3rd South East Europe Energy Dialogue

18 – 19 June 2009, Thessaloniki, Greece

GEOTHERMAL POTENTIAL IN SOUTH-EAST EUROPE

Prof. Michael Fytikas

Dr. Apostolos Arvanitis

Aristotle University of Thessaloniki, Department of Geology
Institute of Geology and Mineral Exploration (I.G.M.E.),

South-East European Countries

Countries:

- ***GREECE***
- ***BULGARIA***
- ***F.Y.R.O.M.***
- ***ALBANIA***
- ***SERBIA & MONTENEGRO***
- ***BOSNIA - HERZEGOVINA***
- ***CROATIA***
- ***ROMANIA***

GREECE

- *Medium and low enthalpy geothermal fields* ***are mostly associated with grabens and post-orogenic sedimentary basins.***

- ***There is a high potential in the areas of Kimolos, Polyegos, Lesvos, Chios and Samothrace islands and in the NE continental mainland.***

- ***The deep water circulation along 'open' faults in grabens all over the country has created a large number of low enthalpy ($T \leq 90^oC$) fields.***

- ***There are > 750 thermal springs and > 50 spas in operation.***

- ***The thermal potential of low enthalpy geothermal resources in Greece exceeds 1000 MW_t.***

GREECE

Geothermal fields in Greece (some photos)

Milos: High enthalpy geothermal field

Akropotamos: Well AKR-1

Almopia: Well ALM-1P (T=38°C)

Nisyros: High enthalpy geothermal field (T~350°C)

Nea Kessani: Geothermal well

Nigrita - Serres: Well TH-1 (Tw=59.4°C + CO_2)

GREECE

Geothermal applications in Greece (end of 2008)

Use	Installed Capacity (MWt) - 2008	Installed Capacity (MWt) - 2000	Annual Energy Use (10^{12}J) - 2008
Space heating	1.4	1.13	16
Greenhouse & soil heating	28.0	20.6	248
Agricultural products drying	0.8	0	4
Aquaculture *	9.3	---	76
Bathing and swimming (balneology)	36.0	35.0	182
Geothermal Heat Pumps	40.0	0.4	200
Total	115.5	57.13	726

** Fish farming & Spirulina cultivation*

- *At present no electric power is produced from geothermal resources in Greece, despite the large high-enthalpy resources in the active Aegean volcanic arc. Moreover, in certain other areas (e.g. Lesvos, Chios and Samothrace Islands) organic Rankine Cycle (ORC) power plants could be installed.*

GREECE

Examples of direct uses of geothermal energy

Nigrita: Cultivation of the microalgae Spirulina

Neo Erasmio - Xanthi: A tomato dehydration unit

Porto Lagos (Xanthi): Anti-frost protection / heating of aquaculture ponds (fish farming)

Angelochori (Thessaloniki): Horizontal Geothermal Heat Pump System (closed-loop system)

Loutraki Aridea (Almopia): Open pool

Sidirokastro (Serres): Geothermal greenhouse (plotted flowers)

