BAD BLUMAU (STYRIA, AUSTRIA) THE SUCCESS STORY OF COMBINED USE OF GEOTHERMAL ENERGY

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INTRODUCTION

The main geothermal resources of Austria (area 83,858 km², 8.05 million inhabitants in 2002, capital city Vienna) are in the sedimentary basins bordering the Eastern Alps (Styrian Basin, Upper Austrian Molasse Basin, Vienna Basin; Figure 1). In the 1977-2004 period, a total of 63 geothermal wells with a cumulative length of some 100 km have been drilled (Goldbrunner, 2005). A high percentage of these wells were intended for balneological use (thermal spas, curing, leisure resorts, hotels). The development of spas had an enormous economic impact especially in the Styrian Basin in SE Austria, where eight new spas were built between 1977 and 2004. Approximately 3.5 million guests visit the thermal spas per year (Hoenig, 2005). One of these spas, Bad Blumau, is an example for successful combination of the use of geothermal heat for power generation, district heating and direct use of the water for swimming and treatments.

Figure 1. Geothermal areas in Austria.

BAD BLUMAU GEOTHERMAL PROJECT

Geological Background

Bad Blumau is situated in the Styrian Basin which is a sub-basin of the Pannonian Basin separated in the subsurface and locally also at the surface by a swell zone, called the Burgenland swell. In contrast to the Pannonian Basin, no economically exploitable hydrocarbon resources have been detected in the Styrian Basin so far. The exploration drillings and seismic surveys of the hydrocarbon industry are the basis for the geothermal exploration.

The Styrian Basin is a Miocene extensional basin. Due to heat flow values of up to 95 mW/m², temperatures of more than 100°C are encountered at depth of 2,000 m. In the structurally higher parts, convective heat flow leads to local anomalies. The basement of the basin is composed of high-grade metamorphic crystalline rocks and anchimetamorphic Paleozoic phyllites and carbonate rocks of the Austroalpine nappe. The carbonate rocks (limestones and dolomites of mainly Devonian age) form an important deep aquifer which is suitable for the use of geothermal energy. The mainly clastic tertiary basin fill consists of sediments of Carpathian to Upper Miocene age with a maximum thickness of 2,900 m. Aquifers bearing thermal waters are in the Badenian and Sarmatian sequence and consist mainly of sand and sandstones with different clay and silt contents. As the transmissivities of the Miocene aquifers are one to two orders of magnitude lower than those in the Paleozoic carbonate rocks, they are exploited only for balneological use.

The success story of Austrian Spas in the second half of the 20th century has started in the Styrian Basin. In the period 1977-2004, 26 geothermal wells with a cumulated depth of 40.7 km were drilled here. More than 80% have been intended for balneology. Since 1977, eight new spas have been established in the region which until then had been dominated by agriculture.

Project History of Bad Blumau

The geothermal project of Bad Blumau had its origin in the hydrocarbon exploratory drilling Blumau 1. It explored a regionally developed normal fault with a throw of more than 1,000 m, thus separating the Paleozoic sequence (Figure 2). Blumau 1, situated in the uplifted part of the throw came into Paleozoic phyllites at a depth of 1,708 m without encountering carbonate rocks. After side track operation, the deviated drilling Blumau 1a ran parallel to the fault and reached fractured Paleozoic carbonate rocks at a measured depth of 2,664 m (2,583 m TVD). Due to fracturing, heavy mud losses occurred which forced drilling to be stopped at a depth of 3,046 m. According to mining regulations the bore had to be closed by setting cement plugs. Work over operations were performed in 1989 and resulted in a one month overflow test. A flow rate of 17 L/s at a temperature of approximately 100°C was encountered. Hydrochemical investigations showed a sodium-bicarbonate-chloride-water type with a TDS of 17.4 g/L. Degassing of CO_2 at the wellhead led to massive precipitation of carbonates. Due to a high organic content, a light red color of the water was observed.

The promising results of the well Blumau Thermal 1a stimulated plans for geothermal and balneological use of the resource. Geological and technical planning had to consider the establishment of a geothermal doublet and the drilling of

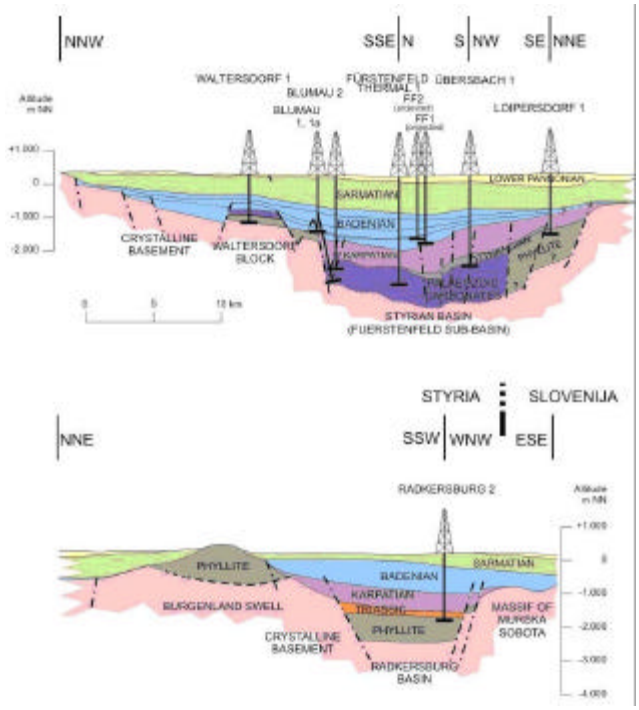

Figure 2. Geological profile.

