Croatia Country Update

Sanja Živković[1], Slobodan Kolbah[2], Mladen Škrlec[2]

[1]Energy Institute Hrvoje Požar, Zagreb, Croatia, szivkovic@eihp.hr
[2]Geotermalna energija d.o.o., Zagreb, Croatia, skolbah@gmail.com, mladen.skrlec@gmail.com

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ABSTRACT

Geothermal energy has been in use in Croatia for a long time since there are many natural springs of warm or hot water. Mostly they are in balneological use but there are few examples of use for heating and greenhouses. Development of geothermal sites for power generation in spite of high potential has been delayed due to lack of investors. Nevertheless, a recent example of privately financed geothermal well construction in eastern part of Croatia gives hope for future employment of vast potential of geothermal energy in the country.

1. INTRODUCTION

Geothermal potential of the Republic of Croatia has been known for a long time and thanks to the ancient Romans who were true fans of thermal waters first baths were built with large temples and auxiliary facilities enabling them comfortable stay (Šimunić, 2008). Ever since the Romans the use of geothermal waters hadn't changed much and it is still mostly used for spas, medical therapy and recreation. Renewed interest in thermal water use for medical therapy was achieved in the end of the 19th and in the beginning of the 20th century when many of the locations in the northern part of Croatia were developed as modern spas.

2. GEOTHERMAL FEATURES OF CROATIA

With regard to geological and geothermal features, Croatia can be divided into two different regions: the Pannonian basin area to the north and Dinarides to the south. The area of Pannonian basin is characterized by average geothermal gradient of 0.049°C/m and in places reaches values of more than 0.07°C/m, and the terrestrial heat-flow density ranges between 60 and 100 mWm-2 (Figure 1). High geothermal potential of this area is indicated by numerous spas with water temperatures up to 85°C. At these locations geothermal energy is used for bathing, and only in few localities also for individual heating of associated accommodation buildings. On the other hand, in the area of Dinaridic mountains geothermal gradient ranges between 0.01 and 0.03°C/m with average value of 0.018°C/m (Figure 1). In this area only a few of sub-thermal events are recorded along the Adriatic coast, and highest temperature of 28°C is present in the central Istria at Livade where today is popular Istria Spa.