Neo Erasmio (Xanthi): Early season asparagus cultivation

BULGARIA

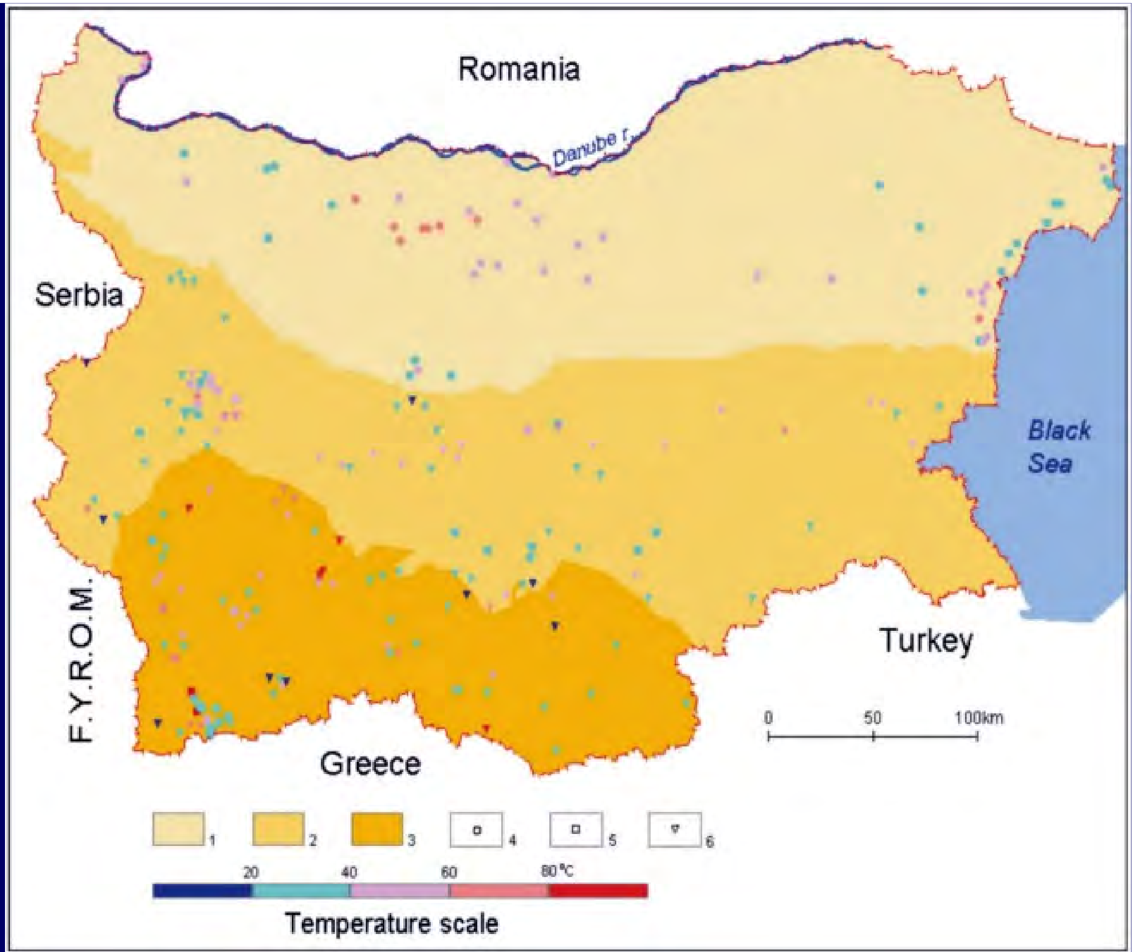
- About 160 hydrothermal fields are located all over the country (102 of them are state-owned).

- Three (3) major hydrothermal units: Moesian plate, Sredna gora zone (incl. Balkan) and Rila-Rhodope massif . Three (3) types of reservoirs are found in Bulgaria: stratified, fractured and mixed (water from a fractured reservoir is secondary accumulated in a younger sedimentary reservoir).

- The water temperature of the discovered reservoirs ranges from 25°C to 100°C.

- Total dynamic flow rate: up to 4,600 l/s. About 43% of the total flow rate are waters of temperature between 40-60^{o}C. 58% of the state owned reservoirs have a temperature (T) of 25-50^{o}C and about 10% have T=76-100^{o}C.

- TDS content of geothermal waters is:
In Southern Bulgaria: 0.1-1.0 g/l (only for a few sites it is between 1-15 g/l)
In Northern Bulgaria: 0.1-150 g/l
About 70% of the thermal waters are slightly mineralized (<1 g/l) with F: 0.1-25 mg/l and mostly low alkalinity.



