Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

GEOTHERMAL ENERGY POTENTIAL AND UTILIZATION IN THE REPUBLIC OF CROATIA

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Key Words: geothermal energy, low temperature reservoirs, medium temperature reservoirs, direct heat use, electric power generation.

ABSTRACT

The average temperature gradient in the north of Croatia, part of the Pannonian sedimentary basin, is considerably above the world average, while in the southern, Dinarides area its value is below that figure. In spite of the considerable geothermal potential accumulated in the reservoirs of the Pannonian area, the level of utilization of geothermal energy is very low. Low temperature thermal water is widely used for bathing, swimming and medical purposes in traditional spas, some of which are also equipped with geothermal space heating systems. Only two out of ten geothermal fields discovered during hydrocarbon exploration are currently in use. According to the Program of Geothermal Energy Utilization, GEOEN, in the near future the energy from the majority of the geothermal fields should be used directly for space heating and in the agricultural sector for greenhouse heating and the industrial processing of fruit and vegetables. Construction of a geothermal electric power plant is planned by the year 2005.

1. INTRODUCTION

Croatia has a centuries-long tradition of using geothermal water from natural springs for medical purposes. In the early 70s, along with research for oil and gas, the existence of geothermal water began being observed. The calculations of temperature gradient based on the data obtained from exploration wells showed that the average gradient in the northern part of the country, part of the Pannonian sedimentary basin, is considerably higher than the world average, while in the southern Dinarides area its value is below that figure (0.049°C/m and 0.018°C/m respectively, compared to 0.03°C/m in the world, Jelić *et al.*, 1995). The temperature gradient distribution in Croatia is shown in Fig. 1.

The geothermal potential of the reservoirs in the northern part of Croatia could be a significant renewable energy resource, substantially contributing to the overall energy efficiency and the environmentally acceptable energy policy. The geothermal energy content of the medium temperature reservoirs (between 100 and 200°C) can be converted into electric energy, while that of the low temperature reservoirs (below 100°C) is perfectly suitable for heating and cooling of buildings, heating greenhouses, in various industrial processes, for medical purposes, etc.

Since geothermal resources had previously been studied by different institutions, in 1997 the Government of the Republic of Croatia set up a Program of Geothermal Energy Utilization, GEOEN, as part of the National Program of the Croatian Energy Sector Development and Organization PROHES. The objective of the program is to promote knowledge and experience in the geothermal energy sector .

The GEOEN Program involves all technical, technological, legislative and other measures with the aim of increasing geothermal energy use and its efficiency, as well as the implementation of the highest ecological standards. Various governmental ministries, scientific and higher education institutions participate in the realization of the program coordinated by the Energy Institute "Hrvoje Požar".

The first phase of the program, completed in April 1998, contained an analysis of the geothermal energy potential and the legislative environment related to its utilization, defining program implementation measures and dynamics, and proposing five pilot projects. The results of the first phase have been included in the Strategy of the Energy Development of the Republic of Croatia.

The second phase, currently in progress, deals with pilot project realization and the implementation of the geothermal energy utilization program.

The geothermal energy potential from the medium and low temperature reservoirs with water temperatures above 65°C presented in this paper are the results of the analysis that forms part of the first phase of the GEOEN Program.

Most of the spas where geothermal water has been traditionally used for swimming, bathing and medical purposes, and more recently also for heating hotels and hospitals, have lower temperatures, and therefore have not been considered by the GEOEN Program. These localities, although contributing in a relatively small percentage to the total geothermal potential, represent a significant part of the present utilization. Therefore additional data collection has been performed in order to include them in the data set necessary for completing this country update.

2. ENERGY POTENTIAL

The northern part of the Republic of Croatia, in geological terms a part of the Panonian sedimentary basin, having an average temperature gradient of 0.049°C/m and vertical conductive heat flow of 76 mW/m^2 (Jelić *et al.*, 1995), can be considered a large geothermal energy accumulator. The great majority of wells drilled for oil or natural gas, being positive or dry in terms of hydrocarbons, penetrated aquifers that, belonging to such a warm environment, could be considered geothermal reservoirs. Nevertheless, taking into account technological and economic criteria, only those producing water with temperatures above 65°C were classified as geothermal wells.

The data obtained from the hydrodynamic measurements and production testing of those wells, performed by the Croatian oil company INA, served as the basis for reservoir engineering calculations, resulting in the definition of ten geothermal fields, one of which (Bizovac) consists of two reservoirs. They were classified in two categories, medium temperature reservoirs with water between 100 and 200°C, and low temperature ones, producing water with temperatures between 65 and 100°C.

