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State, Possible Future Developments in and Barriers to the Exploration and Exploitation of Geothermal Energy in Austria – Country Update

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ABSTRACT

In the 1977-2004 period a total of 63 geothermal exploration wells with a total length of some 100 km have been drilled for geothermal energy in Austria. A large number of wells were intended for tapping thermal waters for balneological use (curing, thermal spas, leisure resorts, hotels etc.). Drilling activities focused on the Styrian Basin and the Upper Austrian Molasse Basin where a high number of geothermal installations and wells for balneological use exists. Since the mid-1990s thermal exploration has also taken place in the hard rock formations of the Alps. These projects have a much higher geological risk than projects in the sediment basins that have been explored by the hydrocarbon industry for centuries. All wells in the Alps were drilled for balneological purposes.

Installed thermal capacity (deep geothermal) in Austria equals 61 MW. 7 geothermal doublets are operating in Austria at present, 6 of them are in the Upper Austrian Molasse Basin. Electric power generation is performed at two sites with a total installed capacity of 1.2 MWe. The reinjection of thermal fluids after use had a positive effect on the aquifer pressure at a regional scale.

Some legal and economic barriers hamper a broader use of geothermal energy in Austria. Economic problems can be overcome by combining different users at one site as it was demonstrated by the Geinberg cascade. Cascade use including generation of electrical power will be very important for the future development of the geothermal business in boosting the economic viability of the projects.

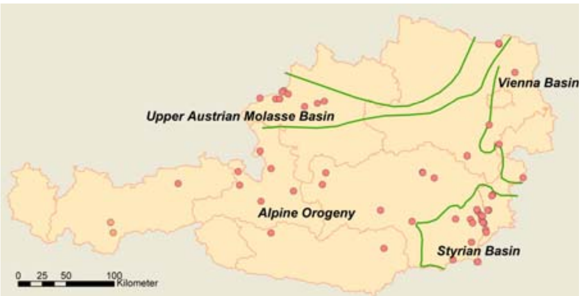

Figure 1: Geothermal exploration wells in Austria (1977-2004).

1. INTRODUCTION

Austria (area 83,858 km², 8.05 million inhabitants in 2002) is subdivided into different geological units, which differ grossly in their hydrogeological properties and their geothermal conditions. Approximately two thirds of the Republic's area is covered by the Eastern Alps, which reach a maximum altitude of nearly 4,000 m (mountain Grossglockner).

Favourable conditions for exploiting geothermal energy exist in the Alpine–Carpathian intramontane basins (Vienna Basin, Pannonian/Danube and Styrian Basin) and the Molasse Basin. The Vienna Basin, which is situated in the transition zone between the Alps and the Carpathians and was created by lateral movements and subsidence during and after the Alpine orogeny, has not seen intensive geothermal exploration so far. It is a main target for hydrocarbon exploration. Some 3,500 wells have been drilled here since the 1930s for exploration and exploitation of hydrocarbons from the basin filling and the basin floor, consisting of allochtonous Alpine units and subthrust floors (HAMILTON, WAGNER & WESSELY, 2000). Favourable geothermal conditions exist in some parts of the basin due to convective heat flow (examples: Oberlaa High south of Vienna and south-eastern part of the basin). An open hole test in the hydrocarbon drilling Aspern proofed temperatures > 100 °C from an aquifer in dolomites of the Calcareous Alps in the allochtonous basin floor (drilling Aspern 1, interval 3,106 – 3,296, artesian overflow 11.6 l/s, RONNER, 1980).

Main geothermal exploration and drilling activity took place in the Styrian Basin, followed by the Upper Austrian Molasse Basin. The area of the Eastern Alps has seen increased drilling activity since 1998 (Table 1, Figure 1).

Table 1: Drilling for thermal water in Austria (period 1977 – 2004).

Unit	No. of wells	Average depth (m)	Cumulative depth (m)
Styrian Basin	26	1,565	40,699
Upper Austrian Molasse Basin	12	2,088	25,056
Vienna Basin and Lower Austrian Molasse Basin	5	1,072	5,360
Northern Calcareous Alps and Upper Austroalpine Units carbonate rocks)	9	1,577	14,190
Lower, Middle and Upper Austroalpine Units (mainly crystalline rocks)	11	1,674	18,415
Total	63		103,720

2. UPPER AUSTRIAN MOLASSE BASIN

2.1 Geological conditions

The Upper Austrian Molasse Basin offers the best conditions for the exploitation of geothermal energy. This is due to enhanced terrestrial heat flow values (up to 95 mW/m²) and low mineralized geothermal fluids. The main aquifer is in autochthonous Upper Jurassic limestones and dolomites in the pre-Neogene/Paleogene basin floor, which are covered by Upper Cretaceous and/or Paleogene-Neogene mainly clastic sediments. The Upper Cretaceous sediments, which are mainly pelitic, act as a cap rock. Due to the generally southward dipping, top of the Upper Jurassic Carbonate Rocks is more than 4,000 m below surface at the border of the Alps. Maximum thickness of the carbonate rocks is in the order of 750 m (NACHTMANN & WAGNER, 1987). Aquifer properties are given by dolomitization and fracturing linked with fault systems of different age. Pre-Neogene faults with vertical throws of up to 1,000 m strike mainly NW-SE and cut the Jurassic and Cretaceous sediments, whereas the Oligocene extensional faults show a W – E trend and a vertical throw of up to 300 m.