Map of hydrothermal deposits of Bulgaria

1. Moesian plate (stratified reservoirs)

2. Sredna gora, incl. Balkan zone (secondary stratified reservoirs, fractured reservoirs)

3. Rila-Rhodopes massif (predominantly fractured reservoirs)

4. Major wells and groups of wells discovering stratified reservoirs in a plate region.

5. Hydrothermal sources associated with waters from fractured reservoirs located in Southern Bulgaria.

6. Hydrothermal sources associated with waters from secondary stratified reservoirs located in Southern Bulgaria.

BULGARIA

Geothermal direct uses in Bulgaria (end of 2004)

- Geothermal energy in Bulgaria has various direct uses and no power generation.

- Currently thermal water applications are mainly in balneology, space heating and domestic hot water supply, greenhouses, swimming pools, bottling of potable water, aquaculture (microalgae) and extraction of chemical derivatives.

- The total installed capacity is estimated to be 109.70 MW_t (incl. balneology).

- The annual energy use is 1,671.43 TJ/yr

(at average load factor 0.48)

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr = 10^{12} J/yr)	Capacity Factor
Individual Space Heating[4]	49.74	721.55	0.46
District Heating [4]			
Air Conditioning (Cooling)	9.80	95.80	0.31
Greenhouse Heating	16.90	261.15	0.49
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	25.60	557.05	0.69
Other Uses (specify)	7.33 aquaculture, extraction of derivatives,etc.	31.51	0.14
Subtotal	109.37	1667.06	0.48
Geothermal Heat Pumps	0.33	4.37	0.42
TOTAL	109.7	1671.43	0.48

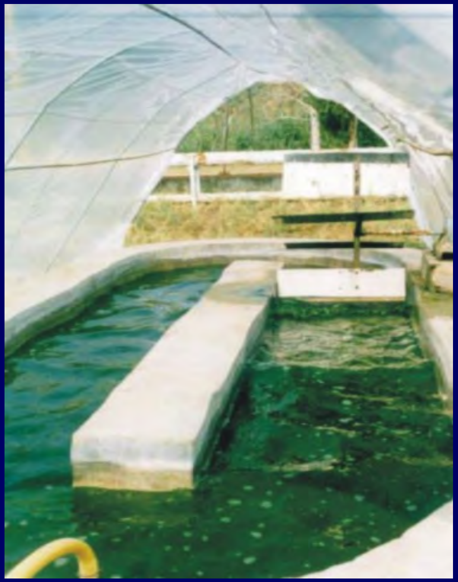
[4] Other than heat pumps
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology

BULGARIA

Types of geothermal water applications (for state-owned hydrothermal sources)

BULGARIA

Examples of direct uses of geothermal energy



Open mass cultivation of the microalgae Spirulina (Roupite area, SW Bulgaria)

Hisar town - Spa hotel "Augusta"

Sapareva Banja: Well C-1 HG (T=98°C) [At present, 7 public buildings are heated by the geothermal water]

Sofia area: Family house heated by ground source heat pump

F. Y. R. O. M.

- There are 18 known geothermal fields in F.Y.R.O.M. with > 50 thermal springs, boreholes and wells drilled at depths 40-2,100 m producing hot waters.
- These discharge about 1,000 l/s water with temperatures of 20-79°C. The highest temperature (79°C) has been measured in the Kocani geothermal field.
- Hot waters are mostly of hydrocarbonate type (HCO_3^-) according to their dominant anion and mixed with equal presence of Na^+, Ca^{2+} and Mg^{2+}. The dissolved minerals range from 0.5 to 3.7 g/l.
- All thermal waters are of meteoric origin.

Geothermal Projects in F.Y.R.O.M.