Geothermal water with temperature below 100°C is perfectly suitable for direct heat use, including space heating and cooling, various industrial processes, greenhouse heating, drying of agricultural products, medical applications, etc, by means of heat exchangers and, optionally, heat pumps. Geothermal energy from the reservoirs with temperatures above 100°C can be effectively used for electric power generation, employing a binary process.

The basic energy data of the geothermal fields are given in Tables 1 and 2, while their locations are indicated in Fig. 2. For each reservoir thermal power and the annual primary energy that could be produced from the existing wells have been calculated, as well as the respective values corresponding to complete reservoir development, i.e. after completion and commissioning of all the projected wells. Annual thermal energy production has been calculated on the basis of a reasonable capacity factor of 50%. All the calculations have been made simultaneously for two possible energy utilization patterns. The first refers to the application of conventional heat exchanger systems assuming an outlet water temperature of 50°C. Another option that has been elaborated is based on the energy use down to the temperature of 25°C, which could be achieved in practice by the implementation of heat pumps as part of the heating systems.

For the medium temperature reservoirs the electric power and the annual electric energy production resulting from the conversion of a part of the available thermal energy into electricity have also been computed (Table 2). The calculations have been made on the basis of an outlet water temperature from the electric power generation process of 80°C, a conversion efficiency factor of 10% and capacity factor of 90%.

As mentioned before, geothermal springs and wells producing water with temperature below 65°C have not been included in the calculations of GEOEN geothermal potential. However, due to the fact that they make a significant contribution to the present geothermal energy utilization, for the purpose of this work it was necessary to consider the resources of that category that are currently in use. Most of them are traditional spas, using water from natural springs and shallow wells. Their basic energy characteristics are shown in Table 1, while the locations are indicated in Fig. 2.

Comparison of the total geothermal energy that could be produced using conventional heat exchange systems with the total primary energy production in Croatia of 198.4 PJ/yr (according to Vuk *et al.*, 1998), shows that an appropriate utilization of geothermal resources would ensure their contribution of 6.7%. Comparison of the same figure with the total primary energy supply, 348.0 PJ/yr, means the potential provides 3.8% coverage of the energy needs of the country. In the case of heat pumps, which means we consider geothermal water outlet temperature down to 25°C, the contribution of geothermal to the total primary energy production and the total primary energy supply would increase to 9.2% and 5.3%, respectively.

Installation of the complete geothermal capacities available for transformation into electricity would result in some 3.9% contribution of geothermal to the total electric energy production, and 2.9% coverage of the electric energy consumption (Table 3). Nevertheless, it should be pointed out that the pre-feasibility study on combined electricity and heat production (Virkir Orkint Consulting Group Ltd., 1995) gave positive results as regards both technical feasibility and financial viability for the Velika Ciglena cogeneration plant, while the Lunjkovec-Kutnjak project was declared questionable in terms of financial viability. Since other potential locations still have not been seriously considered, installing the majority of geothermal capacities available for electricity production is not likely in the near future.

3. PRESENT UTILIZATION

Direct heat use is at present the only utilization of geothermal energy in Croatia. All the localities where geothermal energy is used, with the quantitative characteristics of the energy installations, are listed in Table 4. The majority of the listed localities are spas, usually including hospitals and hotels, equipped with swimming pools and other therapeutic and recreational facilities.

Except for natural springs, some of which have been used for centuries, geothermal water supply to those facilities is also drawn from shallow wells drilled during the last few decades. While in some of the localities thermal water is used only for balneological and recreational purposes, others are heated by geothermal energy, due to water temperatures that allow a useful amount of energy to be extracted by means of heat exchangers and heat pumps.

There are also public recreational centres where geothermal water is used only in open-air swimming pools during the summer season. Obviously, the contribution of those facilities to the overall geothermal energy utilization is small.

A different category of geothermal energy utilization makes use of deep geothermal reservoirs discovered during oil and gas exploration. Two localities of that type are operative at present, both based on the exploitation of low-temperature reservoirs.

“Mladost” Sport Centre, located in the south-western part of the capital Zagreb, uses the water from the Zagreb geothermal reservoir. The whole complex, including open-air and indoor swimming pools with all the accompanying facilities, as well as two sport halls, is entirely heated by geothermal energy, including peak consumption. Heat is extracted from the water flowing in a closed system, consisting of a production well, cascaded heat exchangers, injection pumps and an injection well. Pressure resulting from the density difference of water with different temperatures is used to establish thermosiphon injection. Consequently, the injection system can operate without the support of the injection pumps for more than 7500 hours/year.