The most favourable conditions for tapping thermal waters from the Upper Jurassic Carbonate Aquifer are found in the Innviertel region near the border with Germany, where a high density of geothermal installations and wells for balneological use in spas can be observed (Figure 2). The depth of the Upper Jurassic aquifer ranges from 1,000 m to 2,300 m in this region thus allowing water temperatures from 50 to 105 °C (Figure 3).

The thermal waters are uniform in their hydrochemical properties. They are of the sodium-bicarbonate-chloride type, their TDS range from 1.2 – 1.5 g/l. Isotope investigations showed that the proportion of meteoric recharge in these waters is > 90 %. Water production by single wells during the 1980s and 1990s led to a significant pressure decrease. The negative development was overcome by reinjection measures by the Austrian geothermal installations starting in 1998 and leading to a regional pressure increase of about 1 bar within one year.

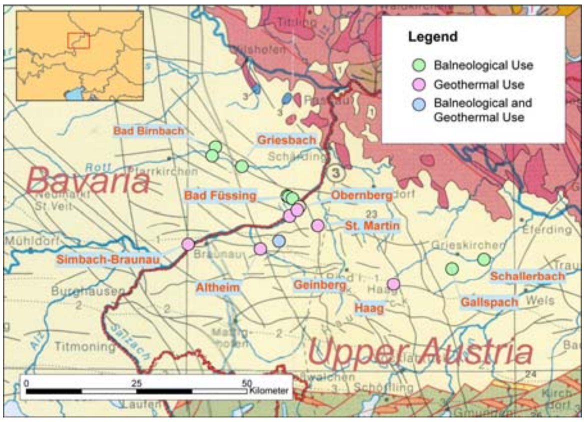

Figure 2: Geothermal wells and wells for balneological use in the Upper Austrian/Bavarian border region.

Table 2 gives a view of the geothermal installations in the Upper Austrian Molasse Basin. The most important installations are Geinberg, Altheim and Simbach-Braunau.

Table 2: Geothermal installations in the Upper Austrian Molasse Basin.

Locality	Altheim	Geinberg	Obernberg	Simbach/ Braunau	St. Martin	Haag
Type	D, E	I, D, B, G	D, E	D	D	D
Capacity (MWt)	18.8	7.8	1.7	9.3	3.3	2.2
Flow Rate l/s	80	25	20	74	20	20
Temperature (°C)	105	105	80	80	90	86
Year of implementation	1990, doublet 1999	1981, doutlet 1998	1996/ 97	2001	2000	1995
District-heating net (km)	14.5	6	17	30	25	12

I = Industrial use, E = Electricity, B = Balneologic, G = Greenhouse, D = District heating

2.2 Geinberg Project

In the small village of Geinberg, situated 5 km from the German border, one of the first geothermal projects was launched in 1980. It was based on an abandoned hydrocarbon exploration well drilled in 1974, which reached the Upper Jurassic carbonate rocks at 2,127 m depth and had to be terminated at 2,166 m after heavy mud losses. After a re-entry and deepening to 2,180 m in 1978, the well was completed as a single geothermal well producing some 22 l/s thermal water at artesian overflow at a temperature of > 100 °C. A small district heating project in the village of Geinberg has been developed since 1980. Due to the general pressure decrease in the Innviertel region, artesian overflow dropped to some 11 l/s in the 1990s. In 1998 a spa and hotel resort was built, thus increasing the need for geothermal energy on the one hand and thermal water for bathing, cures and recreation on the other. The precondition of the water authorities for stabilisation of the aquifer pressure and the growing demand for thermal water caused the planning of a second well to complete a geothermal doublet.

The new "Geinberg Thermal 2" well, partly financed by the THERMIE European programme, was designed as a deviated well situated 20 m from the existing well. In order to prevent a hydraulic shortcut between abstraction and reinjection, the distance of the wells in the aquifer is some 1,600 m. Deviation was directed north, the inclination reached a maximum of 64 °, the build-up rate was 2 °/30 m at maximum. The top of the Upper Jurassic carbonate rocks was tapped at 2,910 m MD (2,117 m TVD). So the vertical depth of aquifer differs only slightly from Geinberg 1 (2,127 m). The bore reached a measured depth (MD) of 3,155 m corresponding to a true vertical depth (TVD) of 2,225 m.

Geinberg is an example of geothermal cascade use. Thermal water is produced at the Geinberg Thermal 2 well at a maximum artesian free overflow rate of 25 l/s. The primary use in the upper thermal segment is for the dairy for industrial processes and the district heating of the village of Geinberg, where 24 private houses and public buildings are heated. The next step in the cascade is the heating of the spa centre and the hotel resort, where the water is cooled down from 75 to 43 °C. In the spa, thermal water is used for swimming and recreation. A quantity of 5 l/s maximum, in practice much less, is not reinjected. The third step of the cascade with an installed capacity of 2 MW is covered by greenhouse use (1.7 ha). The total installed thermal capacity equals 7.8 MW. A temperature interval of 70 °C is used and water is cooled to 30 °C before re-injection. This makes Geinberg the most effective geothermal plant in Austria. The low reinjection temperature allows reinjection without additional pumping because of the higher density of the fluid at that temperature. On the other hand, the low density of the thermal water at 100 to 105 °C enables free overflow in the Thermal 2 well.