F.
Y.
R.
O.
M.

Thermal waters utilization consists of 5 geothermal projects and 6 spas. All are completed before the 80's of the last century. Present state of the projects is as shown in the next table:

GEOTHERMAL LOCATION	GEOTHERMAL FIELD	APPLICATION	HEAT POWER (TOTAL, kW)	HEAT POWER (GEOTH., kW)	HEAT USERS
Istibanja (Vinica)	Kocani	Heating of a greenhouse complex	17.500	7.480	Aerial pipes and vegetative heating, plus heating of benches
Bansko	Strumica	Geothermal District Heating System	10.350	10.350	Heating greenhouses: - Aerial steel pipes in combination with corrugated plastic pipes - Soil heating Space heating: - Aluminium radiators - Air heating system - Sanitary warm water preparation - Swimming pool
Podlog	Kocani	Geothermal District Heating System and balneology	40.700	40.700	Heating greenhouses: - Aerial steel pipes Space heating: - Aluminia radiators - Iron radiators
Smokvica	Gevgelia				Abandoned
Negorci	Gevgelia	Space heating and balneology	250	250	Space heating: - Aerial steel pipes - Aluminia radiators Sanitary warm water preparation
Katlanovo	Skopje	Balneology			
Kumanovo	Kumanovo	Balneology			
Kezovica	Stip	Balneology			
Kosovrasti	Debar	Balneology			
Banjiste	Debar	Balneology			
Banja	Kocani	Balneology			Abandoned
TOTAL			**68.800**	**58.780**	

F.Y.R.O.M. passed more than 15 years of stagnation in geothermal development. Some of previously developed large projects have been abandoned or destroyed. There were no investments in explorations and new projects development.

Geothermal energy production in 2006 dropped down for nearly 50% compared to the situation in 1991. Recently first signs of economy recovery of some users and finalized privatization process resulted with several investments in reconstruction and optimization of geothermal projects. There is interest of the others to do the same and some investors (from FYROM and foreigners) are trying to get concession for development of new projects.

F.Y.R.O.M.

Summary table of geothermal direct heat uses as of 31 December 2003

Present state-of-the-art of geothermal energy use FYROM is mainly a consequence of the process of the political and economic changes in flow.

The economy collapse of the country, unsolved problems with the privatization of production capacities of the geothermal energy users, a list of legal constraints, absence of a strategy for development, absence of the state support for the necessary explorations and investigations and very hard conditions for financing necessary reconstructions and new investments in the sector resulted with a complete stagnation for the period of more than 15 years.

Real change of the situation cannot be expected before resolving the problem of listed constraints. Therefore, even the process of elimination of them is already in flow (new laws for energy, for mineral and water resources and for concessions, etc) it is not possible to expect serious changes during the period of next 5 years.

Use	Installed Capacity MW_t	Annual Energy Use $TJ/yr = 10^{12}$ J/yr	Capacity Factor
Space heating	2,48	25,78	0,330
Air conditioning			
Greenhouses	58.83	557,54	0,300
Fish and Animal Farming			
Agricultural Drying	Out of use		
Industrial process heat			
Snow melting			
Bathing and Swimming			
Other uses (specify)*)	1,05	15,3	0,462
Subtotal	62,36		
Geothermal Heat Pumps			
Total	62,36	598,62	

