Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Geothermal Project Benedikt: Possibilities for Geothermal Energy Use in Small Communities

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Keywords: electricity generation, direct use, district heating, hydrogeology, integrated energy systems, deep fractured aquifers, Slovenia

ABSTRACT

The municipality of Benedikt and the town with the same name, are situated in north-eastern Slovenia, at the south-western margins of the Pannonian basin (the Mura Basin), not far from the Austrian-Slovenian frontier. The municipality encompasses an area of 24 km^2 and has 2.147 inhabitants. Annual energy consumption amounts to 15 GWh (4 GWh of electricity and 11 GWh of heat from other energy sources, mainly biomass (7 GWh). Half of the municipality's inhabitants live in the town of Benedikt. The town's annual heat consumption amounts to 4 GWh, and is assured from diverse energy sources. Today, the biomass share is 42 %, and it is used mainly in individual boilers. The remaining 58 % are classic energy sources, and the aim of the planned project is to replace them with a sustainable geothermal energy source. The final goal of the project is to attain "zero emission" in the town area in "green electricity" for the whole municipality. In the year 2004, the first of three planned geothermal wells was constructed and it proved the existence of an aquifer at a depth of 1800-1900 m. The whole project consists of two geothermal power plants having a total power of 5 MW_e, and two heating stations having a capacity of 12.5 MW_{th}. Planned annual electricity production amounts to 35000 MWh_e at the price of 59 €/MWh, The heat would be further used for district heating, and in the last cascade before reinjection, for heating of greenhouses. Final planned capacity of the district heating station is 2.5 MW_{th} of installed power with annual production of 4100 MWh_{th} of heat at the price of 34.7 €/MWh, and for greenhouse heating station 10 MW of installed power with annual production of 18000 MWh of heat at the price of 15 €/MWh. Simple pay back time is calculated to be 5-6 years.

1. INTRODUCTION

Preliminary studies in the Municipality of Benedikt were carried out from 1988 to 2002. They encompassed mainly geological studies and elaboration of energy planning of the Municipality of Benedikt. The study has shown that the most favourable energy source is geothermal, and somewhat less favourable is biomass. The town of Benedikt decided to use geothermal energy as the primary energy source and biomass as the secondary.

Geological research, which is still ongoing, indicates the existence of a large thermal aquifer in pre-Tertiary basement of the Slovenske Gorice Hills (Kralj, 2001). The first well, Be-2/03, is constructed already. Based on the present state of research, we can assure with high probability the extraction of 100 – 120 l/s of water having the temperature of about 110 °C (per well), if thermally used intact water is reinjected in the parent aquifer. The construction of a triplet (two production and one reinjection wells) would enable production of 220 l/s of thermal water.

Geothermal well and the first stage of district heating works are in the construction stage already, and their costs amount to 1.2 million Euro. The main investor is the Municipality of Benedikt and it is supported by the Ministry of Environment, Space Planning and Energy.

In the first stage the construction of a common heating station is planned. It will use the already constructed well Be-2/03, although later, the well will serve for reinjection. The station will be used for district heating and preparation of hot sanitary water for kindergarten, school, municipal building, post-office, business and dwelling buildings, and the parish church with rectory, altogether having an area of 10000 m^2. In this way, 2 million kWh (168 t.o.e.) of heat will be consumed annually. In comparison with a modern heating station using extra-light oil, annual emission decrease will amount to: 720 t CO_2, 10 kg CO, 290 kg NO_x, 650 kg SO_2, 40 kg volatile hydrocarbons.

In the second stage, the construction of two production wells, two electric power plants, the primary pipelines and the enlargement of the existing heating station is foreseen, along with spreading of the district heating system to the whole downtown. For the rest of the town area, where disseminated individual buildings predominate, modernization of individual boilers is planned. In order to justify economic demands, individual boilers will use biomass or geo-heat-pumps in combination with solar collectors as an energy source.

2. ENERGY SITUATION IN THE MUNICIPALITY AND THE TOWN OF BENEDIKT

The Municipality of Benedikt is dominated by agriculture. More than 50 % of inhabitants make a living from farming. Inhabitants are concentrated in villages, almost a half of them live in the town of Benedikt. Average annual energy consumption in the Municipality amounts to 5493 kWh per person; in the town of Benedikt, it amounts to 6060 kWh per person, and to 5223 kWh per person outside the town. Annual electric power consumption used for machine propelling and district lightening amounts to 3151 MWh; together with heating it amounts to 4205 MWh. Except for biomass, the Municipality imports all energy agents, including electric power. The existing structure of fuels and consumption balance of primary energy sources used for heat production (for space heating and sanitary water) in the town of Benedikt and in the whole Municipality is shown in Table 1.