2.3 Altheim Project (District heating, power generation)

Altheim is an example of the successful exploration and exploitation of geothermal energy by a small community. The village of 5,000 inhabitants is 5 km away from Geinberg. The first Altheim Thermal 1 well was drilled in 1989/90 and reached an end depth of 2,472 m in the basement rocks of the Bohemian Massif. The top of the Upper Jurassic carbonates was encountered at 2,146.8 m, thus only 20 m deeper than in Geinberg. The thickness of the Upper Jurassic carbonates is 282.5 m; permeabilities caused by fracturing zones were observed mainly in the dolomites and dolomitic limestones of the Purbeck (2,150 – 2,305 m). Outflow tests showed a free overflow of 11 l/s. Following technical problems, sidetrack-operation at a depth of 1,772 m was performed at an angle of 4.8 °. The top of the carbonate rocks was reached 20 m south of the abandoned borehole and closer to the fault. Due to this measure, the free outflow increased to 18 l/s. After stimulation with 7.5 % hydrochloric acid, free overflow was 46 l/s (166 m³/h) at a wellhead temperature of 105 °C.

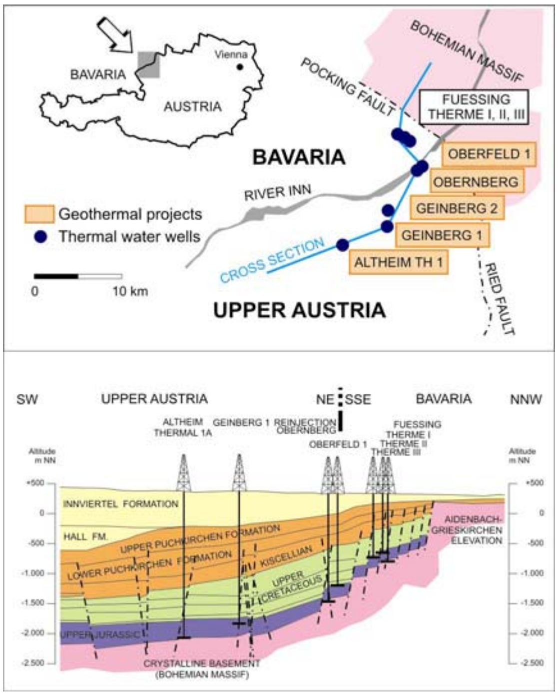

Figure 3: Geologic profile Altheim-Fuessing.

In 1998/99 a reinjection well was drilled at a distance of 50 m from well #1. This is a deviated borehole with a measured depth of 3,078 m, which corresponds to a true vertical depth of 2,165 m; the horizontal distance in the aquifer is 1,600 m, azimut is 178 °. At the end depth of the drilling, heavy mud losses were encountered, which put an end to the drilling operation.

By 2000, Altheim was the first geothermal project to implement ORC (Organic Rankine Cycle) technology for electrical power generation. For this purpose the production rate had to be increased to a maximum of 100 l/s (360 m³/h). A five stage submersible pump with an electrical power of 350 kW was installed at 290 m (PERNECKER, 2000). Reinjection pressure at the head of the Altheim Thermal 2 well was found to be 16 bars at a temperature of 70 °C. The net output of the ORC installation is some 500 kW at a flow rate 82 l/s. Established since 1991, the district heating scheme meets the heating demand of 650 consumers requiring a geothermal power of 10 MW. 40 % of the inhabitants of Altheim are supplied with geothermal energy (PERNECKER, l.c.).

2.4. Simbach-Braunau geothermal project

The largest geothermal project in the South German/Upper Austrian Molasse Basin is at Simbach/Braunau. This German/Austrian cross-border project was launched in 1997, when the two towns of Simbach and Braunau teamed up with regional energy suppliers to form a private limited company for the exploration and use of geothermal energy for district heating purposes. The project was supported by the European Union within the scope of the THERMIE programme.

The geothermal doublet (Figure 4) was situated in Simbach, Bavaria, close to the border with Austria. The first Simbach-Braunau Thermal 1 well is a vertical well which reached the top of the Upper Jurassic carbonate rocks at a depth of 1,737 m. Due to intensive fracturing and carstification the free artesian overflow from the well was measured as high as 81 l/s (292 m³/h). Outflow temperature was 76 °C. Transmissivity of the aquifer is as high as 4 * 10^{-2} m²/s.

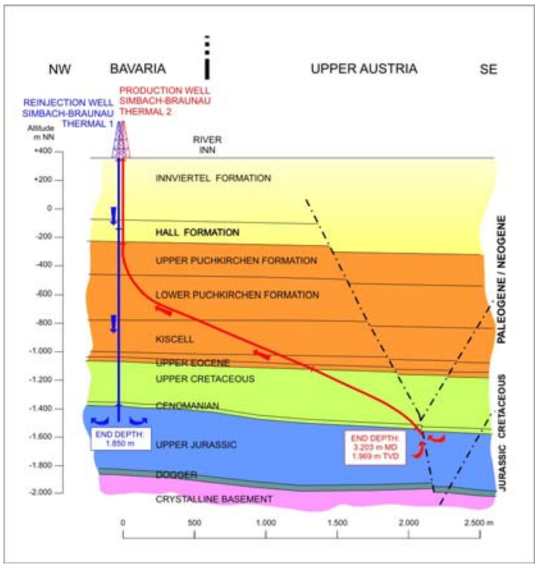

Figure 4: Doublet Simbach-Braunau.