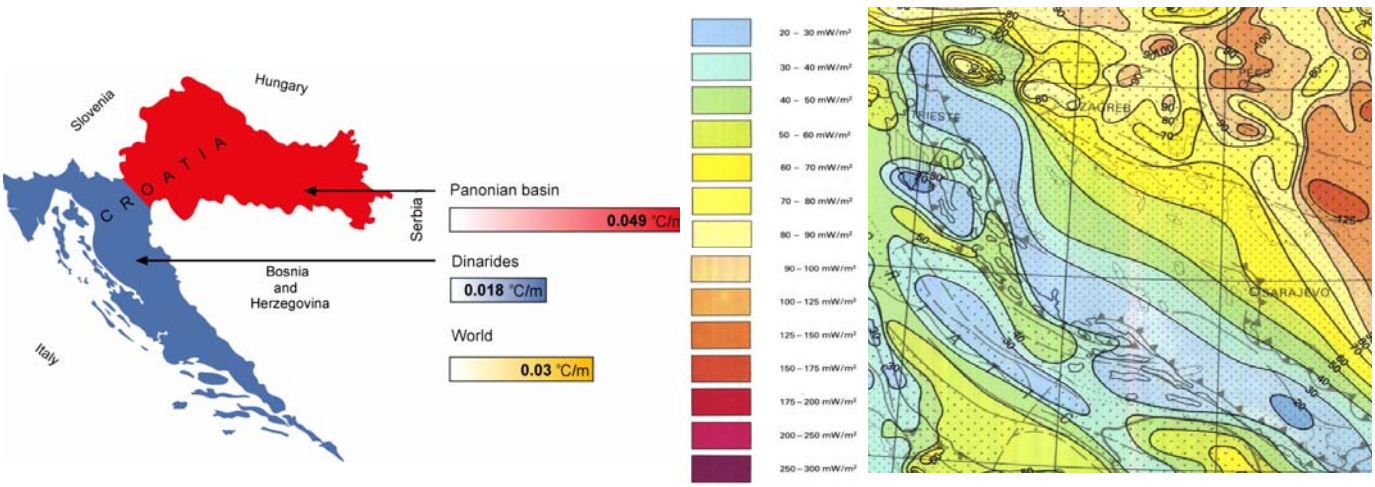

Figure 1: Geothermal gradients and terrestrial heat flow density in Croatia

Most of the geothermal findings in the Pannoninan area had been associated with the oil and gas exploration in the last fifty years. In that period construction of about 4000 exploration and production wells and several thousand kilometers of seismic profiles led to discovery of numerous geothermal water reservoirs. First geothermal field was developed in Bizovac where geothermal water with temperature up to 85°C is used in an oil well born Spa. In the Zagreb area geothermal waters with temperatures between 50°C and 80°C are produces form developed geothermal filed but its full potential has not yet been utilized. A geothermal field Ivanić near Zagreb was put in operation in the vicinity of the oil producing area, with utilization of geothermal waters of 60°C containing therapeutic mineral oils used in rehabilitation hospital.

Alongside to developed geothermal fields and spas there are many locations where drilling has enabled discovery of geothermal waters of high temperatures suitable even for electricity production (Fig. 2). Anyway, only few of these high temperature locations had been developed to a state of geothermal field with licenses for exploration or production.

