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Croatia Geothermal Resources Updates in the Year 2009

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ABSTRACT

In general, there are two different regions in the Republic of Croatia, both in geological and geothermal respect. In the southeastern part of the country, there is the Dinarides mountain chain with predominantly Mesozoic carbonate rocks, characterized by the low geothermal gradients ranging from 0.01 to 0.03°C/m. In the northeast part of the country we find the Pannonian basin, up to several thousands meters deep. There, the geothermal favorite area is marked by a geothermal gradient higher than 0.04 and more than 0.07°C/m at some geothermal fields. The main geothermal reservoirs are in the fractured Mesozoic and older carbonates rocks, mid Miocene carbonates, under the Panonnian basin and younger clastic sediments, with important geothermal reservoirs in their sandstone sequences.

So far, that potential has been used at numerous spas, and occasionally on few geothermal fields, developed by drilling. Most of the further development should relay on the experience, wells and other technical facilities remaining from oil and gas exploration and production in the area. In the last fifty years several thousands exploratory and producing wells were drilled and nearly fifty oil and gas fields and five geothermal fields were put in production. A huge amount of direct information from wells comes in the set with massive and partly modern geophysical measurements including 3D seismic. To define these geothermal resources and to indicate the full range of potential and delineate the best objects, regional geological and detailed studies are performed. Further hydrodynamic tests are performed and technical and legislative documentation is prepared for several most developed objects.

Only 18 spas or fields have been utilized to tap the geothermal resources of the area, and the percentage of usage of their available power is very small. Installed capacities have a thermal power of 67 MWt, with an annual energy production of 469 TJ/yr. Improvement of such a condition can be significant for the future economic development of certain regions in Croatia. Increase of direct geothermal energy usage in the past five years was indicated, while the plans for construction of a geothermal electric power plant are postponed to the year 2010.

1. INTRODUCTION

Geothermal resources capable of supporting direct use and, eventually for production of electricity are found primarily in the Northern part of the Republic of Croatia, in the Pannonian Basin area (Figure 1). However, geothermal heat pumps are not so dependent of favorable geological conditions, so their utilization is possible all over the country.

In spite of discoveries of potential geothermal fields for geothermal electric power production several decades ago, the first production is expected after 2010. Such icebreaking processes are dependent upon a number of factors including competing prices for energy and incentive programs that encourage development of renewable energy resources.

Significant multilateral efforts have been done in last five years in the Republic of Croatia to start taping this national source of energy. Efforts are focused on the pilot project Kutnjak, located in the north Podravina region, in the North West part of the country. Apart from an existing well and appropriate geological studies, another production well will be drilled and production tests will be completed. Expected production will include electric power generation, and direct heat utilization in drying of agricultural products, individual space and district heating, bathing and other purposes. That project is a joint venture of the geothermal water producer INA-Naftaplin, Zagreb, national electric energy producing and distributing firm HEP, Zagreb, food industry Podravka, Koprivnica, and the local government with the state support in energy price policy and funding. Encouraged by this joint initiative, the local operating oil, gas and geothermal water exploring and producing company, INA-Naftaplin, is preparing several other projects including electric power generation.

With success of this project, geothermal energy will remain, however, a small contributor to the electric power capacity and production in the country. Even with ten times more capacity than that Kutnjak-1 plant, in a total projected use by year 2015, geothermal electric capacity will be about 0.23 or 0.64 percent of the total electricity yearly production.

Direct-use, other than geothermal heat pumps, has essentially remained fairly the same, but our attempt in this report was to be more realistic, especially of their capacity utilization level. Our attempt to report geothermal heat pump development in the country failed again, because of unreliable information on this important ongoing activity. Table 2 predicts the future geothermal electric plant capacity at the Kutnjak geothermal field, and in the Table 5 we can find an attempt to specify ways of direct heat uses. Individual Space heating and bathing are nearly even and greenhouse use is coming but data is still not reliable.

2. PRODUCTION OF GROTHERMAL ENERGY

Table 1 presents operable electric production capacity and power generation in the Republic of Croatia and its part of nuclear production of electricity in the neighboring Slovenia. Sources are mostly, as reported, for 2008 and 2009; no reliable data were available at the time of writing this paper. All data, except other renewable, came from HEP Production (website: www.hep.hr) and government institutions.