There are two other localities where geothermal energy from the Zagreb reservoir is used for space heating. The first one, the University Hospital still under construction, at present utilizes only a small part of the energy planned to be used after it is finished and commissioned. The INA-Consulting Company uses the geothermal water from a well of relatively low flow rate to heat its offices.

Another locality where the thermal energy from a geothermal reservoir is used by means of deep production and injection wells is Bizovac, near the town of Osijek in the north-eastern part of the country. "Termia" Recreation Centre, consisting of a hotel equipped with a complex of open-air and indoor swimming pools, is heated by geothermal energy. The circulation of geothermal water is not a closed one like at "Mladost" Sport Centre: after a certain amount of energy is extracted in heat exchangers, water is pumped directly into the swimming pools, which discharge into the sewer, while the reservoir pressure is maintained by injection of fresh water. Such an economically and ecologically inadequate way of using geothermal water should soon be replaced by the waste water treatment and injection system.

Table 4 gives the values related to the real energetic and balneological use of geothermal water. While the outlet temperatures shown in the column representing energy use ("B excluded") correspond to the actual temperatures of water coming from the system of heat exchangers and heat pumps, those cited in column "B included" correspond to the average air temperatures during the year or the summer season, depending on the period of the year when a specific facility is in function.

This methodology has been accepted, taking into account the equivalent fossil fuel energy that would be consumed if the water was heated from ambient temperature; in other words, the energy needed to operate a facility of the same characteristics without a geothermal resource.

Although the correctness of such an approach is subject to debate, the authors have applied it for the following reasons:

Using thermal water in a circulating system of a swimming pool does not have the characteristics of a typical heat exchange, from the energy point of view. In other words, the significance of the process cannot be attributed to the cooling of water in contact with the ambient air itself, but to the amount of energy saved compared to the hypothetical situation of operating an equivalent facility heated by fossil fuel combustion, assuming of course the existence of the installation without a geothermal energy source. Actually, in a constantly circulating system the temperature difference between the inflowing and outflowing water is negligible. Consequently, there is practically no useful heat exchange, but the energetic significance of the use of geothermal water in the above hypothetical terms remains.

Nevertheless, if we do not accept the above speculations and the resulting energy balance method, the balneological and recreational aspects of the geothermal utilization lose their significance in energetic terms. If that approach is applied, the only relevant figures are those relating to the "truly energetic use" of thermal water, expressed in column "B excluded" of the table.

As can be seen from Tables 4 and 5, the total geothermal energy used for space heating in Croatia is 131.4 TJ per year. Adding the 423.3 TJ per year relative to balneological and recreational uses gives a total of 554.7 TJ per year of geothermal energy used as direct heat.

Relating those figures to the total installed geothermal capacity, which is 36.7 MW_t considering only "truly energetic use" or 113.9 MW_t and taking into account balneology and recreation as well, gives capacity factor values of 0.11 and 0.15, respectively. Such a small capacity factor is clear evidence of an inadequate use of the installed geothermal capacities. The reason for this lies primarily in the fact that none of the installations using geoheat is a district heating system with more or less steady energy demand and optimized operation. Instead, in all of the facilities in question the amount of energy used in a certain period varies significantly, depending on the need to change water in swimming pools or heat bigger or smaller portions of accomodation.

As in most cases the quantities of thermal water available are much higher than those needed to satisfy the actual demand, even taking into account peak load situations that in reality rarely occur, it is logical that a large part of the installed capacities remains unused over a long period of time.

Figures regarding the number of geothermal wells drilled (Table 6), and the allocation of professional personnel (Table 7) during the last five years, as well as those relating to the total investments in geothermal during the last fifteen years (Table 8) indicate a certain stagnation in geothermal development, a tendency that is expected to change in the near future by the implementation of the next phases of the GEOEN Program.

4. FUTURE PROSPECTS

The future development of geothermal energy in Croatia has been defined within the GEOEN Program, according to three possible scenarios. Key factors defining those scenarios are the general economic and technological development of the country, energy sector reform and government measures, international energy market development and global environmental constraints.

The first scenario is based on the assumption of a slow introduction of new technologies and insufficient government activities in the energy sector reform and restructuring. The basic characteristic of the second scenario is the implementation of new technologies, made possible by technology transfer resulting from Croatia joining the European Union and supported by state incentive mechanisms. The third scenario is a compilation of highly technological and ecological features, characterized by a strong influence of the environmental protection concept to global economic and energy development. Table 9 shows the geothermal development envisaged in these three scenarios, based on 1995 values. Bathing, swimming and balneology have not been included in the forecast.

The future growth of geothermal use will be based on the total exploitation of the existing geothermal wells in the first phase, and complete geothermal field development by means of newly drilled wells as the next step.