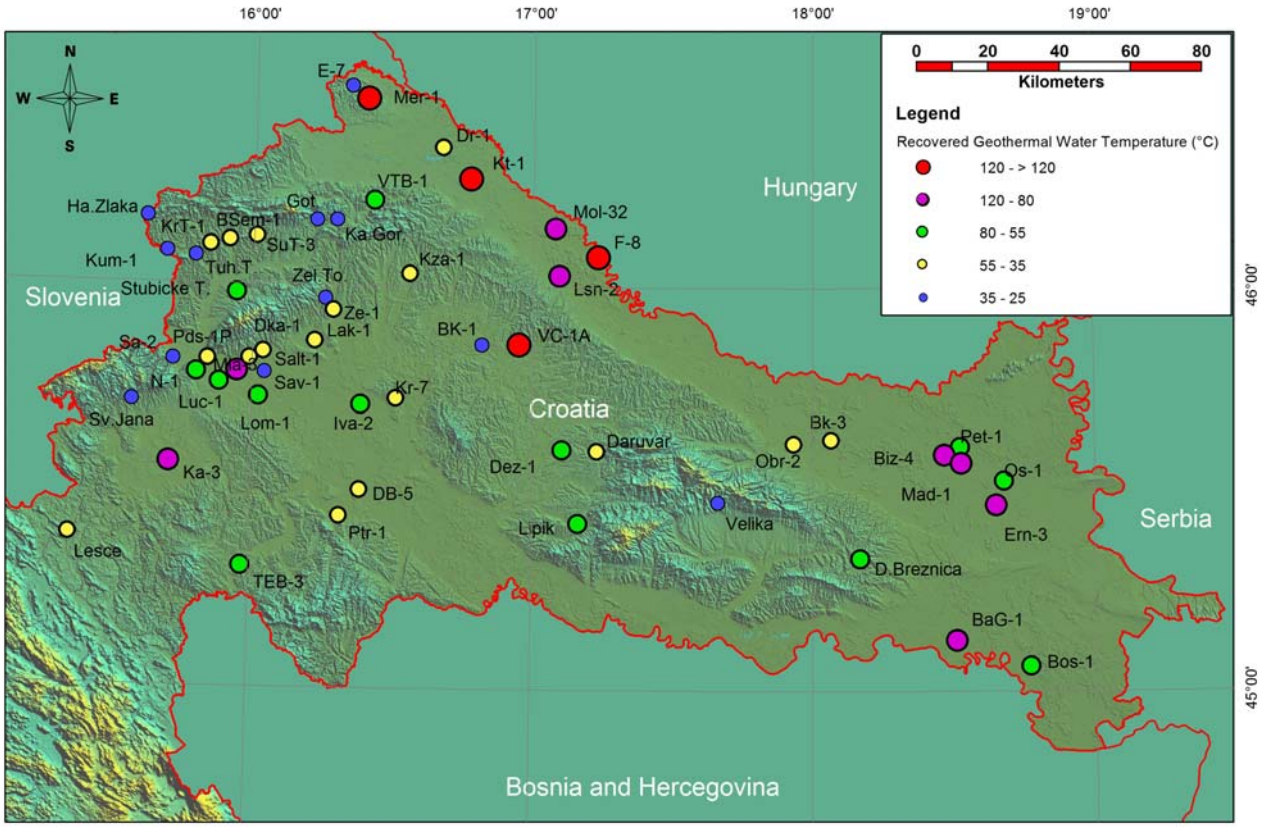

Figure 2: Known geothermal water sources in Croatia

3. GEOTHERMAL ENERGY USE IN CROATIA

Geothermal water is today produced in 18 Spas mostly for bathing and space heating. Total capacity of this production amounts to 54.46 MWt (Table 1). Of this 22.15 MWt is the capacity of bathing and swimming rest being individual space heating. In two locations (Zagreb-University hospital and Zagreb Lucko) geothermal energy is used for individual space heating with the capacity of 13.77 MWt. In another three locations (Bosnjaci, Krapinske Toplice and Sveta Nedjelja) greenhouses are heated by geothermal energy with capacity of 7.53 MWt making geothermal use capacity total 75.76 MWt.

The temperature extraction level of geothermal wells production varies from 25°C up to 85°C. Annual utilization of thermal energy from all geothermal localities using it as a direct heat, calculated on the basis of the average capacity factor of 0.27, could reach nearly 650 TJ/yr. Unfortunately, geothermal heat is in most locations used during approximately 3-4 months a year and therefore considering variations of outlet temperatures, and average flow as well as annual utilization the potential of geothermal energy use in these developed locations is considerably larger.

Table 1: Capacity of geothermal direct heat production locations

	Locality	Type	Capacity (MWt)
1	Bizovac Spa	HB	1,38
2	Bošnjaci	G	2,93
3	Daruvar Spa	B	1,32
4	Ivanić Grad Spa	B	0,38
5	Jezerčica Spa	B	0,63
6	Krapinske Toplice Spa	HB	5,02
7	Krapinske Toplice (Greenhouse)	G	0,63
8	Lešće Spa	B	0,39
9	Lipik Spa	HB	1,44
10	Istarske toplice Spa	B	0,13
11	Samobor Spa - Šmidhen	B	1,24
12	Stubičke Toplice Spa	HB	5,96
13	Sutinske toplice Spa	B	5,02
14	Sveta Jana Spa	B	3,33
15	Sveta Nedelja	G	3,97
16	Sv. Martin Spa	B	0,3
17	Topusko Spa	HB	9,48
18	Tuhelj Spa	B	5,65
19	Varaždinske Toplice Spa	HB	6,20
20	Velika Spa	B	2,20
21	Zagreb – Mladost (swimmingpool)	HB	2,51
22	Zagreb - University Hospital	H	13,60
23	Zagreb - Lucko (Luc-1)	H	0,17
24	Zelina Spa	B	1,88
	TOTAL		75,74

4. BOŠNJACI SJEVER – A RECENT EXAMPLE OF GOOD PRACTICE

Geothermal exploration activities in a small town Bošnjaci in eastern part of Croatian part of the Pannonian basin started in 2009, by an owner of greenhouses for growing hydroponic tomatoes. The greenhouse size of 1.25 acres required a huge amount of natural gas for heating and the owner was looking for alternatives. He approached INA-Oil Industry to explore the possibility of constructing a geothermal well in order to reduce the cost of heating. As the location was in an area of high geothermal potential geological work could start. Two deep exploration wells are located in the vicinity of greenhouses and together with other available geophysical information enabled determination of position for a new deep well.

Drilling started in 2011 and geothermal reservoir in sandstones was reached at depth of 782 m to 1035 m. The value of the geothermal gradient at the well was 0.61°C/km. Water temperature at the top of the reservoir at was 73.3°C with hydrostatic pressure in the reservoir was 101.6 bar. The water salinity of approximately 2 g NaCl/l and absence of heavy metals is making water suitable for use. The resultant output of 20 l/s (1,728 m^3/day) with the water temperature at the mouth of the well of 65°C was more than enough for the intended purpose. Due to greater amounts of sand in the production, sand filters were installed causing the reduction of flow by half to 10 l/s which still satisfied the needs for heat production. The interpretation of hydrodynamic measurements revealed that it was a large areal dispersal reservoir with supported pressure on a boundary and reservoir pressure is not expected to fall during production.