Utilization of geothermal energy for direct heat has basically stayed somewhat constant in the last decades, but in this report we try to put same more reliable values. Table 3 presents more reliable values for the geothermal heat production parameters, especially for the geothermal fields other than spa and recreation centers.

Besides of the growing understanding of the importance of renewable, clean and nationally controlled energy at the industry, social and government levels, great work was done on the geological understanding and delineation of the most important geothermal water bodies, on improvement of testing technologies and test results on geothermal wells. Great effort is done for better understanding of already discovered objects, and to put into production and explore elsewhere.

An important event for the geothermal development and joining the international society happened last summer in Dubrovnik, where the Petroleum engineering summer school on Geothermal Fields Development, took place. Besides local and international experts, distinguished gests such as John W. Lund, Pierre Ungemach, Kiril Popovski, and Hagen Hole have attended.

3. GEOLOGICAL BACKGROUND AND INITIAL GEOTHERMAL ENERGY CONSUMPTION

As is reported in previous country reports (Čubrić at al 1995; Jelić et al 2000 and 2005) the Republic of Croatia can be divided generally into two different regions in geological and geothermal sense: the Pannonian Basin and the Dinarides (Figure 1).

In the Dinarides area the temperature gradient ranges from 0.01 to 0.03 °C/m and the terrestrial heat-flow density from 20 to 60 m Wm^{-2}. But even there we have the Istria spa - Livade (mainly 28 occasionally up 36.5°C) with more subtermal events along the Adriatic coast at Split, Sinj, Omiš and Mokošica near the town of Dubrovnik. In the transition zone to the Pannonian tertiary basins of SW Sava, there are several well-known Spas: Sveta Jana (25.8 °C), Lešće (predominantly 30.7 up to33.4°C) and Topusko (in use 66.6 °C).

The main geothermal potential in Croatia is in the Pannonian area where the temperature gradient ranges from 0.03 to more than 0.07 ^{0}C/m. The terrestrial heat-flow density is also high, ranging from 60 to over than 100 mWm^{-2}. Geothermal potential is indicated by numerous Spas in the NW Croatia: Jezerčica (38.4°C), Krapina Spa (40.7 °C), Stubičke Toplice (53.4 up to 58.2°C), Spa at Zlatar (Sutinske Spa; 33.8 up to 35.7°C), Tuhelj (32.9°C), Varaždin Spa (57.6°C), Samobor (Šmithen; 29.2°C) and Zelina (up to 42°C). Along the Slavonija Mountain rim, connected with the Sava basin in West Slavonia there are more Spas such as Daruvar Spa (42.6 up to 46.9°C), Lipik (58.2 up to 60°C) and Velika (25 up to 28.9°C).

Real opportunities to tap the Pannonian geothermal potential have been realized and reached with the oil and gas exploration and production. In the last fifty years several thousand exploratory and producing wells were drilled and nearly fifty oil and gas fields and five geothermal fields were put in production. First geothermal fields were developed in the Zagreb area with a production from 50 to more than 80°C and near the oil producing area Ivanić Grad with production up to 60 °C. In East Slavonia at Bizovac, geothermal water up to 85 °C is used in an Oil Well born Spa.

In previous country reports and the more recent publications there has been much reported on the discoveries and on the more or less successful geothermal tests as Karlovac in SE Sava area, Babina greda (Kolbah et all; 2004) in E Slavonija, or on the development of the Kutnjak field (Kolbah et all; 2006) in the NW of the Drava area, near by Velika Ciglena (Pravica et all; 2006) and about geothermal energy extraction from the water below the oil field Beničanci in E Drava area (Kulenović et all; 2006). In that time more regional studies have been delivered (Rajković et all; 2006). Except geothermal heat pumps, and some wells relinquished to the public or private users, geothermal production is mostly relaying on the knowledge and properties of the INA-Naftaplin company, which for the moment controls exploration and production rights on the most promising northern part of the country (Figure 2).