One important new consumer of geothermal energy for direct space heating should be the newly constructed University Hospital in Zagreb, with an anticipated annual consumption of about 100 TJ (Zelić *et al.*, 1995). Along with the planned connecting-up of some additional heat consumers to the heating system of "Mladost" Sport Centre, which would significantly increase its capacity factor, introduction of that new user will also contribute to an adequate exploitation of the Zagreb geothermal reservoir.

As all the geothermal reservoirs that are currently still not in use are located in agricultural areas, utilization of geothermal energy for greenhouse heating and the subsequent industrial processing of fruit and vegetable produce would significantly increase the efficiency of the agricultural production. The development of geothermal applications in the agricultural sector greatly depends on the economic interest shown by private agricultural producers and food processing companies. Because the initial investments in geothermal heating are higher than for conventional heating systems, stimulative measures by the Government would be welcome.

Besides the anticipated development in the direct heat segment, the planned construction of the geothermal power plant in Velika Ciglena by the year 2005 would bring Croatia into the group of countries producing electricity from geothermal energy (Table 3). The initial power of 4.4 MW_e obtained from the existing well should be increased to 13.1 MW_e by the construction of two additional production wells by the year 2015. As mentioned before, the pre-feasibility study on combined electricity and heat production in Velika Ciglena showed that such an energy generating plant could operate under economically acceptable conditions.

ACKNOWLEDGEMENTS

The authors are indebted to the Energy Institute "Hrvoje Požar", Zagreb, INA–Oil Industry, Zagreb, management and technical departments of the Termia Hotel, Bizovac, Hospital for the Medical Rehabilitation, Daruvar, Naftalan Hospital for the Medical Rehabilitation, Ivanić Grad, Hospital for the Medical Rehabilitation, Krapinske Toplice, Hospital for the Medical Rehabilitation, Lipik, Istarske toplice Medical Centre, Livade, Prodex d.d., Zagreb, Clinical Hospital, Split, Hospital for the Medical Rehabilitation, Stubičke Toplice, Matija Gubec Hotel, Stubičke Toplice, Komunalno d.o.o, Jastrebarsko, Topusko Medical Centre, Topusko, Mihanović d.d., Tuhelj, Hospital for the Medical Rehabilitation, Varaždinske Toplice, Kamen Ingrad d.d., Požega, Ivančica d.d., Zlatar, and the Climatological Department of the National Hydrometeorological Institute, Zagreb, for help and cooperation in the collecting of data necessary for compiling this Country Update.

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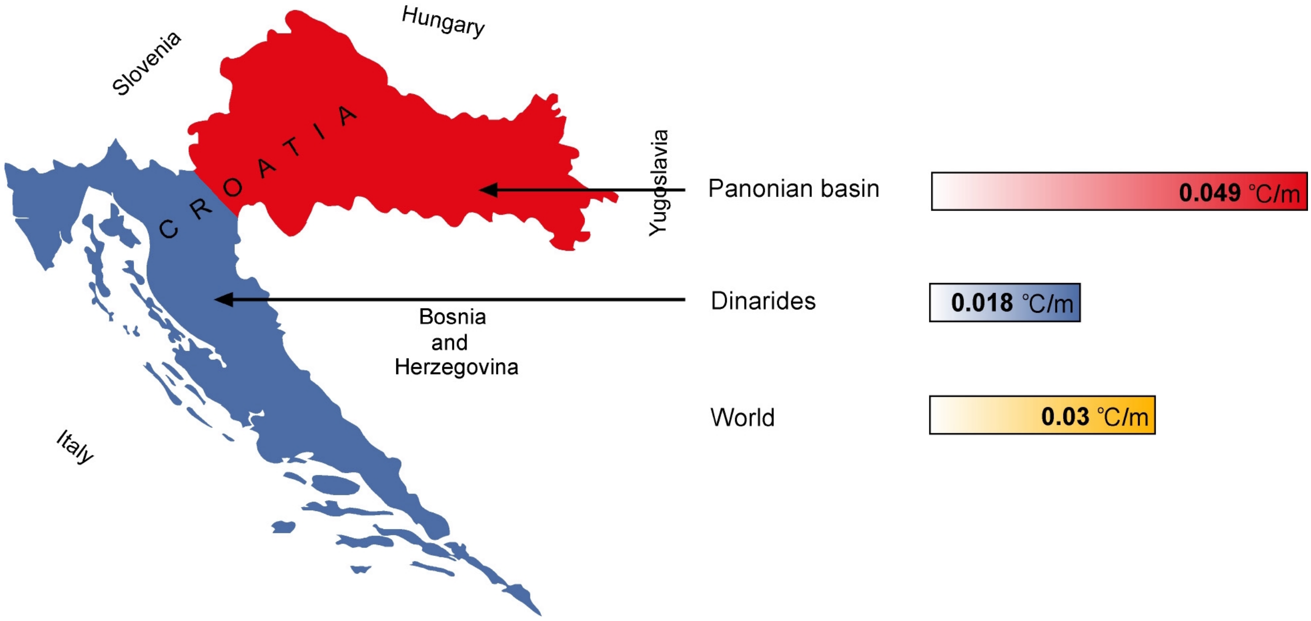