At heat production, various pollutants are released into the environment. According to the type of energy consumed, annual impact to the environment in the Municipality of Benedikt is shown in Table 2.

Table 1: Consumption structure of energents used for heating (Pečarič, 2002)

	Consumption of diverse energy – heating		
	MWh/a		
	The town of Benedikt	Other places	Municipality altogether
Coal	82	194	277
Wood	1756	5220	6976
Extra light oil	1627	1347	2974
Electric power	279	775	1054
LPG	455	57	513
Altogether	**4199**	**7.594**	**11794**

Table 2: Annual emission of pollutants released during heat production in the Municipality of Benedikt (Pečarič, 2002)

	t/a		
	The town of Benedikt	Other places	Municipality altogether
SO_2	1.1	2.2	3.3
NO_x	0.6	1.1	1.7
CO	39.7	115.9	155.6
Dust	0.6	1.5	2.1
C_xH_y	6.5	14.0	25.5
CO_2	1172.3	2244.7	3417.0

3. HYDROGEOLOGICAL SETTING

The Benedikt area is characterized by the highest measured geothermal gradient in Slovenia. It is twice higher than the national average, and for this reason very promising for exploitation of geothermal energy (Kralj, 1997; 1998). The geothermal well Benedikt-2/03 (Be-2/03), penetrated two main aquifers, the smaller at a depth of 1492 m, and the thicker at a depth between 1848 m and the final well depth of 1857 m (Fig. 1). Owing to technical failure it was not possible to continue with drilling activities. At drilling, only fresh water was used as a fluid for the first time in Slovenia. This method proved very successful, as for the first time we succeeded to tap considerable quantities of thermal water in Paleozoic metamorphic rocks.

The temperature in the upper geothermal aquifer amounts to 100°C, and in the lower, the main geothermal aquifer to 115°C. With respect to the mixing shares we suppose that the wellhead temperature of thermal water will amount to at least 110°C.

Geothermal aquifer is characterized by very large transmissivity, which was proven during the drilling works. The well outflow is limited mainly by its technical performances and is estimated to be 120 l/s. As the whole produced amount of thermal water is foreseen to be reinjected into the primary aquifer after taking away a part of its thermal energy, long-term dynamic stability and stable well capacity will be assured in this manner.

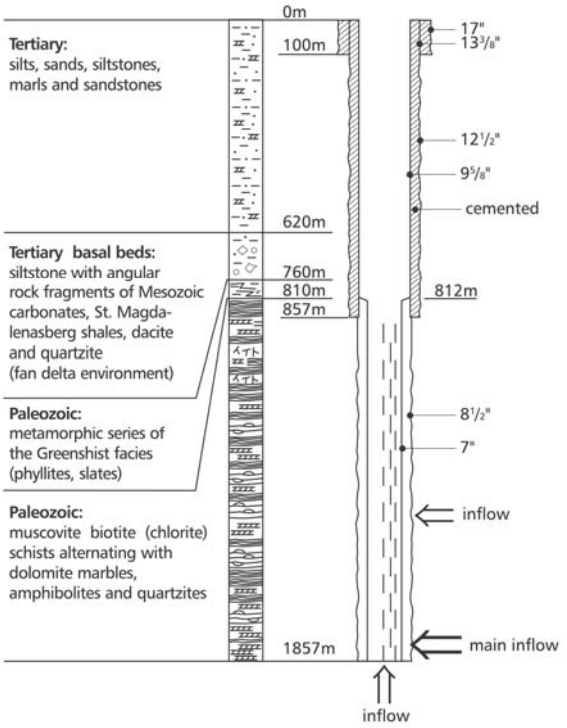

Figure 1. Geological and technical profile of the geothermal well Benedikt-2/03

During drilling of the well Be-2/03, one water sample was taken for preliminary chemical analysis. The analyzed water is low-mineralized (2.5 g/l of total dissolved ions), and this amount is relatively low with respect to the high amount of dissolved gasses (mainly CO_2). Based on this analysis, an uncomplicated technical water management is expected. The analysis is contained in Table 3.