The problem of increasing geothermal energy consumption could be tackled by the cogeneration with the enhanced hydrocarbon production (Kolbah et al, 2007) and the promotion of renewable energy in the European Union (Golub et al, 2007; and Kolbah, Škrlec, et al, 2008). There is a huge future geothermal potential in the gas condensate fields of NW Drava, which are now still the main asset of INA-Naftaplin (Kurevija et al, 2008). There is a whole new group of technologies connected with geothermal consumption, which has to be developed in the near future (Vulin et al, 2008).

Regional studies combined with case reports supporting the geothermal production constitute important efforts to visualize and locate geothermal fields and form the most reliable information for new fields' development. A part of this information, among other, is a structural depth map of the top producing formations (Figure 3).

4. GEOTHERMAL POTENTIAL

Total direct heat capacity of 20 Spas and 5 geothermal fields in the Republic of Croatia is placed blow 70 MWt. We came to this value by adding thermal power used for space heating, bathing and swimming in Spas and recreation centers. Capacity or thermal-power is calculated from each natural thermal spring or abandoned oil well producing thermal water, taking in account the take-off temperature, or the difference between inlet and outlet temperature used for heating, and unit-quantity and thermal quality of specific basin. Including effective consumption time in a year, we can assume annual utilization of each source. The temperature extraction level of geothermal wells production varies from case to case, from 25 up to nearly 70^{o}C, or is about 15^{o}C for thermal take-off in our Spas, from the water of the natural thermal springs. Annual utilization of thermal energy production from all 25 geothermal fields and Spas, calculated on the basis of the capacity factor of 45%, could reach nearly a 500 TJ/yr. According to those calculations for the three most important geothermal wells, based on their multi-years production, the power calculated capacity is nearly 18 MWt, while the annual utilization of geothermal energy comes up to 78 TJ/yr, with the capacity factor of 32%. There are 22 Spas and less important wells with much lower performances, but because of their number they still have 75% useful capacity and over 80% of total annual geothermal heat utilization. Obviously this indicates a much higher geothermal potential of the area.

Looking only at the five geothermal fields with the highest geothermal potential discoveries, having geothermal water above 100^{o}C, a breakthrough in geothermal consumption that seems most promising, with concentrated joint effort, is in the Kutnjak area, which is expected to come in production soon after year 2010. In previous country reports a lot has been publicized about the geology, already existing wells, and their testing as the greatest part of the investment costs. Feasibility studies on combined electricity and heat production were performed. After all these years of efforts we hope that now we will finally have a breakthrough.

As was already said, putting all these discoveries in production with even ten times higher performances than the first one, it will be just a small improvement of the total production of electricity in Croatia, but it will be more important in direct use and indirect effects, which will altogether justify high investments in that clean, renewable and domestic energy.

5. CONCLUSION

All the geothermal localities that have been used for decades for recreational and medical purposes belong to the group of the low temperature natural thermal springs. Some of those spas were equipped with space heating systems based on the utilization of geothermal energy by means of heat exchangers. The geothermal reservoirs that are currently still not in use are located in agricultural areas. Another utilization of geothermal energy for greenhouse heating and the subsequent industrial processing of the produced fruits and vegetables would significantly increase the efficiency of the agricultural production. The foreseen development of the geothermal energy application in the agricultural sector strongly depends on the economic interest by agricultural producers and food processing companies. In accordance with the general orientation towards ecologically acceptable renewable energy resources proclaimed in the Strategy of the Energy Development of the Republic of Croatia, a significant growth of the geothermal energy usage is planned. In the first phase the growth will be based on the total exploitation of the existing geothermal wells together with new, appropriate for high temperature and long-term production. The increase of the capacity factors of the future development will strongly relay on already existing capacities to cut investments. Beside development in the direct heat segment, the planned construction of the geothermal power plant in Kutnjak after the year 2010 would bring Croatia into the group of countries producing electricity from geothermal sources. The initial power of 2.0 MWe obtained from the new producing well should be increased with further development, but in our prediction, not before the year 2015.

Never the less, we strongly believe in it and concentrate our abilities to try to attract other important partners to activate the national geothermal potential.