The second well was drilled at a distance of only 15 m to the vertical well in order to make use of the installations of the common drill site. It is a deviated well that has its geological target at a horizontal distance of more than 2,000 m from the vertical well. The well reached the aquifer within the territory of Austria, thus making it the first water well to be drilled from one state to the other. This was made simpler by the fact that both countries are members of the European Union. Due to the deviation, the total depth of the well is 3,203 m, compared to 1,848 m in the case of the first well. The inclination of the well is 67 °. Because of the higher production temperature of 80.5 °C the deviated well was scheduled as a production well. An electrical submersible pump was installed at a depth of 150 m. The maximum production rate is 74 l/s. The vertical Simbach Braunau Thermal 1 well is used as a reinjection well (Figure 4); maximum reinjection pressure is 4 bars.

Simbach-Braunau is one of the largest district heating schemes in Central Europe. The length of the pipe system is 30 km; the installed thermal capacity is over 30 MW; the number of consumers is 500; and geothermal produced energy is in the order of 9.3 MW.

3. STYRIAN BASIN

3.1 Geological conditions

The second most prospective geothermal province in Austria is the Styrian Basin. It is a sub-basin of the Pannonian Basin separated in the subsurface and in some regions at the surface by the Burgenland swell. The Styrian Basin is a Miocene extensional basin. Heat flow values of up to 95 mW/m² allow temperatures of more than 100 °C at a depth of 2 km. The basement of the basin is composed of high-grade metamorphic crystalline and anchimetamorphic Paleozoic phyllites and carbonates of the Austroalpine nappe complex. The Paleozoic carbonate rocks (limestones and dolomites) form an important deep aquifer offering good prerequisites for the use of geothermal energy. The basin fill consists of sediments of Karpatian to Upper Miocene age with a maximum thickness of 2,900 m. Aquifers bearing thermal waters are in the Badenian and Sarmatian sequence. These aquifers are used for balneological purposes. Since 1972 six new spas have been established in this formerly economically weak region. Table 3 gives a view of thermal wells drilled from 1977 – 2004 in the Styrian Basin.

The Styrian basin is characterised by the occurrence of volcanism (Karpatian/Lower Badenian andesitic volcanism and basaltic volcanoes at the end of the Pliocene). The occurrence of carbon dioxide in some parts of the basin is linked to Neogene volcanism (Figure 5). Cold carbon dioxide waters are bottled by several companies in the south-eastern part of the basin. In thermal waters the occurrence of carbon dioxide causes problems by scaling after degassing.

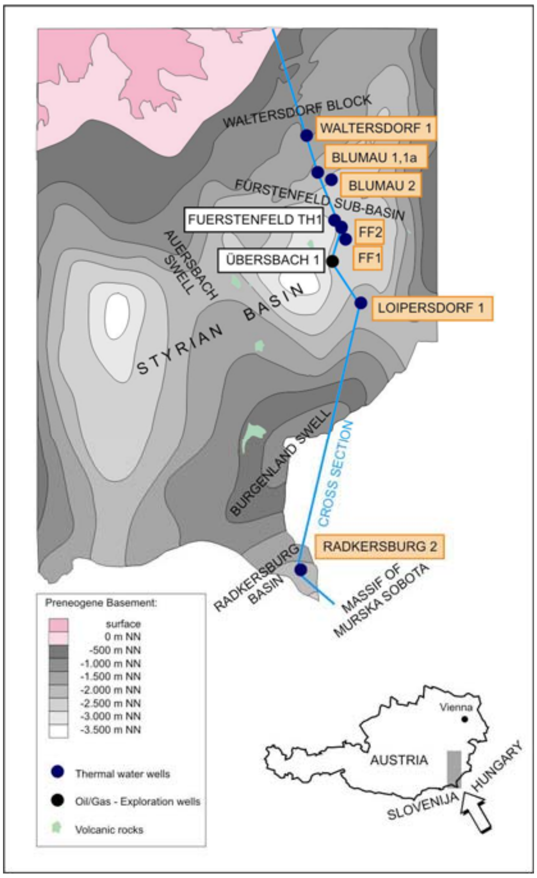

Figure 5: Map of the Eastern part of the Styrian Basin.

Table 3: Selection of wells in the Styrian Basin (period 1977 – 2004).