Table 3. Chemical composition of thermal water from the well Be-2/03 (preliminary)

Ions	mg/l
F^-	0,26
Cl^-	87,6
NO_3^{2-}	2,97
SO_4^{2-}	125,4
HCO_3^-	1592
K^+	45
Na^+	370
Ca^{2+}	79
Mg^{2+}	41
Mn^{2+}	2,9
Fe_{tot}	186

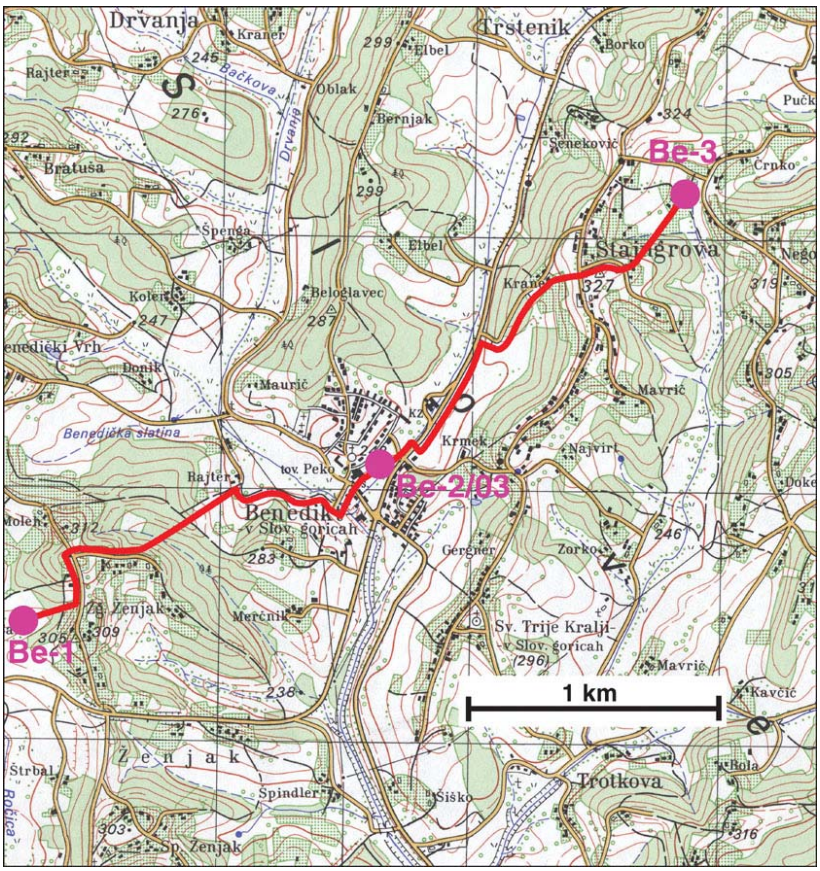

Figure 2. Concept of a triplet system Benedikt

4. THE CONCEPT OF ENERGY USE

Construction of a triplet system consisting of two exploitation and one reinjection wells at a distance of 1.6 km is foreseen (Fig. 2). At both production wells electricity power production plants will be constructed, along with the transport of electric power to the nearby 20 kV network. In this way, the problem of a long-distance transport of high-temperature thermal water will be avoided.

The productive wells will be Be-1 and Be-3, and reinjection well the existing Be-2/03. The length of primary reinjection pipeline between the production and reinjection wells amounts to 3800 m. The pipeline will be made of pre-insulated steel pipes having the diameter of ∅ 300 mm. Due to relatively low temperature of geothermal fluid, electric power plant using ORC or Kalina cycle is planned.

In the newly built gymnasium, located at the reinjection well Be-2/03, a boiler station having the final power of 2.5 MWt is under construction, and it will serve for the district heating also. District heating pipeline (Fig. 3) will be constructed as a primary pipeline having a length of 475 m and a diameter of ∅ 100 mm, and made of pre-insulated steel pipes. The secondary pipeline is planned to have a length of 1954 m and a diameter of ∅ 80 mm, and will be composed of pre- insulated pipes also. Pipelines will be constructed as an underground network.

The use of geothermal source will follow these cascades:

110°C	⇒	70°C	electricity production
70°C	⇒	68°C	heat loss during transport
68°C	⇒	65°C	district heating
65°C	⇒	?°C	agriculture, aquaculture
?°C	⇒		reinjection to the primary aquifer