ACKNOWLEDGEMENTS

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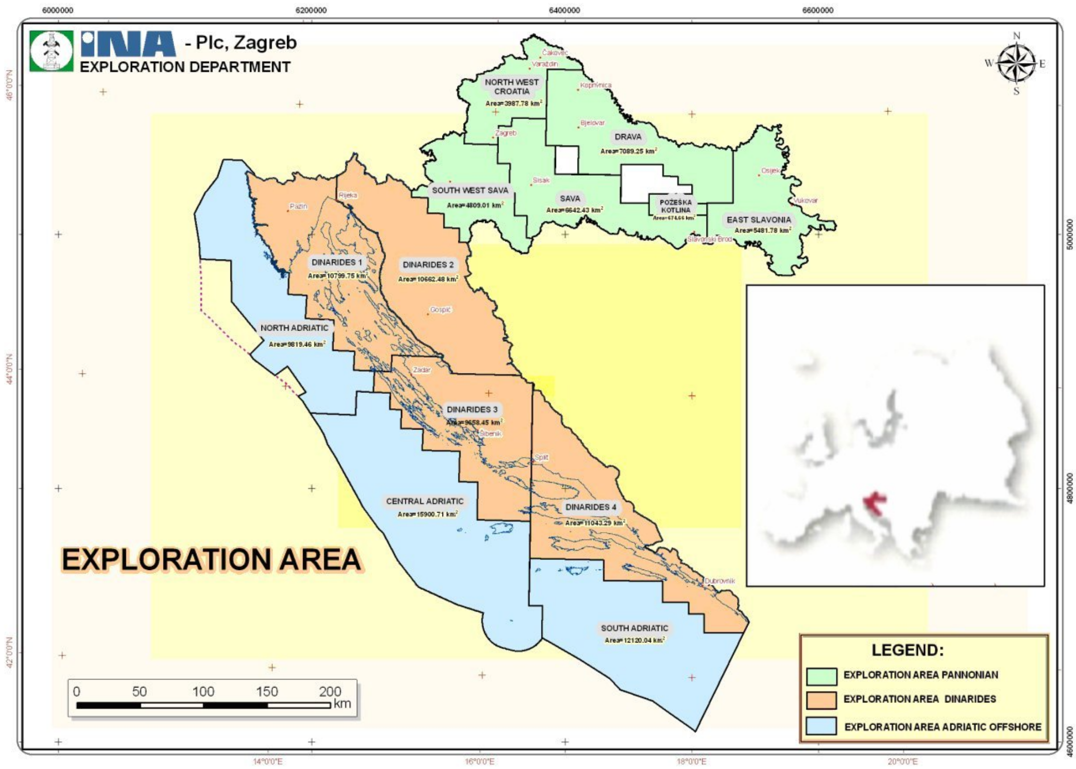

Figure 1 INA Naftaplin Exploration blocks in the Republic of Croatia; in the north are the areas of the Panonian basin, along the Adriatic coast the Dinarides mountainous chain and in the west the Adriatic offshore.