Well	Year	End Depth (m)	T (°C)*	Production interval (m)	Reservoir rocks	Stratigraphy	Production rate (l/s)	T (°C) **	TDS (g/l)	Water type	Use
Blumau 3	1995	1200	53,2	638,9 - 952,0	sandstones	Sarmatian	1,20	39,5	1,3	Na-HCO3	B
Blumau 2	1995/96	2843	123,9	2362,5 - 2843	dolomites	Paleozoic	25,00	110	18-20	Na-Cl-HCO3	D, E, B, G
Ilz Thermal 1	1998	1906	89,8	814,0 - 708,3	sandstones	Badenian	1,20	45,2	5,1	Na-HCO3	B
Radkersburg 3/3a	1998/2001	1917	***	1965 - 1795,7	dolomites	Triassic	16,00	74,4	8,5	Na-HCO3	B
Fuerstenfeld FF 1	1999	1950	82	1909,6 - 1657,8	sandstones	Badenian	21,80	85,0	57,6	Na-Cl	D
Fuerstenfeld FF 2	1999	1800	74	1786,9 - 1535,0	sandstones	Badenian	14,30	84,1	46,3	Na-Cl	D
Stegersbach Thermal 2	1999	1200	48,5	850,0 - 790,0	sandstones	Sarmatian	3,00	42,0	1,28	Na-HCO3	B
Koeflach Thermal 1	1999	1039	35,9	819,9 - 1032,4	limestones	Paleozoic	3,00	28,9	0,38	Ca-Mg-HCO3-SO4	B
Ottendorf Thermal 1	2002	970	44,5	663,0 - 627,7	sandstones	Sarmatian	1,80	46,2	2,29	Na-HCO3	B
Bad Gleichenberg Th. 1	2001	1503	85	1489 - 619,4	volcanic rocks	Karpatian/Badenian	3,00	48,5	10,02	Na-HCO3-Cl	B
Gersdorf Thermal 1	2002	2430	-	-	-	-	-	-	-	-	dry
Bad Tatzmannsdorf Th. 2	2002	1620	-	-	-	-	-	-	-	-	dry
Waltersdorf 4	2002	1061	55	498 - 474,6	sandstones	Sarmatian	2,75	33,5	0,78	Na-HCO3	B
Jennersdorf Thermal 1	2003/04	1750	***	***	sandstones	Sarmatian	***	***	***	***	B

* at end depth

** at well head

*** no data available

B = balneologic, D = district heating, E = Electricity, G = Gas (CO2)

Figure 6 shows a geological profile which crosses the Styrian basin in the area of the Fuerstenfeld sub-basin. At a high structural level the Paleozoic carbonate aquifer was found to bear relatively low mineralized thermal waters of meteoric origin. At Waltersdorf two wells produce thermal water from Devonian dolomites at a depth of 1,100 m. The well-head temperatures are 61 and 68 °C respectively, the cumulative pumping rate is 22 l/s; TDS of the water is 1.5 g/l (sodium-bicarbonate-chloride type). The origin of the water is entirely meteoric. By 1978 Waltersdorf was the first geothermal project in Austria to include a small district heating scheme and the heating of a greenhouse and folia tunnels. Since 1984 a thermal spa and connected hotels has increased the need for thermal water. The current geothermal capacity at Waltersdorf equals 2.3 MW.

The Blumau geothermal project is situated 4 km south of Waltersdorf. In this area the Paleozoic carbonate aquifer is separated from the Waltersdorf region by a fault with a throw of more than 1,000 m. As a result, the hydrocarbon exploration well Blumau 1a well reached the fractured dolomites at a depth of 2,563 m and was terminated at a depth of 3,046 m after heavy mud losses. In 1995 a large-scale geothermal and balneological project was launched. In the course of the project a 1,200 m well intended for spa use was drilled, followed by a deep geothermal well which reached an end depth of 2,843 m and tapped the carbonate aquifer at a depth of some 2,360 m. Long-term outflow tests showed a maximum overflow rate of 80 l/s at a temperature of 110 °C, making Blumau the hottest well in Austria and Southern Germany. Gas/water ratio was found to be as high

