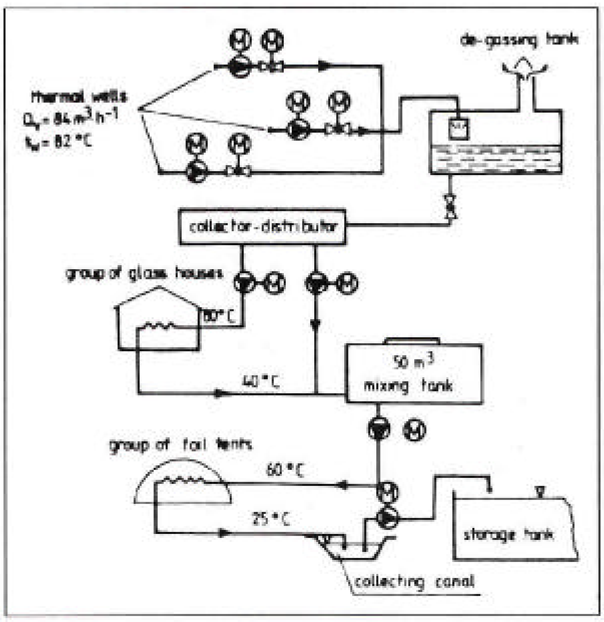

Figure 6. **Scheme of complex geothermal heating system consisting of greenhouses and plastic tents with three wells.**

The heating systems generally use the geothermal waters directly. Although the water is degassed at the wells, the air vents are usually larger than conventional water heater systems. When the entering fluid for the newer greenhouses is above 158ºF (70ºC), it is frequently cascaded through a three-staged heating system. The high stage uses finned pipes at 6 to 6.5 feet (1.8 to 2.0 m) above the ground, extracting about 36ºF (20ºC) from the fluid. The second stage consists of metal pipes placed directly on the ground. These are sometimes also used as tracks for the harvesting trolleys. In these, an additional 18 to 36ºF (10 to 20ºC) is extracted from the fluid. Finally, the fluid is circulated through plastic pipes buried 8 to 24 inches (20 to 60 cm) in the ground. This will reduce the fluid temperature 9 to 18ºF (5 to 10ºC); thus, up to 90ºF (50ºC) is extracted from the water in the three stages. The aboveground heating system can be seen in Figure 7. The secondary system, placed on the ground, is removed during cultivation. In some of the older models, only one or two heating systems are used. The most common is pipes 24 to 48 inches (60 to 120 cm) above the ground with vertical bends (Ottlik, 1989).

Figure 7. **Heating system in glass greenhouses in Szentes.**

In the plastic tents, the typical heating systems consist of plastic pipes laid on the ground, which are removed during cultivation, and pipes buried in the soil. Some, may instead have finned tubed pipes, placed along the sides of the tent as shown in Figures 8 and 9. The plastic tents are used only for growing vegetables and are not operated during the winter months when temperatures can reach -4ºF (-20ºC) for several weeks.

A special gravel bed heating system has been developed for plastic tents, as shown in Figure 10 (Karai, et al., 1990). The soil is first excavated to a depth of 17 inches (43 cm); where, three layers of a reflective sealing foil are spread and then covered with 4 inches (10 cm) of gravel. Plastic pipes of 1-1/4 in. diameter (3.2 cm) are placed in the gravel layer. A 3-in. (8-cm) thick concrete layer is then placed on top of the gravel. Finally, 10 inches (25 cm) of soil is placed on the concrete for crop production. Hot water flowing through the pipes heats the gravel layer, and heat is transferred through the pipes the concrete in a uniform manner to heat the soil. The heat flux in the soil is 25 to 38 Btu/hr/ft^2 (80-120 W/m^2). This system is very effective for crops that require a warm root zone.