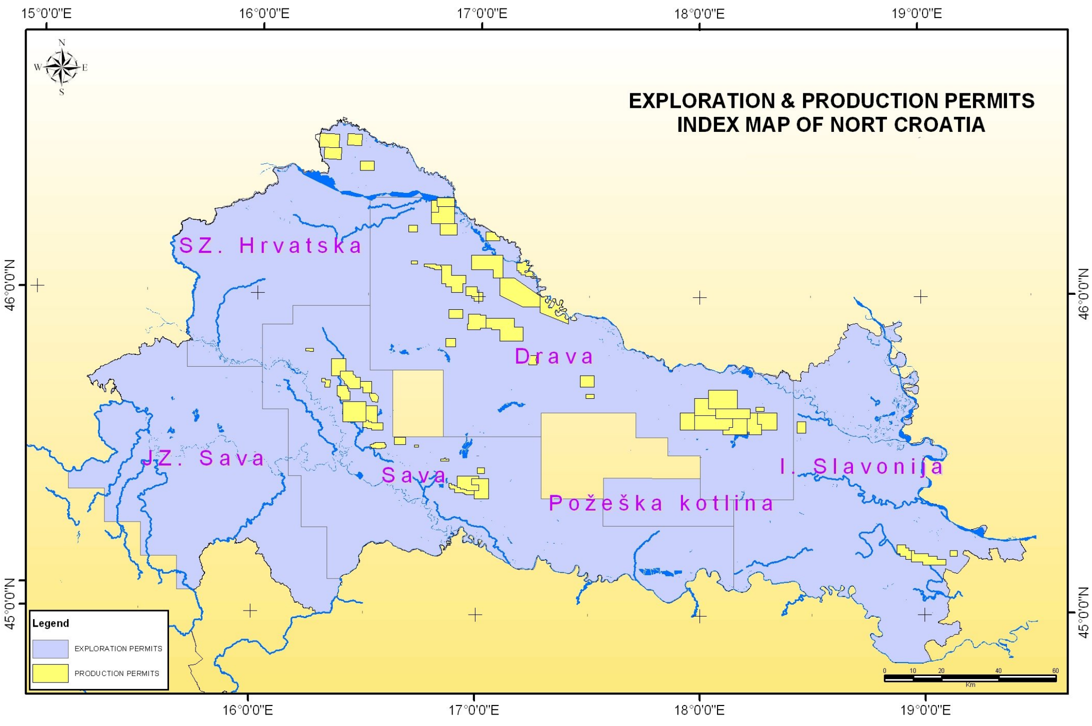

Figure 2 I: NA-Naftaplin Exploration and production blocks in the geothermal areas of the Pannonian basin.

The main direct heat utilization fields in Zagreb and Ivanić-Grad are situated at the NW of the Sava Exploration Block and Bizovac is located in the oil production block in the E. Slavonia Exploration block.

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Most of the Spas (Jezerčica, Krapinske toplice, Stubičke Toplice, Varaždinske toplice, Sutinske toplice, Tuheljske toplice, and Šmidhen) are in the NW Hrvatska Exploration block and some in the NW Sava (Sveta Jana, Lešće, Topusko) and central part of Sava and Požeška kotlina (Daruvar, Lipik, Velika) and Livade

