Serbia Country Update

Mica Martinovic[1] and Mihailo Milivojevic[1]

[1]University of Belgrade, Faculty of Mining and Geology,
Geothermal Research Laboratory, Djusina 7, Belgrade, Serbia

martin@eunet.rs

Keywords: Serbia, geothermal energy, hydrogeothermal systems, heating.

ABSTRACT

Geothermal investigations in Serbia began in 1974, after the first world oil crises. A first assessment of geothermal resources has been made for all of Serbia in 1989. The territory of Serbia has favorable geothermal characteristics. There are four geothermal provinces. The most promising are the Pannonian and Neogen magmatic activation provinces. More than eighty low enthalphy hydrogeothermal systems are present in Serbia. The most important are located at the southern edge of the Pannonian Basin. The reservoirs of this systems are in karstified Mesozoic limestones with a thickness of more than 500 m. Within the territory of Serbia excluding the Pannonian Basin, i.e. the terrain comprising solid rocks, there are 159 natural thermal springs with temperatures over 25 oC. The warmest springs (96 oC) are in Vranjska spa, followed by Josanicka spa (78 oC), Sijarinska spa (72 oC) Kursumlijska spa (68 oC), Novopazarska spa (54 oC). The total flow of all natural springs is about 4000 l/s. Geothermal energy in Serbia is being utilized for balneological purposes, in agriculture and for space heating with heat exchangers and heat pumps. Geothermal energy in Serbia is being utilized for balneological purposes, in agriculture and for space heating with heat exchangers and heat pumps with total thrmal power of 100.8 MWt.

1. INTRODUCTION

Serbia is centrally situated in the Balkan peninsula (Fig. 1). It covers a relatively small surface area (about 88,000 km^2) but its geology is quite complex. The first descriptions of geothermal resources in Serbia were given at the end of 19th century by Radovanovic (1897) in the book "Ground Water". Radovanovic was one of the first Serbian hydrogeologists, and "the father" of Serbian Hydrogeology and Geothermology. Geothermal explorations in Serbia were initiated by hydrogeologists in 1974 and were carried out only for hydrothermal resources.

2. GEOLOGICAL OVERVIEW

Large geotectonic units (Fig. 2) present in Serbia belong to the Alpine Orogeny: Dinarides, Serbian-Macedonian Massif, Carpatho-Balkanides, and Pannonian Basin, and a small part of Mesian Platform (Grubic, 1980).

The Dinarides occupy the largest part of Serbian territory and are mainly Mesozoic rocks, the most significant of which are thick deposits of karstified Triassic limestones and dolomites, Jurassic ophiolitic melange and Cretaceous flysch deposits.

The Rhodope Mountains, or the Serbian-Macedonian Massif (SMM), is composed of very thick Proterozoic metamorphic rocks: gneisses, micaceous shales, various schists, marbles, quartzites, granitoid rocks, magmatic rocks, etc. The Proterozoic complex of the Serbian-Macedonian Massif extends across eastern Macedonia and northern Greece into Turkey and farther eastward. The Serbian portion of the Serbian-Macedonian Massif is actually the upper part of the crustal "granite" layer. This Massif includes magmatic, or intrusive-granitoid and volcanic rocks of Tertiary age (Milivojevic, 1992). The Carpatho-Balkanides were formed in the Mesozoic as a carbonate platform separated from the Dinarides by the Serbian-Macedonian Massif. This unit is dominantly composed of Triassic, Jurassic, and Cretaceous limestones. The Pannonian Basin, or its southeastern part in Serbia, consists of Paleogene, Neogene and Quaternary sediments with a total maximum thickness of about 4000 meters.

3. GEOTHERMAL BACKGROUND

Geothermal characteristics of Serbia are very interesting. The Earth's crust varies in thickness, increasing to the south. This thickness is uniform, about 25-29 km, in the Pannonian Basin area (Dragasevic et al., 1990). South of it, in the Dinarides, the thickness increases to about 40 km in extreme southwest Serbia. In the Serbian-Macedonian Massif, the crustal thickness is about 32 km, and in the Carpatho-Balkanides from 33 to 38 km. Values of the terrestrial heat flow density (Fig. 3) under most of Serbia are higher than the average for continental Europe. The highest values (>100 mW/m^2) are in the Pannonian Basin, Serbian-Macedonian Massif, and in the border zone of the Dinarides and the Serbian- Macedonian Massif, or the terrain of Neogene magmatic activation. These values are the lowest in the Mesian Platform (Milivojevic et al., 1992). The mentioned high heat flow densities indicate the presence of a geothermal anomaly (Milivojevic, 1992) which is certainly an extension of the geothermal anomaly of the Pannonian Basin (Bodri & Bodri, 1982). The thickness of the lithosphere, estimated by on a geothermal model (Milivojevic, 1993), is least thinnest in the Pannonian Basin, Serbian-Macedonian Massif, and its border zone on the Dinarides, only 40 km. In the Carpatho-Balkanides and the rest of the Dinarides, this thickness is up to 150 km. The lithosphere is the thickest in the Mesian Platform - from 160 to 180 km.