a separate well intended for balneological use. The latter had to tap water with a mineralization much lower than of the well Blumau 1 without post volcanic CO_2 (Goldbrunner, 1993).

Well Blumau 3 which was intended for balneological use reached an end depth of 1,200 m. By single tests of perforated intervals of the 9-5/8" cemented casing productive intervals (sandy gravels) in the Sarmatian were determined in the section between 960 and 630 m. The hydrochemistry and the stable isotope content of the tested intervals differ only slightly thus proofing a uniform hydraulic system over a section of more than 300 m. The well was completed with stainless steel WWL-filters and a gravel pack (casing inside gravel pack). The hydrochemical composition of the water is presented in Table 1. Maximum temperature at well head is 47°C; artesian flow rate is 1.5 L/s (shut-in pressure at well head is 0.2 MPa), production tests with pump were performed at a flow rate of 8 L/s and a drawdown of 130 m. The transmissivity of the aquifer is 5.4 x 10^{-5} m^2/s.

Geothermal Cascade

The 250-kW geothermal project at Bad Blumau is the first geothermal project developed in Austria by the private sector following the deregulation of the electricity industry in this country. What makes the project unique besides its private ownership structure is its ability to generate electrical power and district heating for the Rogner Bad Blumau Hotel & Spa by using a low-temperature geothermal resource. Installed in the record time of less than a week, the air-cooled ORMAT® Energy Converter (OEC) CHP module has been in commercial operation since July 2001. With an annual availability exceeding 99%, between October 2001 and December 2002, the plant delivered 1,560,000 kWh to the local grid. The geothermal CHP module utilizes brine at ~110°C, available from a 300-m deep production well. Exiting the OEC unit at a temperature of ~85°C, the brine is then fed into the district heating system, providing heat for the Rogner Bad Blumau Hotel & Spa. The geothermal brine is returned from the district heating system and injected into a 3000-m depth reinjection well. The system is a pollution-free, unattended operating power generation module, which has avoided more than 1100 kg of CO_2 emissions over its first operating year (Legmann, 2003).

The thermal water of Blumau 3 is used for the pools in the spa (total area 2,500 m²). The spa and some outdoor pools are shown in Figure 3. Due to the favorable mineralization water treatment measures can be kept at a minimum. Production rate for the spa is 1.5 L/s and can be provided by the artesian overflow.

Table 1. Hydrochemical and Isotopic Composition of Thermal Water of the Well Bad Blumau 3 and Blumau 2 (Ionic concentration in mg/l)

Well	Bad Blumau 3	Bad Blumau 2
Depth of aquifer (m)	630 – 960	2,368 – 2,843
Sample date	1996	2003
Temperature (°C)	47	110
Sodium (Na^+)	345.9	5,799
Potassium (K^+)	3.3	129
Magnesium (Mg^{++})	2.8	6.4
Calcium (Ca^{++})	2.8	31.7
Chloride (Cl^-)	39.9	3,634
Iodine (I^-)	0.1	2.5
Sulfate (SO_4^{--})	12.8	508
Bicarbonate (HCO_3^-)	883.5	7,834
Sum	**1,291**	**17,942**
Water type	$Na\text{-}HCO_3$	$Na\text{-}Cl\text{-}HCO_3$
Free CO_2 (g/L)	<0.005	15.1
Deuterium (d ‰ SMOW)	-72.3	-57.5
Oxygen-18 (d ‰ SMOW)	-10.2	-7.97

Figure 3. Bad Blumau. Spa and outdoor pools.

Figure 4. ORC installation at well Blumau 2.

Figure 5. Installation for cleaning and drying CO_2 gas produced from well Blumau 2.

For heating the spa complex and the hotels the establishment of a geothermal doublet comprising the existing well Blumau 1a and a new well named "Blumau 2" was launched. This well was designed as a vertical well 2,300 m (at surface) apart from well Blumau 1a. Blumau 2 reached the Palaeozoic dolomites at a depth of 2,360 m and encountered fractured dolomites to its end depth of 2,843 m. Due to heavy mud losses, the section in the carbonate rocks (bit diameter 5-7/8") was drilled with water. The fracturing is caused by an antithetic fault which was passed at a depth of 2,368 m by the drilling. Top of the Palaeozoic dolomites is 222 m higher at Blumau 2 than in Blumau 1a. The horizontal difference between the two borings is 1,800 m at the top of the dolomite due to the deviation of well Blumau 1a.