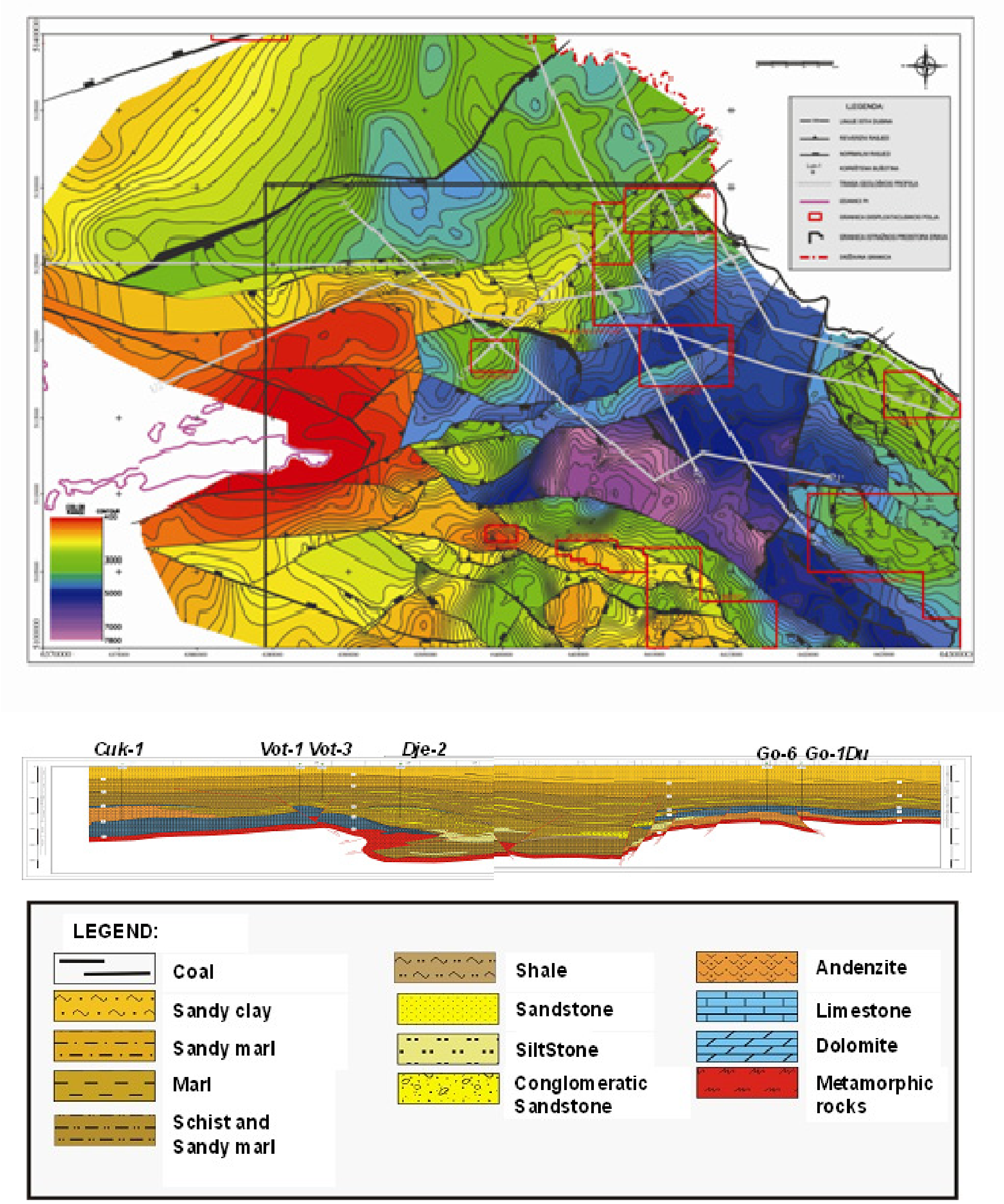

Figure 3: Structural map of the north Drava area, or regional setting of Kutnjak – Lunjkovec geothermal field. The map is showing the Top of the carbonate reservoirs below the Tertiary basin clastic cover. On the geological cross section, running north from the mentioned field to the east, at the Gola Plato, also looks promising. Between mostly insulating Tertiary basin filed rocks, colored white, brown and red except sandstone colored yellow (some of which are good aquifers), we can find limestone and dolomite carbonates (colored blue) where the best geothermal reservoirs of the area are encountered.

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

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)[1]		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2008			1,798.5	8,992.5	2,149.3	7,164.2	353.5	2,714.0	2,063.9	4,127.8	6,365.2	22,998.5
Under construction in December 2009			0.0		42.0	140.0	0.0		1,168.5	2,337.1	1,210.5	
Funds committed, but not yet under construction in December 2009	2.0		1,150.5	5,750.0	0.0		0.0		0.0		1,152.5	
Total projected use by 2015	2.0	20.0	2,948.5	14,742.5	2,191.3	7,304.2	353.5	2,714.0	3,232.5	6,464.9	8,727.7	31,245.6

[1] Biomass 9, Biogas 15, Wind 85, Solar 11, Small Hydro 53, Cogeneration 5

Gross Production is predicted on a level of 2008

TABLE 2: UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2009

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 2009 if available

Locality	Power Plant Name	Year Com-missioned	No, of Units	Status 1)	Type of Unit2)	Total Installed Capacity Mwe	Annual Energy Produced 2009 3) GWh/yr	Total under Constr, Or Planned Mwe
Croatia	Kutnjak	2010	1	N	B	2.0		2.0
Total						2.0		2.0

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TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT

AS OF 31 DECEMBER 2008 (other than heat pumps)

1) I = Industrial process heat

C = Air conditioning (cooling)

A = Agricultural drying (grain, fruit, vegetables) D = District heating (other than heat pumps)

F = Fish farming B = Bathing and swimming (including balneology)

K = Animal farming G = Greenhouse and soil heating

S = Snow melting O = Other (please specify by footnote)