4. HYDROGEOTHERMAL RESOURCES

Within the territory of Serbia excluding the Pannonian Basin, i.e. the terrain comprising solid rocks, there are 159 natural thermal springs with temperatures over 15 ^{o}C. The warmest springs (96 ^{o}C) are in Vranjska Spa, followed by Josanicka Spa (78 ^{o}C), Sijarinska Spa (72 ^{o}C) Kursumlijska Spa (68 ^{o}C), Novopazarska Spa (54 ^{o}C). The total flow of all natural springs is about 4000 l/s. The highest flows are from thermal springs draining Mesozoic karstified limestones, and the next highest are those from Tertiary granitoids and volcanic rocks. The greatest number of thermal springs are in the Dinarides, then the Carpatho-Balkanides, the Serbian-Macedonian Massif, and the lowest, only one in each, the

Pannonian Basin and the Mesian Platform. As to the elevation, the greatest number of thermal springs are within the range 200-300 m More than 90% of all thermal springs are at elevations below +600 m.

Considering the present state of our knowledge of the geologic composition and hydrogeothermal properties of rocks to a depth of 3000 m, there are 60 convective hydrogeothermal systems in Serbia. Of this number, 25 are in the Dinarides, 20 in the Carpatho-Balkanides, 5 in the Serbian-Macedonian Massif, and 5 in the Pannonian Basin under Tertiary sediments (Fig 4).

Conductive hydrogeothermal systems are developed in basins filled with Paleogene and Neogene sedimentary rocks. The majority of these are in the Pannonian Basin in Vojvodina, northern Serbia. The other 14 systems are less interrelated and less important.

4.1. Pannonian Basin

Within this geotectonic unit, which is also a geothermal province (Milivojevic, 1989) comprising a complex hydrogeothermal conductive system with a number of separate reservoirs, four groups of reservoirs are individualized by depth. The first group of reservoirs have a maximum thickness of 2000 m. The highest water temperature in the reservoirs is 120 ^{o}C, (Fig.5). The average flowing well yields are 1-13 l/s. Total mineralization of thermal waters is 1-9 g/kg, mostly 3-5 g/kg. Chemically, thermal waters are of HCO_3-Na type. Water temperature at well-heads are 40-55 ^{o}C, maximum 82 ^{o}C (Tonic et al., 1989).

The second group of reservoirs are in Lower Pliocene and Pannonian sediments, composed of sandstones of a lower porosity than the aquifers of the first group. Thermal waters in this reservoir are of HCO_3-Cl-Na type and of mineralization rate 4-20 g/kg, mostly 5-12 g/kg. The maximum expected water temperature in this reservoir group is up to 160 ^{o}C. Average yields of flowing wells are 2.5 to 5 l/s, and the well-head water temperatures are 50-65 ^{o}C on average.

The third group of reservoirs are those at the base of Neogene or Paleogene sediments. These are Miocene limestones, sandstones, basal conglomerates, and basal breccias, (Fig.5). Thermal water contained in these rocks is highly mineralized (to 50 g/kg), and its chemical composition is of the HCO_3-Na type. Average well yields are 5-10 l/s and water temperature at well-heads are 40-50 ^{o}C.

The fourth group of reservoirs are in Mesozoic and Paleozoic rocks under Paleogene end Neogene sediments. The most important reservoirs of this group and of the entire Pannonian hydrogeothermal system in Serbia are Triassic karstified and fractured limestones and dolomites. Similar reservoirs extend beyond the Serbian border, in the Pannonian Basin, in Hungary and Slovakia. Far from the basin's margin, at depths exceeding 1500 m, thermal waters in Triassic limestones are of Cl-Na type. In the marginal zone of the basin, where Neogene sediments are 1000 m deep over Triassic limestones and where water-exchange is active, thermal waters are of HCO_3-Na type and have mineral contents of up to 1 g/kg. Average well-yield is 12 l/s, or 40 l/s from reservoirs near the basin's margin. The water temperatures at well-heads are mostly 40-60 ^{o}C.

4.2. Dinarides

Hydrogeothermal systems in this geothermal province differ in their types, kinds of reservoirs and their extents, etc., as a result of varying geology. Rocks that have the largest distribution are Mesozoic in age: (1) karstified Triassic limestones and dolomites; (2) ophiolitic melange including large Jurassic peridotite massifs whose origin is associated with the subduction of Dinaridic plate under the Pannonian and the Rhodopean plates; (3) Cretaceous flysch; (4) Paleozoic metamorphic rocks; (5) Paleogene and Neogene granitoid and volcanic rocks; and (6) isolated Neogene sedimentation basins, (Fig. 5).