Long-term outflow tests showed a maximum overflow rate as high as 80 L/s at a temperature of 110°C which makes Blumau the hottest thermal water well in Austria. Artesian flow is caused by degassing. The gas/water ratio was found to be high as 9:1, the gas phase being dominated by CO_2 (CO_2 = 97%). The hydrochemical composition of the water is similar to Blumau 1a. Production logs involving density measurements showed that degassing started at a depth of 560 m and became dominating at 300 m.

The precipitation of carbonates was overcome by adding polyphosphate 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.

The thermal energy is used for heating the spa complex and the hotels (1,000 beds) since the year 2000. In 2001, an air cooled ORC turbine was installed having a net output of 180 kW of electrical power (Figure 4). As the next 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 5).

The latest development is the outdoor pool named "Vulkania" (area 1,000 m²). For this pool, water from the well Blumau 2 is directly used (flow rate 0.5-1.2 L/s). The temperature of the outdoor pool is kept stable by heating the overflow water from the pool by geothermal energy of well Blumau 2.

Water is re-injected in the former hydrocarbon well Blumau 1a; the maximum re-injection pressure is in the order of 0.7 MPa, minimum re-injection temperature is 50°C.

Thermal output of the Blumau geothermal cascade can be summarized as follows:

Heated Object/installation	Installed Thermal Capacity (MWt)
Thermal equivalent power generation (ORC) assuming 10% efficiency	2.5
Space heating (spa centre, hotels)	3.5
Outdoor pool	1.5
Direct use (pools, water from Blumau 2 & 3)	0.1
Total	7.6

The spa was a purely private investment of €55 million ($66 million). The project was backed up by the Styrian Government by investing €20 million ($24 million) for the deep drillings and the improvement of the local and regional infrastructure (road construction, drinking water supply, sewage system, village restoration). The overnight stays in the region increased from 2,200 in 1995, to 37,490 in 2003 (without thermal resort), and 340 jobs in the thermal

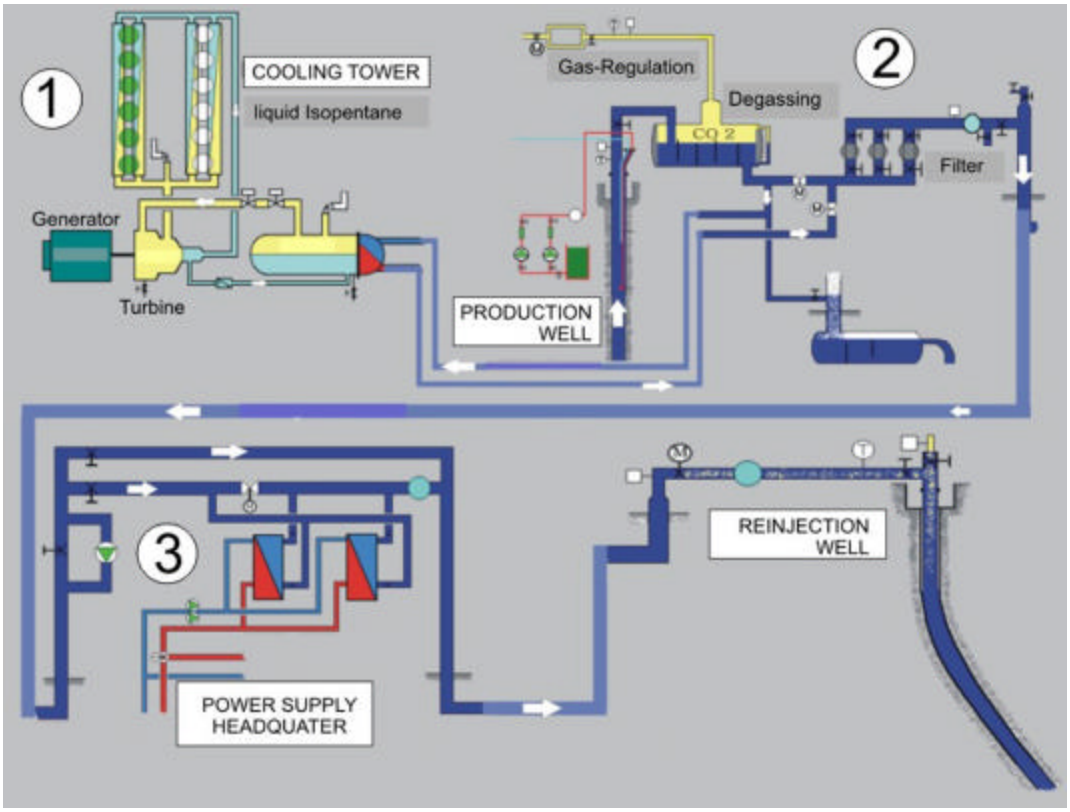

Figure 6. Blumau geothermal project: (1) ORC, (2) CO_2 -gas, and (3) district heating.

resort hotel and 170 jobs in regional services have been created (Hoenig, 2005).

A schematic of the Bad Blumau project is shown in Figure 6.

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