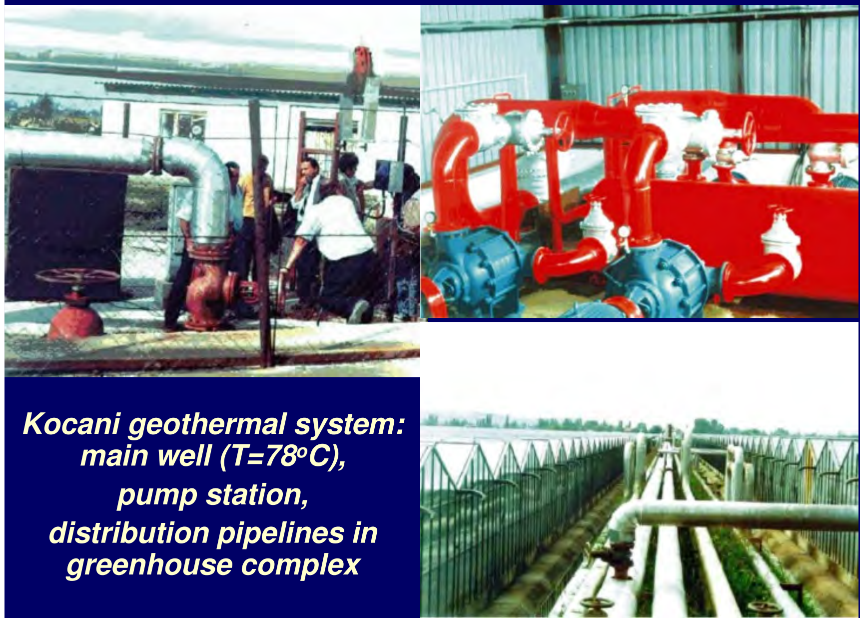
*) Balneology, Sanitary water preparation

F.Y.R.O.M.

Examples of direct uses of geothermal energy

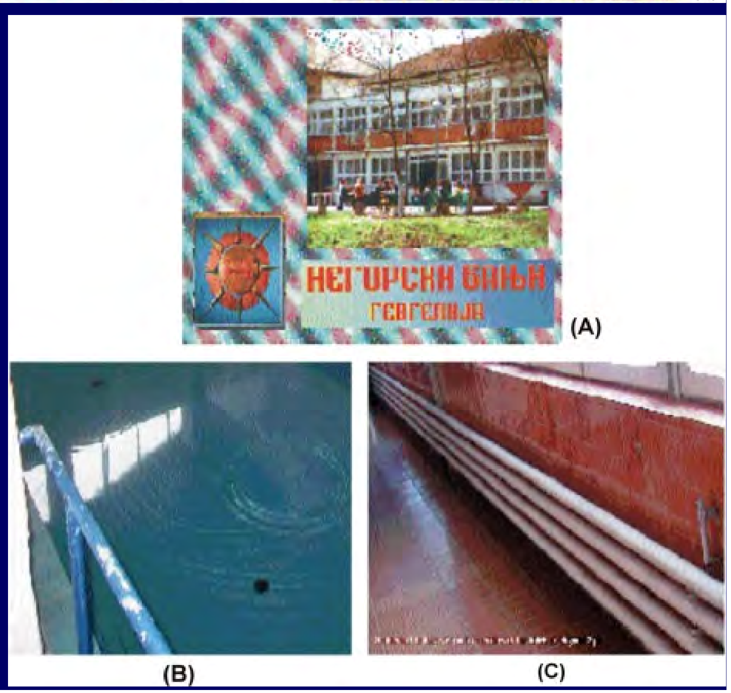
Vinica: Geothermal greenhouse complex

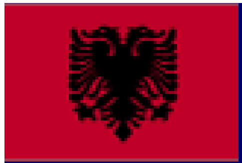
“Bansko” geothermal system: (A) Hotel “Car Samuil” (complex) (B) Swimming pool in the hotel “Car Samuil” (C) Connection station of the Hotel “Car Samuil” and (D) Greenhouse complex (3.2 ha),



Kocani geothermal system: main well ($T=78^oC$), pump station, distribution pipelines in greenhouse complex

Characteristic parts of the Negorci Spa geothermal system: (A) Heated complex of 5 spa buildings, (B) Medical geothermal pool, and (C) Characteristic heating installation for halls in the hotels part of the complex





ALBANIA

- In Albania there are many thermal water springs and wells of low enthalpy with temperatures up to 65.5°C.

- The thermal water springs are mainly near zones of regional tectonic fractures. Generally the water circulates through carbonate rocks of the structures and evaporitic beds at some kilometers of depth. The water of these springs contains salt, absorbed gas and organic matter.