Hydrogeothermal systems have formed in terrains of: (1) Neogene sedimentation basins with reservoirs in Triassic limestones under them; (2) peridotite massifs and ophiolitic melange with reservoirs in Triassic limestones; (3) granitoid intrusions and respective volcanic rocks with reservoirs in the same rocks; and (4) Paleozoic metamorphic rocks with reservoirs in marbles and quartzites. The best aquifers are Triassic limestones, as the thermal water contained has low mineral content (<1 g/kg) of HCO_3-Na or HCO_3-Ca-Mg type. Springflows are very high, up to 400 l/s, and well yields are up to 60 l/s. Maximum temperatures of waters at well-heads are 80 ^{o}C.

The second important reservoirs are those in granitoid intrusions and their marginal thermometamorphosed fracture zones, (Fig. 5). The contained thermal waters are also low in total mineralization (>1 g/kg), of HCO_3-Na type, and maximum yield to 15 l/s. The highest temperature of waters at well-heads are 78 ^{o}C. There are few occurrences of thermal water in Paleozoic metamorphic rocks. Such springs have low flows (<1 l/s), low water temperatures (<20 ^{o}C), mineralization rates 5-7 g/kg, HCO_3-Na in type, and high concentrations of free CO_2 gas.

4.3. Serbian-Macedonian Massif

There are two types of hydrogeothermal systems in this geothermal province. One is the type formed in the Proterozoic metamorphic complex, with the reservoir in marbles and quartzites up to 1500 m in thickness, (Fig. 5). Thermal waters in this reservoir have total mineral content of 5-6 g/kg. Their chemical composition is HCO_3-Na-Cl type water with high concentration of free CO_2. This gas is formed by thermolysis of marble at temperatures above 100 ^{o}C in the presence of water, as verified by isotopic studies (Milivojevic, 1990). Thermal water temperature at springs is 24-72 ^{o}C and springflow is of gas-lift type due to the high CO_2 gas content. The second type of hydrogeothermal system was formed in contact with and in the marginal zones of the Neogene granitoid intrusions. The reservoir rocks are granitoids, metamorphic and contact-metamorphic rocks, heavily fractured as a result of heating and cooling. The thermal springs of Vranjska Spa belong to this system type and have the warmest water in Serbia, 80-96 ^{o}C, (Fig. 5). Its mineral content varies from 0.1 to 1.2 g/kg. The water type is HCO_3-Na-SO_4-Cl. Springflows are up to 80 l/s.

4.4. Carpatho-Balkanides

This geothermal province has many hydrogeothermal systems, most of them formed in regions of isolated Neogene sedimentary lake basins. Reservoir rocks are karstified Triassic, Jurassic or Cretaceous limestones. Thermal karst springs have flows of 60 l/s, with water temperatures to 38 ^{o}C. Total mineralization is 0.7 g/kg and the water type is HCO_3-Ca. Another type of hydrogeothermal systems in this geothermal province was

formed in the Upper Cretaceous paleorift of Eastern Serbia, where Mesozoic limestones were penetrated and thickly covered with andesite lavas and pyroclastics. These water contained are up to 0.8 g/kg and the water is of SO_4-Na-Cl type, or HCO_3-Na-SO_4-Cl type where it is in limestones. Water temperatures at thermal springs are up to 43 ^{o}C, and springflows are up to 10 l/s.

5. EXPLORATION WORK

Geothermal exploration in Serbia began in 1974. A year later, the first preliminary assessment was made of the national geothermal potential (Milivojevic et al., 1975; Alimpic, 1975). Then a number of pilot studies were prepared for discrete areas (Peric & Milivojevic, 1976; Milivojevic, 1979). Another, more detailed regional exploration of geothermal resources began in 1981 and ended in 1988 (Milivojevic, 1989). This regional study was conducted in parallel with the exploration of some of the previously known hydrogeothermal systems. In the Serbian part of the Pannonian Basin, the first borehole, 1454 m deep, was drilled in 1969, the second was drilled 2509 m deep in 1974. From 1977 to 1988, 58 boreholes were drilled with a total drilled depth of about 50,000 m. The overall yield of all these wells is about 550 l/s, and the heat capacity about 48 MW (calculated for dT=T-25 ^{o}C) (Tonic et al., 1989). From 1988 to 1992, only four more boreholes were drilled. In other geothermal provinces, 45 test holes were drilled before 1992, with a total drilled depth of about 40,000 m. Only three of these as are deep as 1800 m, fourteen are 1000-1500 m deep, thirteen are 500-1000 m, and fifteen are 300-500 m deep. Most of these boreholes freeflow and are used as production wells. The total yield of these wells is about 500 l/s. Production wells have not been drilled anywhere else, because none of the hydrogeothermal systems have been well enough explored. For the same reason, the total geothermal energy reserve has not been assessed for any of the systems. The total heat capacity of all these wells is about 108 MW (thermal); the total heat capacity of all flowing wells drilled in Serbia is about 156 MW. The total heat capacity of all natural springs and wells is about 320 MW (calculated for dT=T-12 ^{o}C).