Figure 1. Temperature Gradient Distribution in Croatia

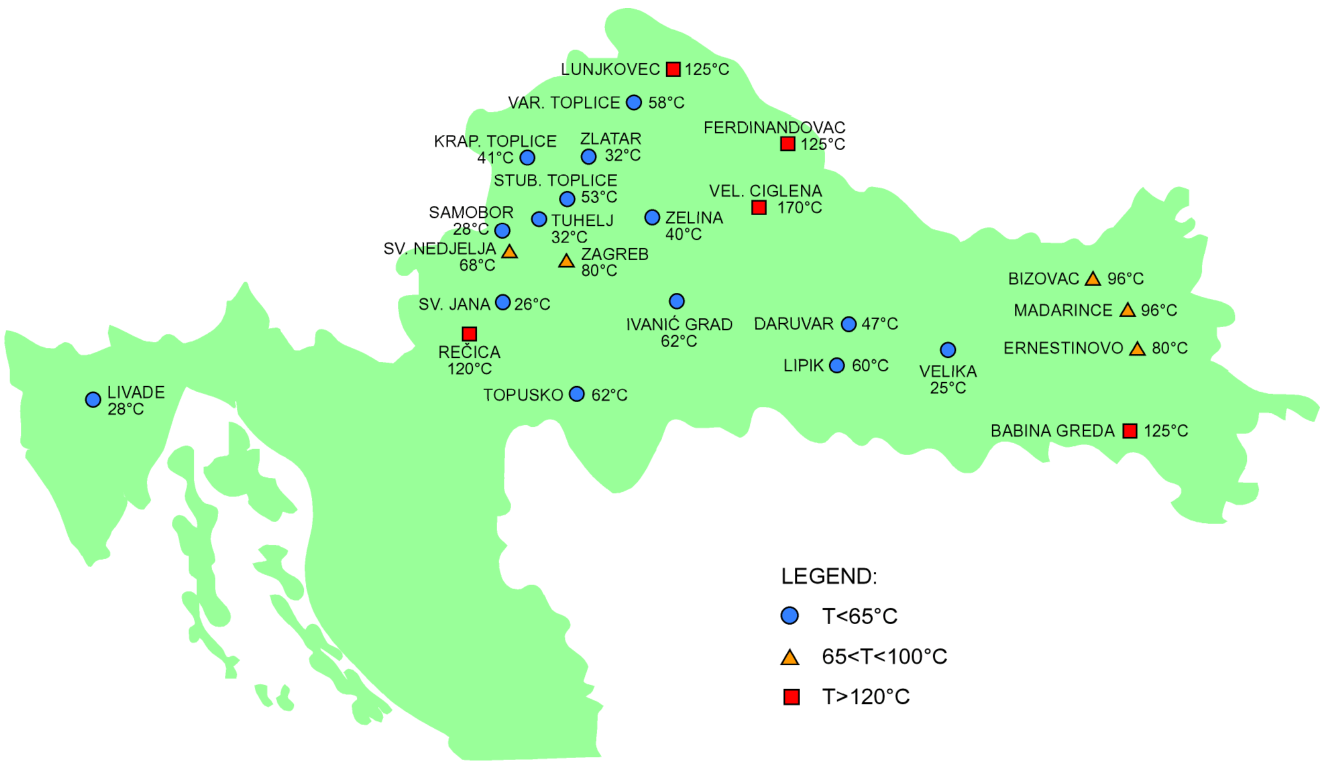

Figure 2. Geothermal Resources of Croatia

Table 1. Geothermal Resources in Croatia - Direct Heat Potential

	Locality	T (°C)	Thermal Power (MW_t)				Thermal Energy (TJ/yr)[1]			
			To 50 °C		To 25 °C		To 50 °C		To 25 °C	
			Actual	Possible	Actual	Possible	Actual	Possible	Actual	Possible
Medium temperature geothermal reservoirs	Babina Greda	125.0	31.38	31.38	41.84	41.84	494.63	494.63	659.50	659.50
	Ferdinandovac	125.0	15.69	31.38	20.92	41.84	247.31	494.63	329.75	659.50
	Lunjkovec-Kutnjak	125.0	48.95	489.53	65.27	652.70	771.62	7716.15	1028.82	10288.20
	Reèica	120.0	14.64	29.29	19.87	39.75	230.83	461.65	313.26	626.53
	Velika Ciglena	170.0	58.07	174.21	70.17	210.51	915.33	2746.00	1106.03	3318.08
	Subotal		**168.74**	**755.79**	**218.07**	**986.64**	**2659.71**	**11913.05**	**3437.36**	**15551.81**
Low temperature geothermal reservoirs	Bizovac-TG	96.0	0.58	0.58	0.89	0.89	9.10	9.10	14.05	14.05
	Bizovac-PP	90.0	3.85	46.19	6.26	75.06	60.67	728.09	98.60	1183.14
	Ernestinovo	80.0	2.89	5.77	5.29	10.59	45.51	91.01	83.43	166.85
	Madarince	96.0	1.92	1.92	2.97	2.97	30.34	30.34	46.82	46.82
	Sveta Nedjelja	68.0	3.39	6.78	8.10	16.19	53.42	106.84	127.61	255.23
	Zagreb (Mladost SC)	80.0	6.28	6.28	11.51	11.51	98.93	98.93	181.36	181.36
	Zagreb (University Hospital)	80.0	6.90	6.90	12.66	12.66	108.82	108.82	199.50	199.50
	Subtotal		**25.81**	**74.42**	**47.67**	**129.86**	**406.78**	**1173.12**	**751.37**	**2046.96**
Geothermal springs with the water temperature below 65°C	Daruvar (Daruvar Spa)	47.0	0.00	0.00	1.66	1.66	0.00	0.00	26.12	26.12