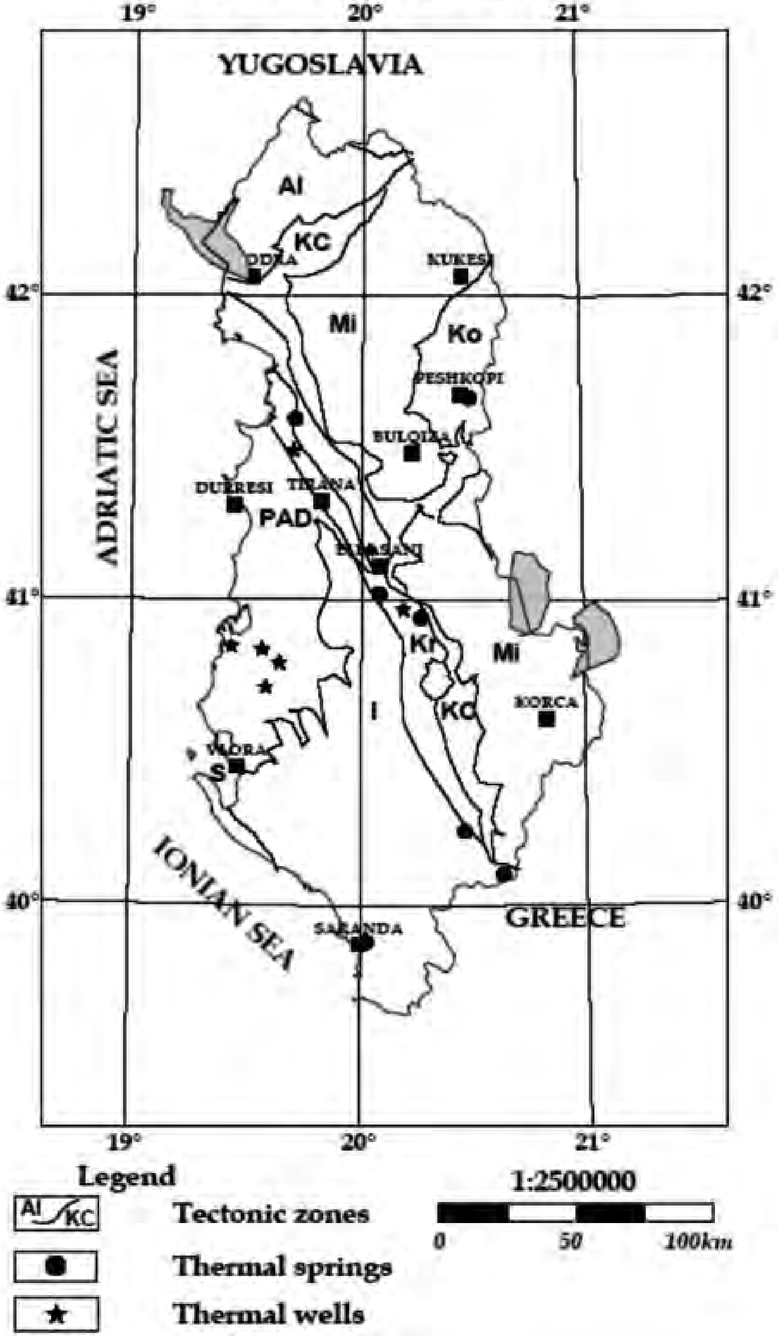
- In many deep oil and gas wells there are thermal water outputs with T=32-65.5°C.

- The temperature is 105.8°C at a depth of 6,000 m in the central part of the Peri-Adriatic Depression (PAD).