6. UTILIZATION OF GEOTHERMAL ENERGY

The commonest use of geothermal energy in Serbia are the traditional ones: balneology and recreation. Certain archeological evidence indicates similar uses by the ancient Romans in the localities of the presently known spas: Vranjska Spa, Niska Spa, Vrnjacka Spa and Gamzigradska Spa. There are today in Serbia 59 thermal water spas used for balneology, sports and recreation and as tourist centers. Thermal waters are also bottled by nine mineral water bottling companies. The direct use of thermal energy for space heating or power generation is in its initial stage and very modest in relation to its potential capacity. In the hydrogeothermal system of the Pannonian Basin, thermal water is used from 25 wells. This direct use began in 1981. Water from four wells is used for heating green-houses, from three wells for heating pig farms, from two for industrial process in leather and textile factories, from three for space heating, and from thirteen wells for various uses in spas and for sport and recreation facilities. The total heat capacity of the wells presently in use is 24 MW (Tonic et al., 1989). Thermal waters outside of the Pannonian Basin region are used for heating in several localities. Space-heating started in Vranjska Spa forty years ago. Thermal water is used there to heat flower green-houses, a poultry farm, a textile workshop, premises of a spa rehabilitation center and a hotel. A large hotel and rehabilitation center with a swimming pool is heated in Kursumlijska Spa. In Niska Spa, a heating system is installed for the hotel and rehabilitation center, including heat pumps of 6 MW, which directly use thermal waters at 25 ^{o}C. Thermal direct use in Sijarinska Spa is for heating the hotel and recreation center. A similar use is practiced in Ribarska Spa. Thermal water in Lukovska Spa is used in the carpet industry. A project has been completed for geothermal direct use at Debrc for drying wheat and other cereals. Another use at Debrc is for space heating.

7. FUTURE PROSPECTS

Exploration to date has shown that geothermal energy use in Serbia for power generation can provide a significant component of the national energy balance. The prospective geothermal reserves in the reservoirs of the geothermal systems amounts to 400 x 10^6 tonnes of thermal-equivalent oil. The prospects for use of heat pumps on pumped ground water from alluvial deposits along major rivers are very good. For intensive use of thermal waters in agro- and aqua-cultures and in district heating systems, the most promising areas are west of Belgrade westward to the Drina, i.e. Posavina, Srem, and Macva. Reservoirs are Triassic limestones and dolomites >500 m thick, which lie under Neogene sediments. The priority region is Macva, where reservoir depths are 400-600 m, and water temperatures are 80 ^{o}C. The economic blockade (1991-2000) of Serbia stopped a large project in Macva: space-heating for flower and vegetable green-houses over 25 ha (1st stage). The completed studies indicate that thermal water exploitation in Macva can provide district heating system for Bogatic, Sabac, Sremska Mitrovica, and Loznica, with a population of 150,000. In addition to the favorable conditions for geothermal direct use from hydrogeothermal reservoirs in Serbia, geothermal use can also be made from hot dry rocks, as there are ten identified Neogene granitoid intrusions. Geothermal exploitation programmes have been prepared, but they have not been brought into operation.