	Ivaniæ Grad (Naftalan Hospital)	62.0	0.14	0.14	0.42	0.42	2.14	2.14	6.59	6.59
	Krapinske Toplice (Krapina Spa)	41.0	0.00	0.00	4.69	4.69	0.00	0.00	73.86	73.86
	Lipik (Lipik Spa)	60.0	0.17	0.17	0.59	0.59	2.64	2.64	9.23	9.23
	Livade (Istria Spa)	28.0	0.00	0.00	0.03	0.03	0.00	0.00	0.40	0.40
	Samobor (Šmidhen SRC)	28.0	0.00	0.00	0.38	0.38	0.00	0.00	5.94	5.94
	Stubièke Toplice (Stubica Spa)	53.4	1.35	1.35	11.29	11.29	21.30	21.30	177.93	177.93
	Sveta Jana (Sveta Jana RC)	26.0	0.00	0.00	0.22	0.22	0.00	0.00	3.50	3.50
	Topusko (Topusko Spa)	62.0	6.25	6.25	19.27	19.27	98.53	98.53	303.80	303.80
	Tuhelj (Tuhelj Spa)	32.0	0.00	0.00	2.20	2.20	0.00	0.00	34.62	34.62
	Varaždinske Toplice (Varaždin Spa)	58.0	0.90	0.90	3.73	3.73	14.25	14.25	58.76	58.76
	Velika (Toplice RC)	25.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Zagreb (INA-Consulting)	55.0	0.12	0.12	0.69	0.69	1.81	1.81	10.88	10.88
	Zelina (Zelina RC)	40.0	0.00	0.00	1.88	1.88	0.00	0.00	29.68	29.68
	Zlatar (Sutinske Spa)	32.0	0.00	0.00	6.44	6.44	0.00	0.00	101.56	101.56
	Subtotal		**8.92**	**8.92**	**53.47**	**53.47**	**140.66**	**140.66**	**842.87**	**842.87**
	TOTAL		**203.47**	**839.14**	**319.21**	**1169.97**	**3207.16**	**13226.83**	**5031.60**	**18441.63**

[1] Capacity factor 0.5

Table 2. Geothermal Resources in Croatia - Electricity Production Potential

Locality	T (°C)	Electric Power (MW_e)		Electric Energy (GWh/yr)[1]	
		Actual	Possible	Actual	Possible
Babina Greda	125.0	1.88	1.88	14.84	14.84
Ferdinandovac	125.0	0.94	1.88	7.42	14.84
Lunjkovec-Kutnjak	125.0	2.94	29.37	23.15	231.48
Reèica	120.0	0.84	1.67	6.60	13.19
Velika Ciglena	170.0	4.36	13.07	34.32	102.97
TOTAL		**10.95**	**47.88**	**86.33**	**377.33**