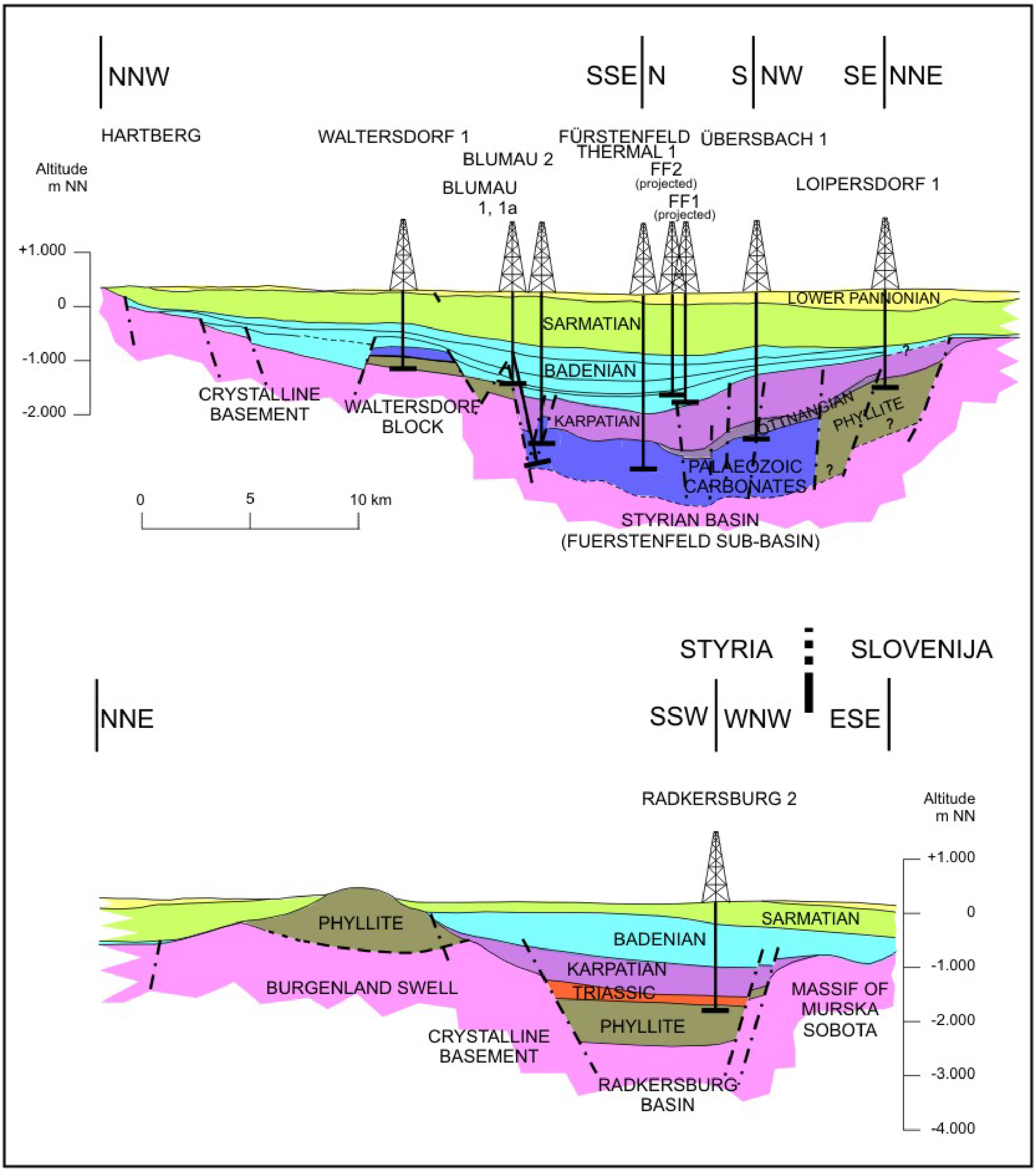

Figure 6: Cross section – Styrian Basin.

as 9 : 1, the gas phase being nearly entire CO_2. Degassing of CO_2 at the Upper Section of the well and at the well head caused heavy carbonate scaling.

The precipitation of carbonate minerals was overcome by adding polyphosphate to the water flow at a depth of 500 m. The polyphosphate results in complexation of calcium thus preventing the development of $CaCO_3$. Maximum admissible artesian flow is 30 l/s showing stable hydrochemical conditions. Thermal water is used for heating the spa complex and the hotels; the thermal output is as high as 5 MW. In 2001 an air-cooled ORC turbine was installed with a net output of 180 kW of electrical current. As a last step, the use of the CO_2 gas was realized at the end of 2002. The capacity is 1.5 t/h liquid CO_2 (Figure 7).

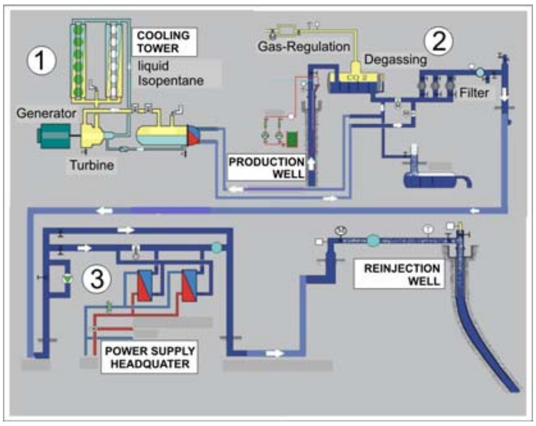

Figure 7: Blumau geothermal project: (1) ORC, (2) CO_2-gas, (3) district heating.

Water is reinjected in the Blumau 1a well; the maximum reinjection pressure is in the order of 7 bar.

4. GEOTHERMAL EXPLORATION IN THE ALPS

4.1. Preliminary remarks

The economic success of the spas in the Styrian basin and the Upper Austrian Molasse basin has stimulated exploration for thermal waters in the Alpine regions since 1990, although the geological units of the Alps are less prospective. This is due to the fact that heat flow values are generally lower in the Alps and the hydrogeological properties of the rocks are less favourable. As the alpine units have not been a main target for hydrocarbon exploration, geological and geophysical data (especially from reflection seismic) are scarce, thus increasing the risk of unsuccessful thermal projects.

4.2. Laengenfeld thermal project (Tyrol)

Situated in the Oetztal valley (in the federal province of Tyrol), Laengenfeld is an example of a successful alpine thermal water project. The altitude of the village of Laengenfeld is 1,100 m a.s.l. The peaks of the surrounding Oetztal and Stubai Mountains reach altitudes of up to 3,300 m above sea level.

In Laengenfeld, polymetamorphic rocks of the Oetztal-Stubai Crystalline Complex crop out. This Middle Austroalpine unit of metapelites, orthogneiss and amphibolites is characterised by a dominant amphibolite-facies Variscan event. The Buendner Schiefer is thought to underlie the crystalline Complex at a depth of about 2,000 m.

On the eastern edge of the valley a natural sulphide spring of the Ca-Na-HCO_3-type (TDS 160 mg/l, temperature 12 °C, discharge 1 l/s) has been known since ancient times and was used for recreational purposes. It was the outflow of a tectonically induced ascending flow system in the jointed crystalline rocks. To increase temperature and mineralization of the water, some shallow wells were sunk in the vicinity of the spring followed by a 900 m drilling (well Thermal 1; Figure 8) in 1992, which failed because of technical problems. In the mid 1990s a second well, Laengenfeld Thermal 2, was drilled some 100 m apart from well Laengenfeld Thermal 1 with the aim of exploiting thermal water for spa utilization. This design of drilling operation by Geoteam was based on geological and tectonic investigations by MOSTLER (1995) evaluating strong brittle deformation of the metamorphic rocks at the eastern edge of the Oetztal valley induced by regional strike-slip faults parallel to the Oetztal valley. Several zones of brittle deformation had been distinguished in the amphibolites and eclogites and were interpreted as cataclastic rocks or fault breccias. These cataclastic zones were considered to exhibit good aquifer properties and were defined as the main targets for the deep drilling.