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Figure 1. Geographical location of Serbia
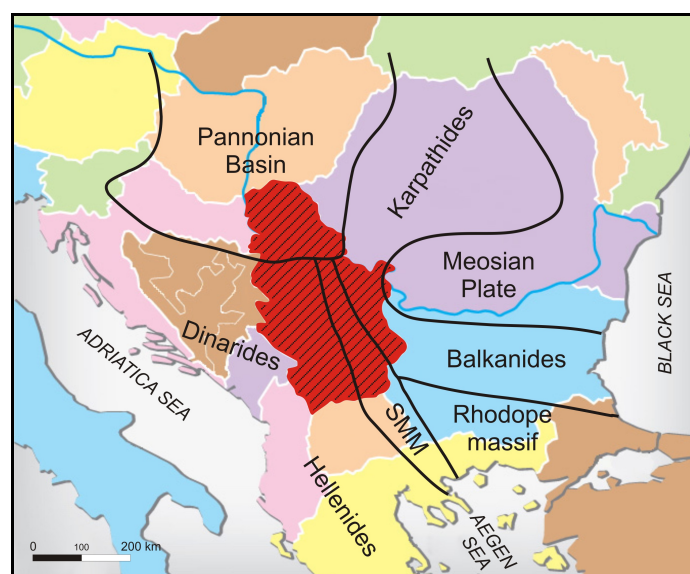
Figure 2. Tectonic map of Balkan penninsula
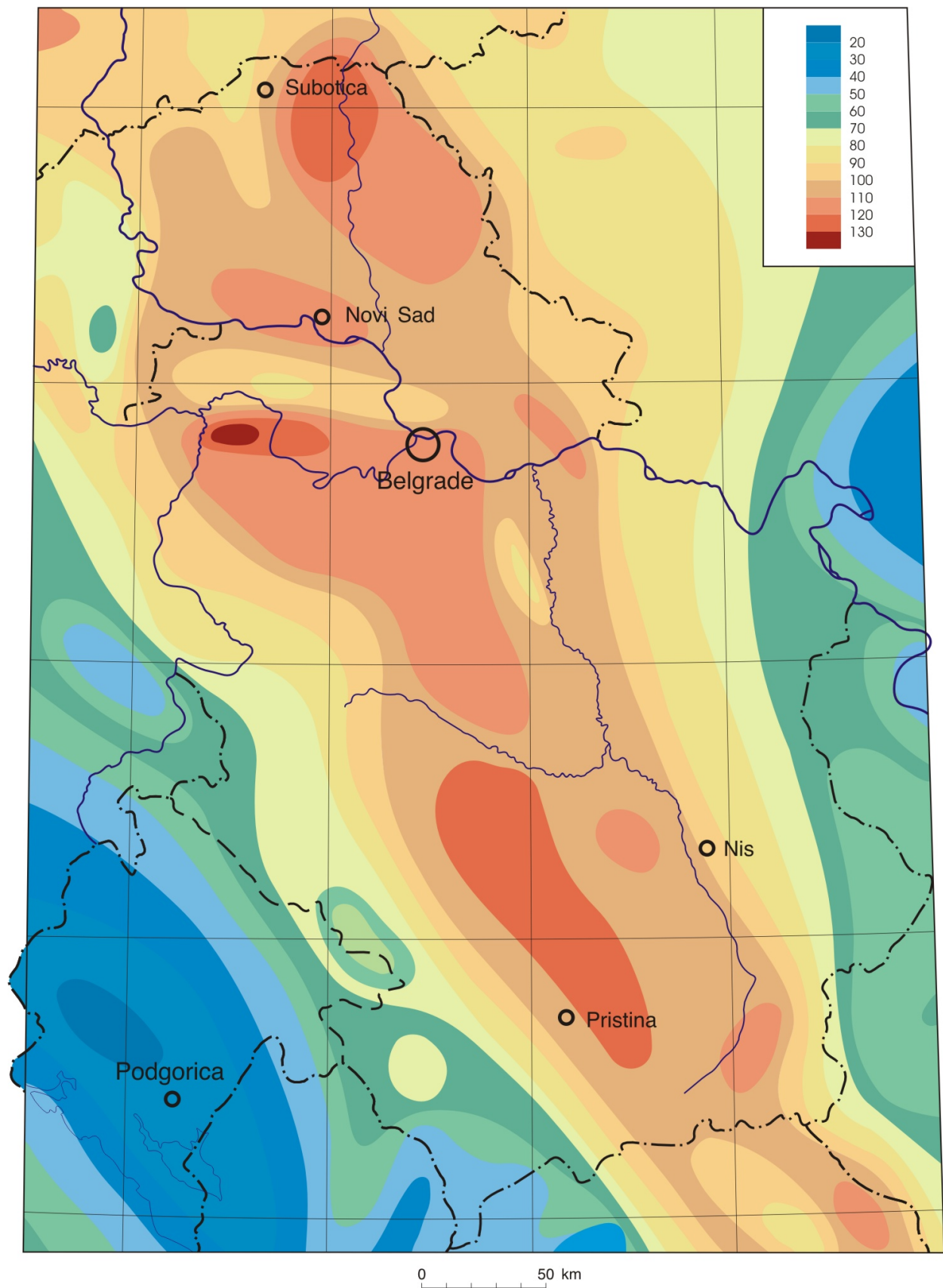
Figure 3 Heat Flow Density Map of Serbia
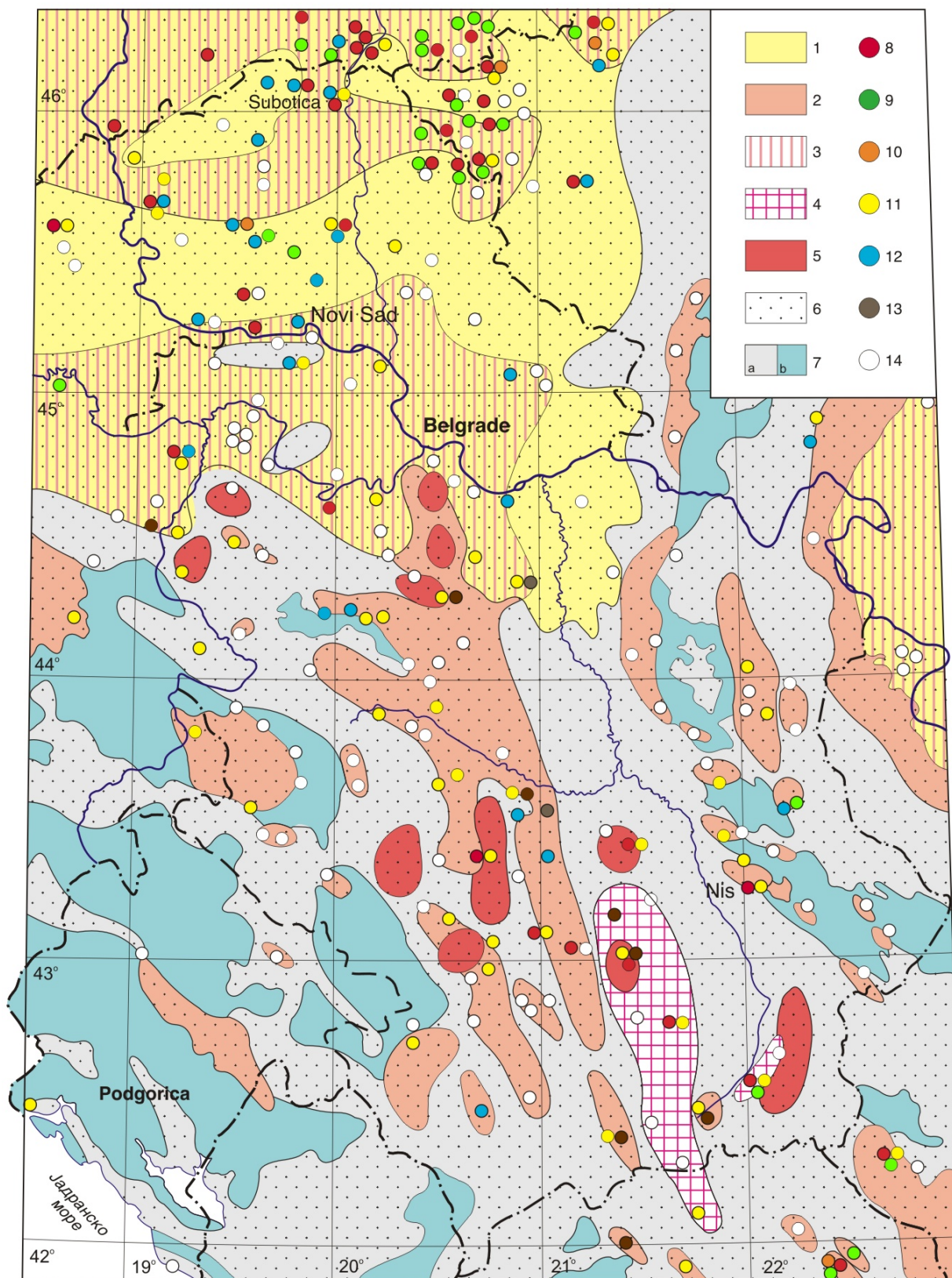
Fig. 4 Map of geothermal resources of Serbia and Montenegro