[1] Capacity factor 0.9

Table 3. Present and Planned Production of Electricity in Croatia

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables[1]		Total	
	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr	Capacity MW_e	Gross Prod. GWh/yr
In operation in January 2000	0.0	0.0	1820.6	6572.9	2091.0	6062.4	0.0	0.0	0.0	0.0	3911.6	12635.3
Under construction in January 2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Funds committed, but not yet under construction in January 2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total projected use by 2005	4.4	34.3	2467.6	8945.8	2152.0	6373.8	0.0	0.0	26.0	53.0	4650.0	15406.9

[1] solar energy, wind energy

Table 4. Utilization of Geothermal Energy for Direct Heat as of 31 December 1999 in Croatia

Locality	Type[1]	Maximum Utilization: Flow Rate (kg/s)	Temperature (°C): Inlet	Outlet: B excl.	Outlet: B incl.[2]	Capacity[3] (MW_t): B excl.	Capacity: B incl.	Annual Utilization: Average Flow (kg/s): B excl.	Average Flow: B only	Average Flow: B incl.[4]	Energy[5] (TJ/yr): B excl.	Energy: B only	Energy: B incl.	Capacity Factor[6]: B excl.	Capacity Factor: B incl.
Bizovac (Termia RC)	HB	26.0	90.7	50.0	11.0	4.43	8.67	5.1	5.1	5.1	27.48	26.34	53.82	0.20	0.20
Daruvar (Daruvar Spa)	B	18.0	47.0		10.8	0.00	2.73	0.0	5.5	5.5	0.00	26.26	26.26	0.00	0.31
Ivaniæ Grad (Naftalan Hospital)	B	2.7	62.0		10.8	0.00	0.58	0.0	1.3	1.3	0.00	8.78	8.78	0.00	0.48
Krapinske Toplice (Krapina Spa)	HB	70.0	41.0	28.0	9.8	3.81	9.14	2.6	2.8	5.4	4.48	11.52	16.00	0.04	0.06
Lipik (Lipik Spa)	HB	8.3	60.0	55.7	10.7	0.15	1.71	4.5	4.5	4.5	2.54	26.59	29.13	0.54	0.54
Livade (Istria Spa)	B	2.0	28.0		11.3	0.00	0.14	0.0	0.7	0.7	0.00	1.54	1.54	0.00	0.35
Samobor (Šmidhen SRC)	B	30.0	28.0		20.2	0.00	0.98	0.0	4.0	4.0	0.00	4.12	4.12	0.00	0.13
Stubièke Toplice (Stubica Spa)	HB	95.0	53.4	38.0	10.1	6.12	17.21	1.7	3.7	3.7	3.49	17.58	21.07	0.02	0.04
Sveta Jana (Sveta Jana RC)	B	53.0	26.0		19.0	0.00	1.55	0.0	5.1	5.1	0.00	4.74	4.74	0.00	0.10
Topusko (Topusko Spa)	HB	124.5	62.0	50.0	19.7	6.25	22.03	30.0	1.3	31.3	47.48	7.36	54.85	0.24	0.08
Tuhelj (Tuhelj Spa)	B	75.0	32.0		10.0	0.00	6.90	0.0	75.0	75.0	0.00	217.64	217.64	0.00	1.00
Varaždinske Toplice (Varaždin Spa)	HB	27.0	58.0	39.0	10.0	2.15	5.42	5.3	5.3	5.3	13.16	20.08	33.24	0.19	0.19
Velika (Toplice RC)	B	35.0	25.0		20.0	0.00	0.73	0.0	8.8	8.8	0.00	5.77	5.77	0.00	0.25
Zagreb (INA-Consulting)	H	5.5	55.0	30.0		0.58	0.58	0.1	0.0	0.1	0.40	0.00	0.40	0.02	0.02
Zagreb (Mladost SC)	HB	50.0	80.0	50.0	10.5	6.28	14.54	6.6	6.6	6.6	26.12	34.39	60.50	0.13	0.13
Zagreb (University Hospital)	H	55.0	80.0	50.0		6.90	6.90	1.6	0.0	1.6	6.29	0.00	6.29	0.03	0.03
Zelina (Zelina RC)	B	30.0	40.0		20.2	0.00	2.49	0.0	3.0	3.0	0.00	7.83	7.83	0.00	0.10
Zlatar (Sutinske Spa)	B	220.0	32.0		19.4	0.00	11.60	0.0	1.7	1.7	0.00	2.78	2.78	0.00	0.01
TOTAL		927.0				36.66	113.90	57.5	134.3	168.6	131.43	423.32	554.75	0.11	0.15

[1] I = Industrial process heat; H = Space heating & district heating (other than heat pumps)
C = Air conditioning (cooling); B = Bathing and swimming (including balneology)
A = Agricultural drying (grain, fruit, vegetables); G = Greenhouse and soil heating
F = Fish and animal farming; O = Other
S = Snow melting

[2] Outlet temperature for bathing and swimming is equalized with the average air temperature in the period during which swimming pools are in function (whole year or the summer season).