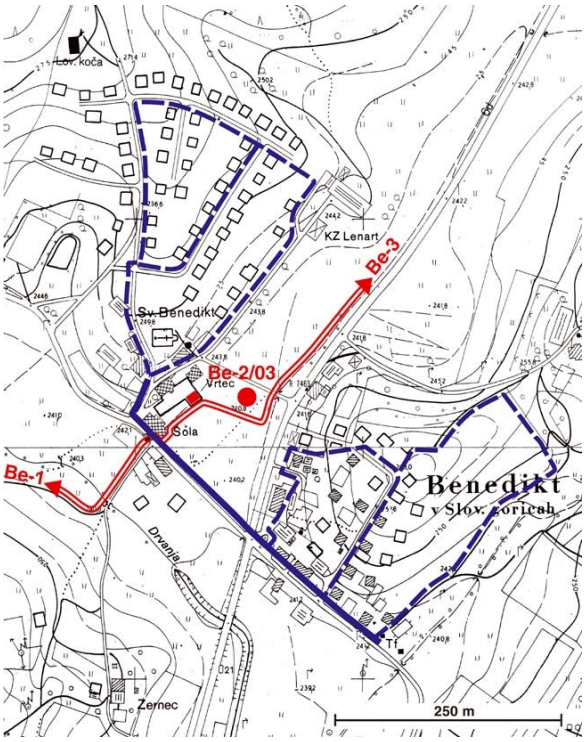

Figure 3. The District heating scheme of Benedikt

red square – boiler station
red double unbroken line – pipeline for geothermal water
blue unbroken line – primary district heating pipeline
blue broken line – secondary district heating pipeline

5. FINANCIAL ESTIMATION OF THE INVESTMENT

5.1 Planned energy prices

The sale of "green energy" is regulated by law in Slovenia, and must be entirely accepted into the electric supply system. The price (March 2004) for a kWh of electricity produced in a geothermal power plant amounts to 14.1 SIT (0.059 €).

Calculated selling price of heat (34.7 €/MWh) to the district heating network is for about 10% lower than the lowest sale price of heat in Slovenia.

In Slovenia, the construction of greenhouses is in the starting stage already. In order to attract investors to invest in the Municipality of Benedikt, we had to lower appreciably the price of offered heat. We believe that the sale price of 15 €/MWh is suitable. At the moment, we do not have user yet, and for this reason, the sale of energy for greenhouses is not considered in our calculations.

5.2 Estimation of investment costs

Investment costs are obtained by project estimations and informative invoices, and do not include the financing costs. The estimation comprises only the costs of investment for electricity production and district heating. The investment costs are shown in Table 4.

Table 4. Investment costs

Construction works	Costs (k€)	Share (%)
Three wells	2.850	24,1
Two geothermal power plants 2,5 MWe each	3.900	33,0
Connection of GeoPP to the electric network	170	1,4
Reinjection pipeline network	2.300	19,4
Reinjection station	260	2,2
Heat station and the pipeline network	2.350	19,9
ALTOGETHER	**11.830**	**100,0**

5.3 Financial construction

Financial construction is based on proposition that a new company for construction supervision and the following system operation will be established, and that the company would use the financing sources as shown in Table 5.

Table 5. Financial construction of the investment

Source	Amount (k€)	Share (%)
Company's own funds	3.830	32,4
Grants	3.000	25,4
Credits	5.000	42,2
ALTOGETHER	**11.830**	**100,0**

5.4 Operation costs

For the needs of the system operation, mainly recycling pumps, calculated annual electricity consumption is estimated to 500 MWh, and it will be obtained from the network or own production. For supervising and minor reparations, four full-time employment places are foreseen. The majority of other maintenance costs for the first ten years of operation are estimated to 1 % of the whole investment. Predicted annual operation costs are shown in Table 6.

Table 6. Predicted annual operation costs

Cost	Amount (€)	Share (%)
Energy (500 MWh/a)	29.500	25,1
Employees (4 persons)	76.200	64,9
Other (0,1% of investment costs)	11.800	10,0
ALTOGETHER	**117.500**	**100,0**

5.5 Incomes

The projects for greenhouse and aquaculture production are not yet elaborated, and these incomes are not taken into account at the present calculations. The income structure, shown in Table 7 comprises only the incomes related to electricity production and heat sale.

Table 7. Annual income structure

Income	Amount (k€)	Share (%)
Electricity production (35.000 MWh/a)	2.065	93,5
Heat production (4.100 MWh/a)	0.143	6,5
ALTOGETHER	**2.208**	**100,0**

6. CONCLUSIONS

At the present time (May 2004), the well Be-2/03 is drilled and heat station constructed already. The whole documentation related to district heating is elaborated. Up to the present costs amount to 1.2 million €, and represent 10 % of the total foreseen investment costs only. This share, however, is very important as it represented the risk capital, by which the existence of geothermal aquifer was proved (the mining risk). Cost benefit calculation confirmed the prognoses about economical justification of the Benedict Project, as foreseen simple pay back is less than 6 years.

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