RESOURCES: 1-Hydrogeothermal aquifer in Cenosoic rocks; 2-Hydrogeothermal aquifer in Mesosoic rocks; 3-Hydrogeothermal aquifer in Mesosoic rocks bellow Cenosoic rocks; 4-Hydrogeothermal aquifer in Paleosoic rocks; 5-Petrogeothermal resources in Tertiary granitoide rocks; 6-Hydro-petrogeothermal resources up to 200 m for exploitation   of geothermal energy with heat pumps; 7-Areas without significance hydrogeothermal resources: a) terrains with rocks of Paleosoic and Proterosoic age, b) karstic terrains; UTILIZATION OF RESOURCES: 8-Heating; 9-Food production; 10-Industry 11-Balneotherapy; 12-Recreation and sport;

Figure 5. Geothermal crossections through Serbia and Montenegro

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables(specify)		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 December 2004	-	-	5,638	23,450	4,569	13.568	-	-	-	-	10,207	37,118
Under construction in December 2004	-	-					-	-	-	-		
Funds committed, but not yet under construction in December 2004	-	-	-	-	-	-	-	-	-	-	-	-
Total projected use by 2010	-	-	6,100	24,500	4,569	13,568	-	-			10,669	38,068

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT IN DECEMBER 2008

1) I = Industrial process heat   H = Individual space heating (other than heat pumps)
    C = Air conditioning (cooling)   D = District heating (other than heat pumps)
    A = Agricultural drying (grain, fruit, vegetables) B = Bathing and swimming (including balneology)
    F = Fish farming   G = Greenhouse and soil heating
    K = Animal farming   O = Other (please specify by footnote)
    S = Snow melting