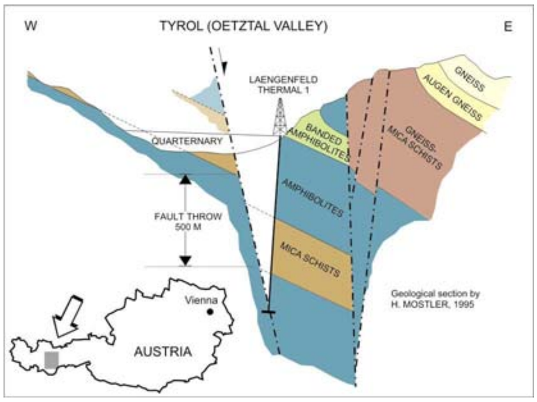

Figure 8: Geological Cross-Section of the eastern part of the Oetztal valley.

Because of the almost vertical dipping of the cataclastic zones, the well had to be designed as a deviated well. The directional drilling kicked off at 877 m. At a measured depth of 1,480 m the maximum inclination of the well was reached at 28°. From this point to the bottom hole at the measured depth of 1,865 m the angle was kept constant. The measured depth at the bottom hole corresponds to a true vertical depth of 1,800 m. At this depth there is a horizontal displacement from the vertical of about 195 m (direction SE). The section between 811 m (setting depth of 9.5/8" casing) and 1,865 m measured depth was drilled with 8.1/2" bit and remained open without completion (Figure 9).

In the open-hole section different types of amphibolites in interplay with mica schist occur. Distinct fracture zones were identified by changes in penetration rate during drilling and open-hole borehole logs including flow meter measurements between 890 and 1,000 m, 1,490 – 1.540 m and 1,800 – 1,835 m respectively. The net pay is as high as 60 m. At a production rate of 4.5 l/s (389 m³/d) a drawdown of 450 m was observed.

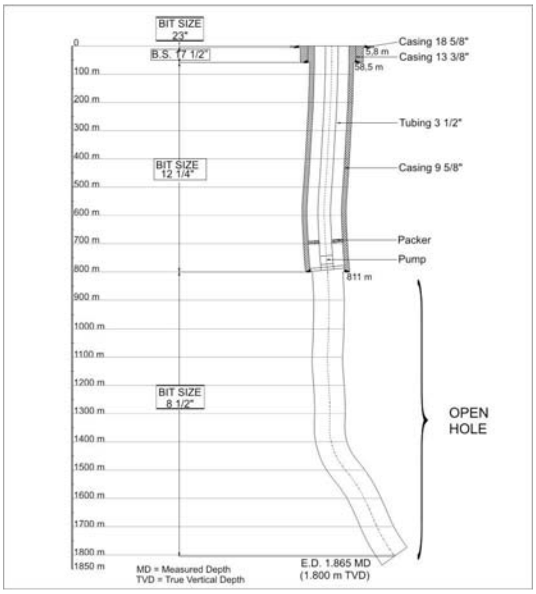

Figure 9: Completion scheme of the thermal well Laengenfeld Thermal 2.

Hydraulic evaluation of the pumping tests yields transmissivity of $T=1.29\times10^{-5}\,m^2/s$ of the aquifer on average. Considering a thickness of 60 m, the hydraulic conductivity k for the aquifer in the crystalline rocks is 2.15×10^{-7} m/s. The storage coefficient was estimated regarding the compressibility of the rock and the water respectively. This value amounts to $S=3.13\times10^{-5}\,m^2/s$ (KRIEGL et al., 2001).

Maximum borehole temperature was measured at 69 °C. Well-head temperature during production tests reached 47 °C at a production rate of 4.5 l/s. The thermal water differs grossly in water type and mineralization to the sulphide spring at surface. It is of the $Na\text{-}Cl\text{-}SO_4$ water type with TDS of 430 mg/l. The high sulphide content of 10 mg/l is the result of subsequent reduction of sulphate. Sulphur-isotopes show that the sulphate can be derived from oxidation of pyrite. The water pH of 9.8 is remarkable. This is the highest value ever found in natural groundwaters in Austria.

The success of the Laengenfeld project formed the starting point for the construction of a thermal spa, which will open in autumn 2004.

5. BARRIERS AND POSSIBLE FUTURE DEVELOPMENTS

Barriers to the enhanced use of geothermal energy in Austria are provided by Austrian water law, which states that the groundwater below the land belongs to the landowner, regardless of depth. This fact is extremely important when deviated drillings have to be realized.

The second barrier to a broader geothermal use is the priority of the balneological use, which leads to limitation of further geothermal projects despite reinjection measures; fears on the part of the spa enterprises concerning reduction of underground temperatures and changes in water and gas chemistry could not be dissipated in public discussions. Concurrence between different geothermal users could hamper future geothermal projects in the most prospective areas of the Upper Austrian Molasse Basin and the Styrian Basin, which have already reached a relative high density of installations.