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

[4] Total flow equals the previous two if the whole quantity of water is used for bathing after a certain amount of heat was extracted, or is calculated as a sum of the two if water is used separately.

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

[6] Capacity factor = [Annual energy use (TJ/yr) x 0.03171]/Capacity (MW_t)

Table 5. Summary Table of Geothermal Direct Heat Uses in Croatia as of 31 December 1999

Use	Installed Capacity[1)] (MW_t)	Annual Energy Use[2)] (TJ/yr)	Capacity Factor[3)]
Space Heating[4)]	0.00	0.00	0.00
Individual Space Heating	36.66	131.43	0.11
Air Conditioning (Cooling)	0.00	0.00	0.00
Greenhouse Heating	0.00	0.00	0.00
Fish and Animal Farming	0.00	0.00	0.00
Agricultural Drying[5)]	0.00	0.00	0.00
Industrial Process Heat[6)]	0.00	0.00	0.00
Snow Melting	0.00	0.00	0.00
Bathing and Swimming[7)]	77.24	423.32	0.17
Other Uses	0.00	0.00	0.00
Subtotal	113.90	554.75	0.15
Geothermal Heat Pumps	0.00	0.00	0.00
TOTAL	113.90	554.75	0.15

1) Installed Capacity (thermal power) (MW_t) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalphy (kJ/kg)] x 0.001 (MW = 10^6 W)

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

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MW_t)] x 0.03171

4) Includes district heating (individual space heating reported separately)

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 in Croatia from 1 January 1995 to 31 December 1999

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	0	0	0	0	0
Production	>150° C	0	0	0	0	0
	150-100° C	0	0	0	0	0
	<100° C	0	1	0	0	0.85
Injection	(all)	0	0	0	0	0
TOTAL		0	1	0	0	0.85

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

Table 7. Allocation of Professional Personnel to Geothermal Activities in Croatia
(Restricted to personnel with a University degree)

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995	0	5	2	3	0	3
1996	0	6	2	0	0	3
1997	1	12	9	0	0	3
1998	1	11	9	0	0	2
1999	1	13	3	0	0	2
TOTAL	3	47	25	3	0	13

Table 8. Total Investments in Geothermal in Croatia in 1999 (in US$)

Period	**Research & Development** Incl. Surface Explor. & Exploration Drilling (Million US$)	**Field Development** Including Production Drilling & Surface Equipment (Million US$)	**Utilization**		**Funding Type**	
			Direct Million US$	Electrical Million US$	Private %	Public %
1985-1989	4.0	1.0	2.8	0.0	0.0	100.0
1990-1994	2.0	0.0	1.7	0.0	1.8	98.2
1995-1999	0.0	0.0	1.9	0.0	20.6	79.4

Table 9. Three Possible Scenarios of Geothermal Energy Utilization in Croatia

First Scenario:

Use	Annual Energy Use (TJ/yr)							
	1995	2000	2005	2010	2015	2020	2025	2030
Space Heating & Cooling	70	200	300	400	400	400	400	400
Agriculture	0	0	174	385	571	698	761	795
Electricity Production	0	0	1236	1236	3707	3707	3707	3707
TOTAL	**70**	**200**	**1710**	**2021**	**4678**	**4805**	**4868**	**4902**

Second Scenario:

Use	Annual Energy Use (TJ/yr)							
	1995	2000	2005	2010	2015	2020	2025	2030
Space Heating & Cooling	70	226	334	433	505	569	614	677
Agriculture	0	0	217	432	632	776	866	984
Electricity Production	0	0	1236	1236	3707	3707	3707	3707
TOTAL	**70**	**226**	**1787**	**2101**	**4844**	**5052**	**5187**	**5368**

Third Scenario:

Use	Annual Energy Use (TJ/yr)							
	1995	2000	2005	2010	2015	2020	2025	2030
Space Heating & Cooling	70	253	378	505	623	722	785	857
Agriculture	0	0	307	587	776	930	1056	1191
Electricity Production	0	0	1236	1236	3707	3707	3707	3707
TOTAL	**70**	**253**	**1921**	**2328**	**5106**	**5359**	**5548**	**5755**