    Enthalpy information is given only if there is steam or two-phase flow

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

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

    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.
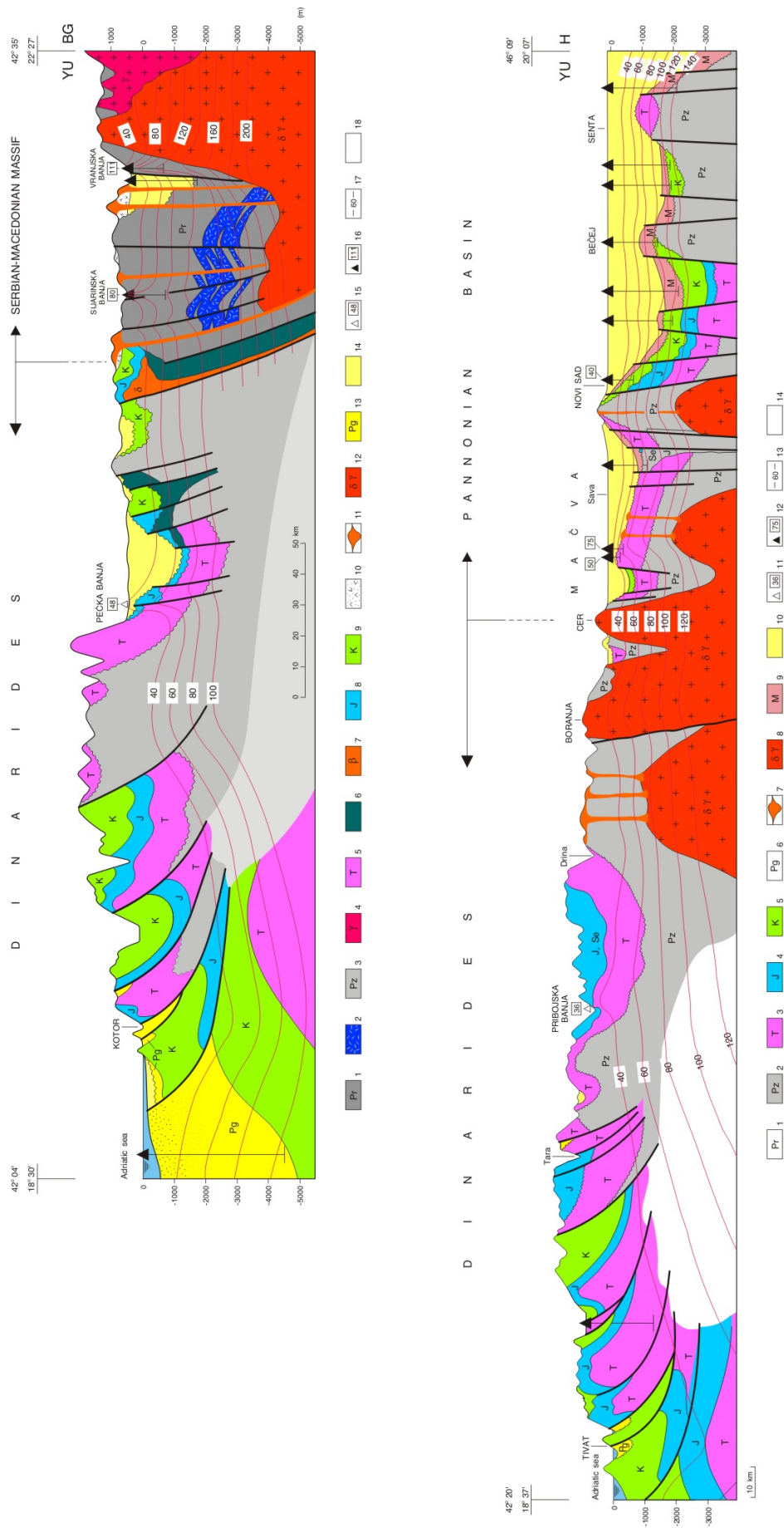
Locality	Type[1]	Maximum Utilization							Annual Utilization	
		Flow rate	Temperature ^{o}C		Enthalpy[2] kJ/kg		Capacity	Average Flow rate	Energy use[3]	Capacity Factor
		kg/s	Inlet	Outlet	Inlet	Outlet	MWt	kg/s	TJ/yr	
Kanjiza - 1	D/B	5	41	26			0.314	3	5.936	0.60
Kanjiza - 2	D/B	14	65	26			2.284	8	41.153	0.57
Kula - 1	B	9.5	50	25			0.994	6	19.785	0.63
Kula - 2	I	8.3	53	25			0.972	5	18.466	0.60
Kula - 4	I	8.5	51	26			0.889	4	13.190	0.47
B. Petrovac - 1	G	16.7	46	25			1.467	10	27.699	0.60
B. Petrovac - 2	A	11	45	24			0.967	7	19.389	0.63
Prigrevica	D/B	21	54	25			2.548	10	38.251	0.47
Srbobran	G	11.7	63	24			1.909	5	25.721	0.42