4.1 Economic viability of the geothermal energy project

Economic and financial assessment of geothermal energy production is considered for the next twenty years (which does not mean the end of production). The assessment is made on the basis of the annual production of geothermal water of 154 000 m^3 per

year which corresponds to the energy consumption of 600 000 m^3 of natural gas.

Even with the high investment of the deep well construction and the entire geothermal system, the exploitation of geothermal water with a projected production achieved positive economic effects.

The planned extraction of geothermal water is a subject of direct and indirect expenses and liabilities charged to the future income. The structure of expenditure includes investment of 1.6 million EUR, material production costs, and allocated costs in the amount of 5% and the concession fee in the amount of 3% to the total revenue. With the discount value of 8% the payback period is 8 years and the net present value (NPV) amounts to about 744 000 EUR.

The investors can expect to have approximately 20-25% less energy costs compared to the costs realized by natural gas heating. Moreover, after closing the loan (time depending on the loan terms) the investor can count on approximately 50-75% lower energy expenses than before introduction of geothermal energy use. In such conditions, geothermal energy is the energy source able to ensure long-term safe and cheap energy supply.

5. POSSIBILITIES OF GEOTHERMAL POWER GENERATION IN CROATIA

In the last few years, interest for geothermal exploration and production by several domestic and international companies. Their interest have been focused mostly towards power generation at and in the vicinity of existing production licenses at Lunjkovec-Kutnjak and Velika Ciglena geothermal fields. Their work gave rise to geological understanding and delineation of the most important geothermal reservoirs focusing on improving testing technologies and interpretation of gathered data. This was accompanied by deep wells and surface facilities design, construction and final equipment for production. Such an approach increased awareness of local and overall geothermal potential in Croatia. Geological exploration of other geothermal objects led to approval of 10 new exploration licenses. Of these, eight are holding licenses for power generation (Draskovec, Prelog, Kotoriba, Legrad-1, Mali Bukovec, Ferdinandovac-1, Slatina, and Babina Greda). Two exploration licenses were approved for direct use of geothermal energy at Bošnjaci sjever and Sveta Nedelja in Zagreb area. (Fig. 3).

Locations suitable for power production are limited to the extremely strong hydrodynamic water flows which are possible from massive carbonate bodies, and highest reservoir water temperatures preserved, in the Pannonian Basin, under the thick Tertiary clastic sediment cover, generally at depths of 1500 – 2000 m, but in places even deeper.

Geothermal field Kutnjak-Lunjkovec is a highly explored area which is currently in stage of additional testing necessary to establish production. It is seated on the huge massive and fractured carbonate rock range covered by Tertiary sediments of Drava basin supporting high hydrodynamic performances of the reservoir.