The third barrier is the lack of public support through national geothermal programmes.

The fourth barrier is the difficulty of combining different users, especially district heating and agricultural use at a specific site.

This combination of different users in geothermal cascades including generation of electrical power will be very important for the future development of the geothermal business in boosting the economic viability of the projects. Public reimbursement for geothermal electrical power in Austria was fixed at 7 Euro Cent per kWh. At more than double as much, the rate in Germany has given impetus to a large number of projects. Increasing the reimbursement rate in Austria would help to stimulate projects in the deep sedimentary basins, especially in the Vienna Basin which has been lacking geothermal installations so far.

REFERENCES

Hamilton, W., Wagner, L. and Wessely, G.: Oil and Gas in Austria, *Mitt.Oesterr.Geol.Ges., 92* (2000).

Kriegl, Ch., Vasvari, V. and Goldbrunner, J.: Deep drilling Laengenfeld Thermal 2 – First hydrogeological results from a deviated well in metamorphic rocks of the Austroalpine Oetztal-Stubai crystalline complex, Tyrol, *Proceedings of the XXXI nternational Association of Hydrogeologists Congress Munich/Germany, Vol 2* (2001).

Mostler, H.: Geologische Untersuchungen zur Festlegung eines Bohrpunktes (Tiefbohrung zur Erschließung warmer Schwefelwasser; Laengenfeld in Tirol), *Unpublished final report* (1995).

Nachtmann, W. and Wagner, L.: Mesozoic and Early Tertiary Evolution of the Alpine foreland in Upper Austria and Salzburg, Austria, *Tectonophysics*, 137 (1987).

Pernecker, G.: Geothermische Energieversorgung Altheim – Waerme und Strom, *Tagungsband Geothermie in der Praxis* (2000).

Ronner, F.: Geothermische Energie.- In: R.Oberhauser (Ed.) Der geologische Aufbau Oesterreichs, 574 – 579, Springer, Wien–New York (1980).

GEOTHERMAL UTILISATION – OVERVIEW

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2004	1,2	3,2									1,2	3,2
Under construction in December 2004	-	-										
Funds committed, but not yet under construction in December 2004	-	-										
Total projected use by 2010	6	15									6	15

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2004

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)
2F = Double Flash H = Hybrid (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

3) Data for 2004 if available, otherwise for 2003. Please specify which.

Locality	Power Plant Name	Year Commissioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe	Annual Energy Produced 2004[3)] GWh/yr	Total under Constr. or Planned MWe
Blumau	Blumau	2001	1		ORC	0.2	1,2	
Altheim	Altheim	2002	1		ORC	1.0	2,0	
Total							3,2	

3) Data are for 2003

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2004 (other than heat pumps)

1) I = Industrial process heat; H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling); D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology)
F = Fish farming; G = Greenhouse and soil heating
K = Animal farming; O = Other (please specify by footnote)
S = Snow melting; E = Electricity (ORC)

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

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

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

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Altheim	D, E	100	105	60			18,8	40	237,4	0,4
Geinberg	I, D, B, G	25	105	30			7,8	17	168,2	0,7
Simbach-Braunau	D	74	80	50			9,3	50	197,9	0,7
Obernberg	D	20	80	50			2,5	8	31,7	0,4
St. Martin im Innkreis	D	20	90	50			3,3	8	42,2	0,4
Haag am Hausruck	D	20	86	50			3,0	8	38,0	0,4
Bad Schallerbach	B, D	55	38	15			5,3	30	91,0	0,5
Bad Blumau	B, D, E	30	110	50			7,5	25	197,9	0,8
Bad Waltersdorf	B, D	17	63	30			2,3	10	43,5	0,6
Loipersdorf	B	4	61	30			0,5	3,5	14,3	0,9
Bad Radkersburg	B	5	70	30			0,8	4	21,1	0,8
TOTAL		370	888	445			61,4	203,5	1083,1	

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2004

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

Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps
Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)
Report the COP = (output thermal energy/input energy of compressor) for your climate
Report the equivalent full load operating hours per year, or = capacity factor x 8760
Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (^oC)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
No detailed information available; a total number of some 25,000 installations can be assumed by 2004.								
TOTAL								

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

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

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

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

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	-	-	-
District Heating [4]	45,5	643,7	0,5
Air Conditioning (Cooling)	-	-	-
Greenhouse Heating	1,8	26,4	0,5
Fish Farming	-	-	-
Animal Farming	-	-	-
Agricultural Drying[5]	-	-	-
Industrial Process Heat[6]	2,1	44,8	0,7
Snow Melting	-	-	-
Bathing and Swimming[7]	2,6	65	0,9
Electricity (ORC)	10,5	204,4	0,7
Subtotal	62,5	984,3	
Geothermal Heat Pumps	No information available!		
TOTAL	62,5	984,3	

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

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

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

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)		13			20,16
Production	>150^o C					
	150-100^o C					
	<100^o C					
Injection	(all)					
Total			13	10		20,16

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

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	1			3		1
2001	1			3		4
2002	1			4		4
2003	1			4		4
2004	1			4		4
Total	4			18		17

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1990-1994	12,1	1,5	15,5		59	41
1995-1999	44,3	6	19	3	59	41
2000-2004	24,2	1,8	1,5		60	40