Kikinda - 1	D	6.2	50	27			0.597	4	12.135	0.64
Kikinda - 2	F	15.2	51	26			1.590	8	26.380	0.52
Mokrin	F	10.5	51	26			1.098	6	19.785	0.57
Vrbas	B	4.3	51	23			0.504	2	7.386	0.46
Temerin	B	20	41	25			1.339	10	21.104	0.50
B. P. Selo	F	10	43	26			0.711	4	8.969	0.40
Becej	D	19.4	65	24			3.328	10	54.079	0.51
Vranjska Spa	I/D/B/G	80	96	50			15.397	32	194.157	0.40
Sijarinska Spa	D/B	7.4	76	25			1.579	4	26.908	0.54
Josanicka Spa	D/B	17	78	40			2.703	9	45.110	0.53
Lukovska Spa	D/B	12	67	35			1.607	7	29.546	0.58
Kursumlija	D/B	20	68	25			3.598	8	45.374	0.40
Mladenovac	B	19	53	25			2.226	9	33.239	0.47
S. Palanka	B/O	13	56	25			1.686	6	24.533	0.46
N. Pazar	B	10	52	28			1.004	6	18.994	0.60
Mataruge	D/B	47	43	24			3.736	18	45.110	0.38
Ribarska Spa	D/B	37	44	25			2.941	20	50.122	0.54
Pecka Spa	B	4	36	25			0.184	3	4.353	0.75
Ilidza (Pec)	B	17.5	48	26			1.611	9	26.116	0.51
Bujanovacka Spa	D/B/O	7	43	24			0.556	5	12.531	0.71
Gamzigrad	D/B	10	42	24			0.753	6	14.245	0.60
Ovcar Spa	D/B	50	38	27			2.301	25	36.273	0.50
Vrnjacka Spa	B	13	36	25			0.598	6	8.705	0.46
Niska Spa	D/B	60	37	25			3.012	35	55.398	0.58
Pribojska Spa	B	70	36	30			1.757	25	19.785	0.36
Klokot	B	15	34	25			0.565	8	9.497	0.53
Koviljaca	B	110	30	24			2.761	15	11.871	0.14
Brestovacka Spa	B	4	40	30			0.167	2	2.638	0.50
Rajcinovica Spa	B	8	36	28			0.268	4	4.221	0.50
Bukovicka Spa	B	15	34	28			0.377	12	9.497	0.80
Prolom Spa	B/O	15	31	24			0.439	10	9.233	0.66
G. Trepca	B	20	30	24			0.502	10	7.914	0.50
Debrc -1	G/D	24	53	30			2.310	12	36.404	0.50
Vrdnik	B	12	32	25			0.351	8	7.386	0.66
Kravlje	B	10	33	25			0.335	5	5.276	0.50
Rgoste	B	70	31	25			1.757	15	11.871	0.21
Radalj	B	8	29	25			0.134	4	2.110	0.50
Zvonacka Spa	B	18	30	25			0.377	10	6.595	0.55
Ljig	B	7	32	25			0.205	4	3.693	0.57
Debrc-2	G/D	50	56	22			7.113	20	89.692	0.40
Kucura	G	12	56	30			1.305	7	24.006	0.58
Dublje	G	9.5	29.5	20			0.378	5	6.265	0.52
Obrenovac	B	5	36	24			0.251	2.5	3.957	0.50
Vrujci	B	40	33	24			1.506	13	15.432	0.32
Sisevac	B	20	36	24			1.004	6	9.497	0.30
Total		1157.7					90.868		1326.980	

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2008

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

1)   Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2)   Report type of installation as follows: V = vertical ground coupled   (TJ = 1012 J)
                                                    H = horizontal ground coupled
                                                    W = water source (well or lake water)
                                                    O = others (please describe)

3)   Report the COP = (output thermal energy/input energy of compressor) for your climate

4)   Report the equivalent full load operating hours per year, or = capacity factor x 8760

5)   Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319

      or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (^{o}C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Niska spa	25	180	6	W	3	4320	79.0	-
Belgrade	22	65	1	W	3	4320	10.7	-
Belgrade	12	10	30	W	3.2	8310	3.9	
Nis	22	60	1	W	3	4320	11.0	-
Knjazevac	22	65	1	W	3	4320	11.4	-
TOTAL			39				115.0	

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES

[1] Inst. thermal power (MW$_t$)=Max. water flow rate (kg/s) x (Inlet temp.(^{o}C) - Outlet temp.(^{o}C)) x 0.004184

[2] Energy use (TJ/yr)=Annual average water flow rate (kg/s) x (Inlet temp.(^{o}C) - Outlet temp.(^{o}C)) x 0.1319

	Installed Thermal Power[1] MW$_t$	Energy Use[2] TJ/yr
Space heating	20.9	356
Bathing and swimming	39.8	647
Agricultural drying	0.7	10
Greenhouses	18.5	128
Fish and other animal farming	6.4	128
Industrial process heat	4.6	58
Snow melting	-	-
Air conditioning	-	-
Other uses (specify)	-	-
Subtotal	90.9	1327
Heat pumps	9.9	83
Total	100.8	1410

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2005 TO DECEMBER 31, 2008 (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	>150 °C					
	150-100 °C					
	<100 °C		2			1.58
Injection	(all)					
Total						

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			2			
2006			3			
2007			3			
2008			3			2
2009			4			2
Total			15			4

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	
	Million US$	Million US$	Direct Million US$	Electrical Million US$	Private %	Public %
1990-1994	5.0	7.5	5.0	-	-	100
1995-1999	9.2	-	-	-	-	100
2000-2004	0.8	1.2	4.0	-	80	20
2004-2009	1.5	2.2	6.5	-	90	10