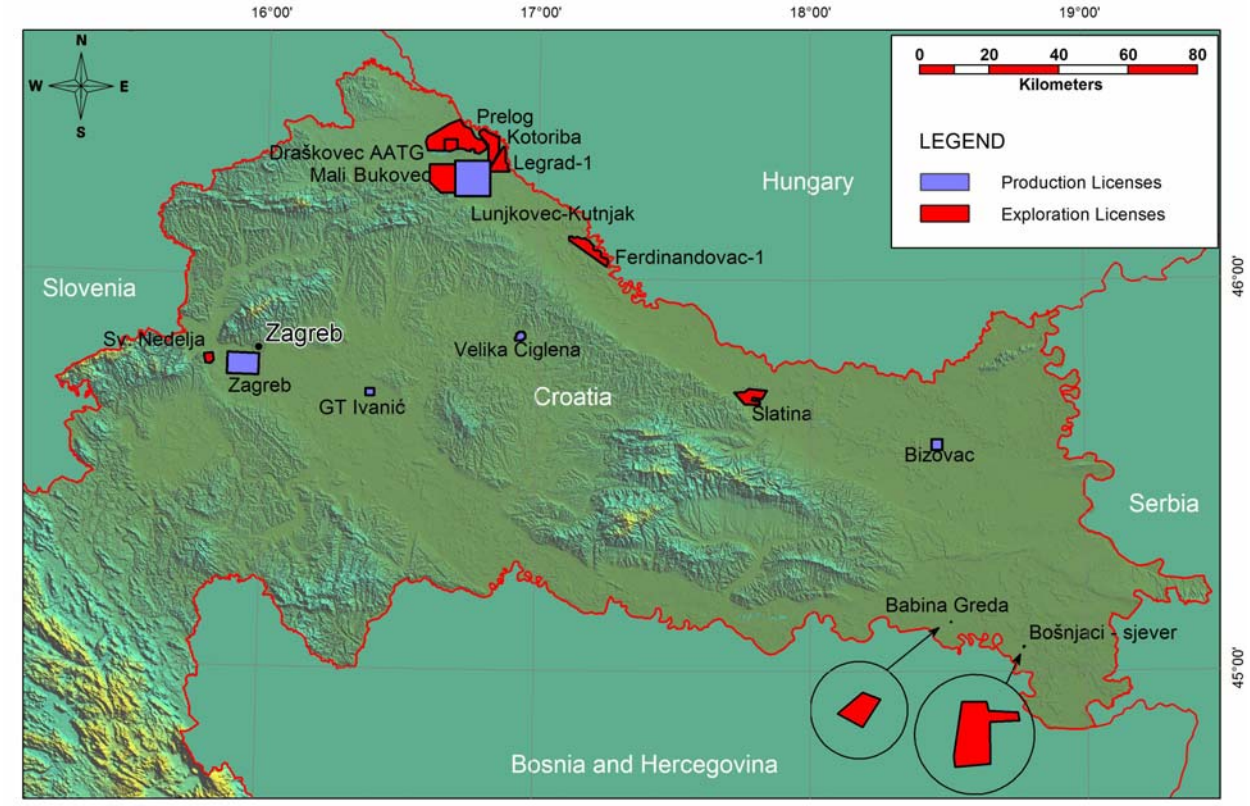

Figure 3: Exploration and production blocks licensed by the government in the northern Croatia

Geothermal field Velika Ciglena is already holding production license and with high water temperatures and several studies conducted is having the best chance to start operation in short time.

Another interesting location holding the exploration license is Draškovec where in the consumed geothermal water abundant quantities of natural gas are dissolved. This gas, also known as Aquifer gas presents an unconventional gas resource which have been recoded also in another locations. In Draškovec, after separation of gas from the geothermal water, it is used for electricity production at the site

Bearing in mind the exploration level of the most perspective localities in the next 10 years production could be expected in five of them with proven geothermal potential.

Considering conducted preliminary analyses and studies in the sense of feasibility, no power production project is feasible without utilization of residual heat. The best way of residual heat utilization is on the cascade principle where it can be used for district heating and cooling, in a number of industrial uses, in greenhouses, aquaculture etc. In that regard production of 30.09 MW_e and 187.27 MW_t at these five locations can realistically be expected (Table 2).

Table 2: High water temperature reservoirs in Croatia with issued exploration or production licences

Location	Water temp. (°C)	State of the project	Licence	Possible installed power[a] (MWe)	Possible installed heat power[b] (MWt)
Babina Greda (BaG-1)	125	Planned	EL	2,36	36,90
Draškovec	113	Ongoing	EL	n.a.	n.a.
Ferdinadovac (F-8, Drk-1)	138	Under development	EL	1,77	27,67
Kutnjak–Lunjkovec (Lun-1, Kut-1)	116-140	Under development	PL	10,50	50,00
Velika Ciglena (VC-1)	170	Ongoing	PL	14,70	62,20
Kotoriba licence	120-150	Under development	EL	n.a.	n.a.
Mali Bukovec licence	120-150	Under development	EL	n.a.	n.a.
Prelog		Under development	EL	n.a.	n.a.
Slatina	190	Under development	EL	n.a.	n.a.
Legrad field (Leg-1)	120	Under development	EL	n.a.	n.a.
Total				>30,09	>187,27

[a] Inlet at 80°C
[b] Cascade use; inlet at 35°C

6. FUTURE DEVLOPMENTS

Along with above mentioned locations with already issued licenses there is a number of perspective findings of high temperature geothermal waters which need more exploration and testing in order to evaluate their true potential. Some of them are listed in the following table 3.

Croatia surely has got a lot of work to do in realization of all of its geothermal potential which can serve as an initiator of local development.

Table 3: High water temperature reservoirs in Croatia

Location	Water temp. at the borehole (°C)
Dravka-1, Slavonka-1	100
Rečica	120
Babina Greda; Ferdinadovac	125
Otok; Ranisavlje; Madarinci-1	130
Kutnjak–Lunjkovec	140
Merhatovec	150
Draškovec-1	113
Velika Ciglena	175
Hadošan-2	180
Slatina	190

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