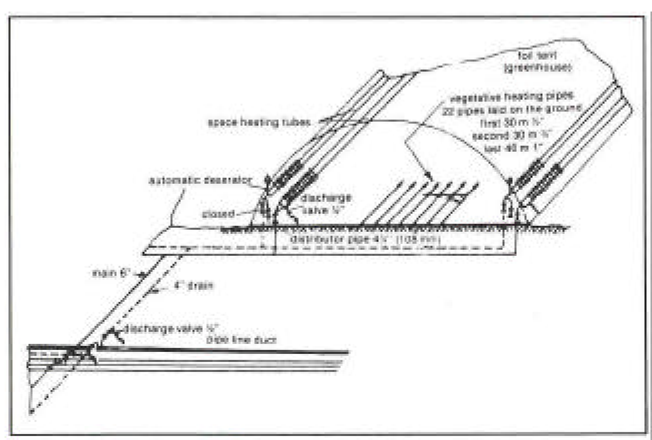

Figure 8. **Scheme of vegetation heating system.**

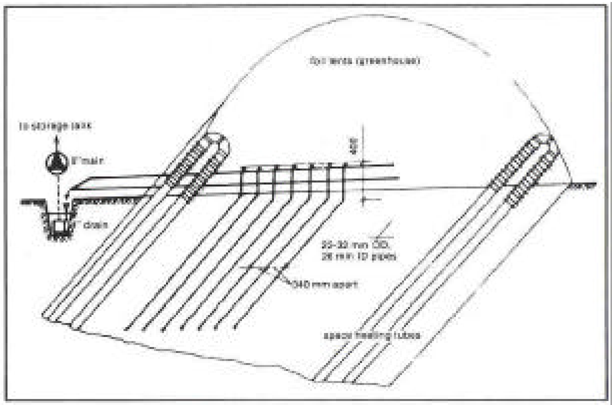

Figure 9. **Scheme of system with the combination of space and soil heating.**

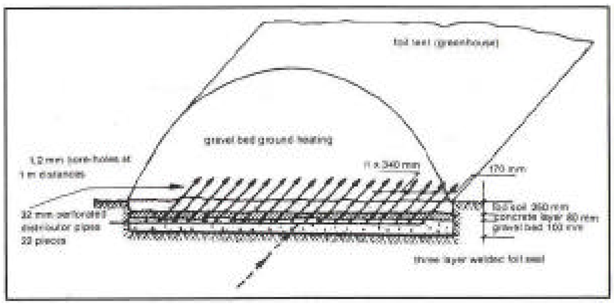

Figure 10. **Soil heating by pebble bed.**

EXAMPLES OF A MODERN AGRICULTURAL FARM

Automatic controls have been recently introduced in a number of agricultural farms. These systems save energy and increase crop yields, thus providing a rapid payback period (estimated at one year). An example of an automatic control system is illustrated in Figure 11. The details are described in Karai, et al. (1990). There are two sites in the country where the geothermal heating system for greenhouses is fully computerized. These installations have their own meteorological station measuring the outside temperature, the solar radiation and wind speed. These input data control the amount of water that flows from the wells, as well as controlling ventilation, etc. A computer program, developed by the Danes, is used to monitor and control the operation.

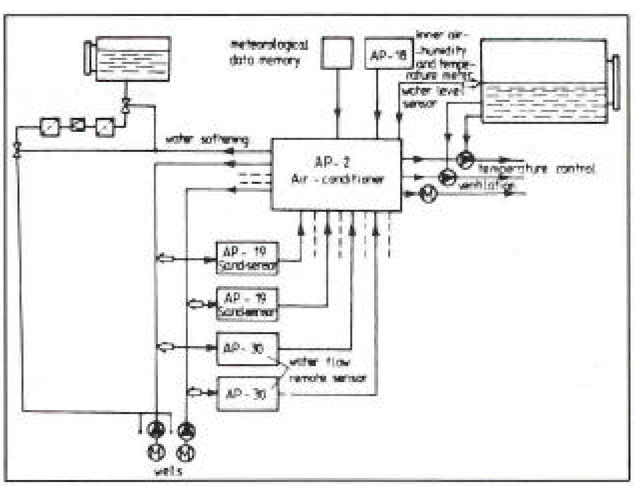

Figure11. **Computer controlled geothermal heating system.**

The best example of this modern installation is the "Arpad" Agricultural Cooperative in Szentes in southern Hungary. Here 18,500 acres (7,500 ha) of land are used to grow vegetables (tomatoes, cucumbers, lettuce, yellow peppers, and the main crop of red peppers for paprika). Geothermal fluids are used to heat 54 acres (22 ha) of glass greenhouses and 37 acres (15 ha) of plastic tents (Figures 4 and 5). Approximately 70% of their produce is exported.

Fourteen wells, 5,900 to 7,900 feet (1,800 to 2,400 m) deep and located 2 to 3 miles (3 to 4 km) away, provide 169 to 194ºF (76 to 90ºC) water to the complex. These wells also provide water for heating buildings and for animal breeding. A total of 1,200,000 turkeys; 600,000 geese and 1,800 cows (600 for milking) are raised each year.

The cooperative was originally established in 1960, using a well drilled for heating a hospital. Their first well was drilled in 1964. The wells were originally artesian, but now require pumping. The water is used directly in the heating system without heat exchanger.

A three-staged heating system is used in the greenhouses, similar to that described earlier in this article. Those above the ground are located 8 to 10 feet (2.5 to 3.0 m) above the surface. The plastic tents are 650 feet (200 m) long and are constructed with a double layer of plastic. Two sets of plastic pipes are used for heating, one on the surface and the other buried 24 inches (60 cm) below the surface. Working in these long "tunnels" during the summer without ventilation must be a real survival test.

Nearby is a 16.5 ton/hr (15 tonne/hr) geothermal drying facility (Figure 12). It is used to dry peas, corn and rice by a gravity flow system. The grain is introduced through the top and counter flows with the geothermally-heated air introduced from the bottom. Approximately 20% moisture is removed from the grain.

Figure 12. **Geothermal grain drier at Szentes.**

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