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 = 106 W)

or = Max, flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.002

4) Energy use (TJ/yr) = Ave, flow rate (kg/s) x [inlet temp, (^oC) - outlet temp, (^oC)] x 0.1319 (TJ = 1012 J)

or = Ave, flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03155

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 (kg/s)	Temperature (°C)		Enthalpy[2)] (kJ/ kg)		(MWt)	Ave, Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
			Inlet	Outlet	Inlet	Outlet				
Bizovac (Termia RC)	HB	6.0	85.0	30.0			1.38	5.01	36.36	0.84
Daruvar (Daruvar Spa)	B	21.8	42.6	27.6			1.36	5.44	10.76	0.25
Ivanić Grad (Naftalan)	B	3.0	60.0	30.0			0.38	0.02	0.08	0.01
Jezerčica (Jezercica Spa)	B	10.0	38.4	23.4			0.63	2.50	4.95	0.25
Krapinske Toplice (Krapina Spa)	HB	81.6	40.7	26.0			5.12	20.40	40.36	0.25
Lešće (Llesce Spa)	B	6.2	30.7	15.7			0.39	1.55	3.07	0.25
Lipik (Lipik Spa)	HB	23.0	58.7	43.7			1.44	5.75	11.38	0.25
Livade (Istria Spa)	B	2.0	28.0	13.0			0.13	0.50	0.99	0.25
Samobor (Šmidhen SRC)	B	19.7	29.2	14.2			1.24	4.93	9.74	0.25
Stubičke Toplice (Stubica Spa)	HB	95.0	53.4	38.4			5.96	23.75	46.99	0.25
Sveta Jana (Sveta Jana)	B	53.0	26.0	11.0			3.33	13.25	26.22	0.25
Topusko (Topusko Spa)	HB	151.0	66.6	51.6			9.47	37.75	74.69	0.25
Tuhelj (Tuhelj Spa)	B	85.0	32.9	17.0			5.33	21.25	42.04	0.25
Varaždinske Toplice (Varaždin Spa)	HB	95.0	57.6	42.0			5.96	23.75	46.99	0.25
Velika (Toplice RC)	B	35.0	25.0	10.0			2.20	8.75	17.31	0.25
Zagreb (Mladost SC)	HB	12.0	80.0	30.0			2.51	5.15	33.96	0.43
Zagreb (Univ, Hospital)	H	65.0	80.0	30.0			13.59	1.11	7.32	0.02
Zagreb Lucko (INA)	H	2.0	50.0	30.0			0.17	0.49	1.28	0.24
Zelina (Zelina RC)	B	30.0	40.0	25.0			1.88	7.50	14.84	0.25
Zlatar (Sutinske Spa)	B	80.0	33.8	18.8			5.02	20.00	39.57	0.25
TOTAL		876.3					67.48	208.84	468.89	0.31

TABLE 4: GEOTHERMAL (GROUND -SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2009

No detail information is available; a total number of several hundreds installations can be assumed by 2009

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

1) Installed Capacity (thermal power) (MWt) = 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 enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave, flow rate (kg/s) x [inlet temp, (°C) - outlet temp, (°C)] x 0.1319 (TJ = 1012 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 = 106 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

Use	Installed Capacity [1] (MWt)	Annual Energy Use [2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating [4]	34.78	253.05	0.24
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying [5]			
Industrial Process Heat [6]			
Snow Melting			
Bathing and Swimming [7]	32.70	215.84	0.23
Other Uses (specify)			
Subtotal	**67.48**	**468.89**	**0.24**
Geothermal Heat Pumps			
TOTAL	**67.48**	**468.89**	**0.24**

4) Other than heat pumps

5) Include 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, 2009 TO DECEMBER 31, 2009 (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)					
Production	>150o C					
	150-100o C			1		3.15
	<100o C					
Injection	(all)					
Total		0	0	1	0	3.15

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 Programs (6) Private Industry

Year	Professional Person-Years of Effort					
	1	2	3	4	5	6
2005	0	3	4	0	0	15
2006	0	3	4	0	0	15
2007	0	3	4	0	0	15
2008	0	3	4	4	0	15
2009	0	3	4	0	0	15
Total	**0**	**15**	**20**	**4**	**0**	**75**

TABLE 8: TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) 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	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
2000-2004	0.0	1.0	2.0	0.0	40.0	60.0
2005-2009	0.0	0.5	0.2	0.0	45.0	55.0