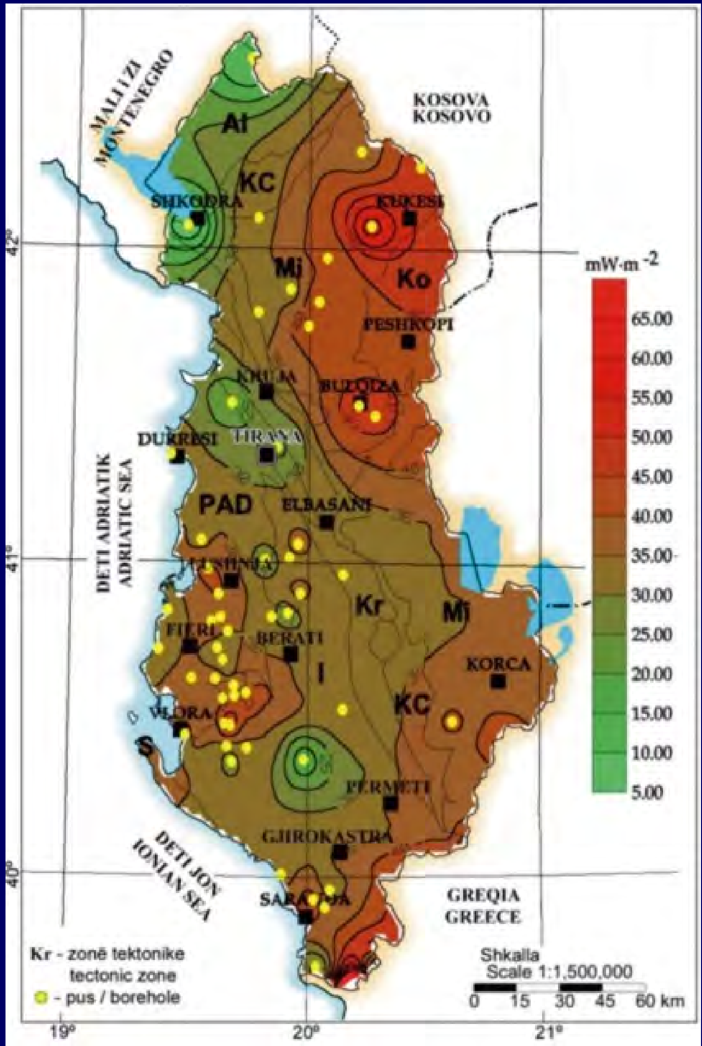
Thermal water springs in Albania

N° of Springs	Location	Temperature in °C	Salt in mg/l	Artesian Spring yield in l.s-1
1	Llixha Elbasan	60	0.3	0
2	Peshkopi	5-43	9	10
3	Krane-Sarande	34		<10
4	Langarica-Permet	6-31		>10
5	Shupal-Tirana	29.5		10
6	Sarandoporo-Leskovik	26.7		>10
7	Tervoll-Gramsh	24		>10
8	Mamurras-Tirane	21	26	>10

THERMAL SPRINGS AND WELLS IN ALBANIA



ALBANIA



Heat flow density map

The high heat flow density value of 42 mW/m² is found in the center of Peri-Adriatic Depression (PAD) of the External Albanides. In the ophiolitic belt at eastern part of Albania, the values of heat flow density are up to 60 mW/m².

Geothermal thematic map (Geothermal zones in Albania)

Albanian geothermal areas have different geologic and thermo-hydrogeological features. Thermal sources are located in three geothermal zones (Kruja, Peshkopia and Ardenica geothermal zones).

ALBANIA

Summary table of geothermal direct heat uses as of 31 December 2004

Use	Installed Capacity (MWt)	Annual Energy Use ($TJ/yr = 10^{12}$ J/yr)	Capacity Factor
Individual Space Heating[4)]	---	---	---
Bathing and Swimming[7)]	9.57	8.53	0.131
Other Uses (specify)	---	---	---
Subtotal			
Geothermal Heat Pumps	---	---	---
TOTAL	9.57	8.53	0.131

4) Other than heat pumps
7) Includes balneology

Langarica-Permeti thermal springs *(T=31°C)*

SERBIA

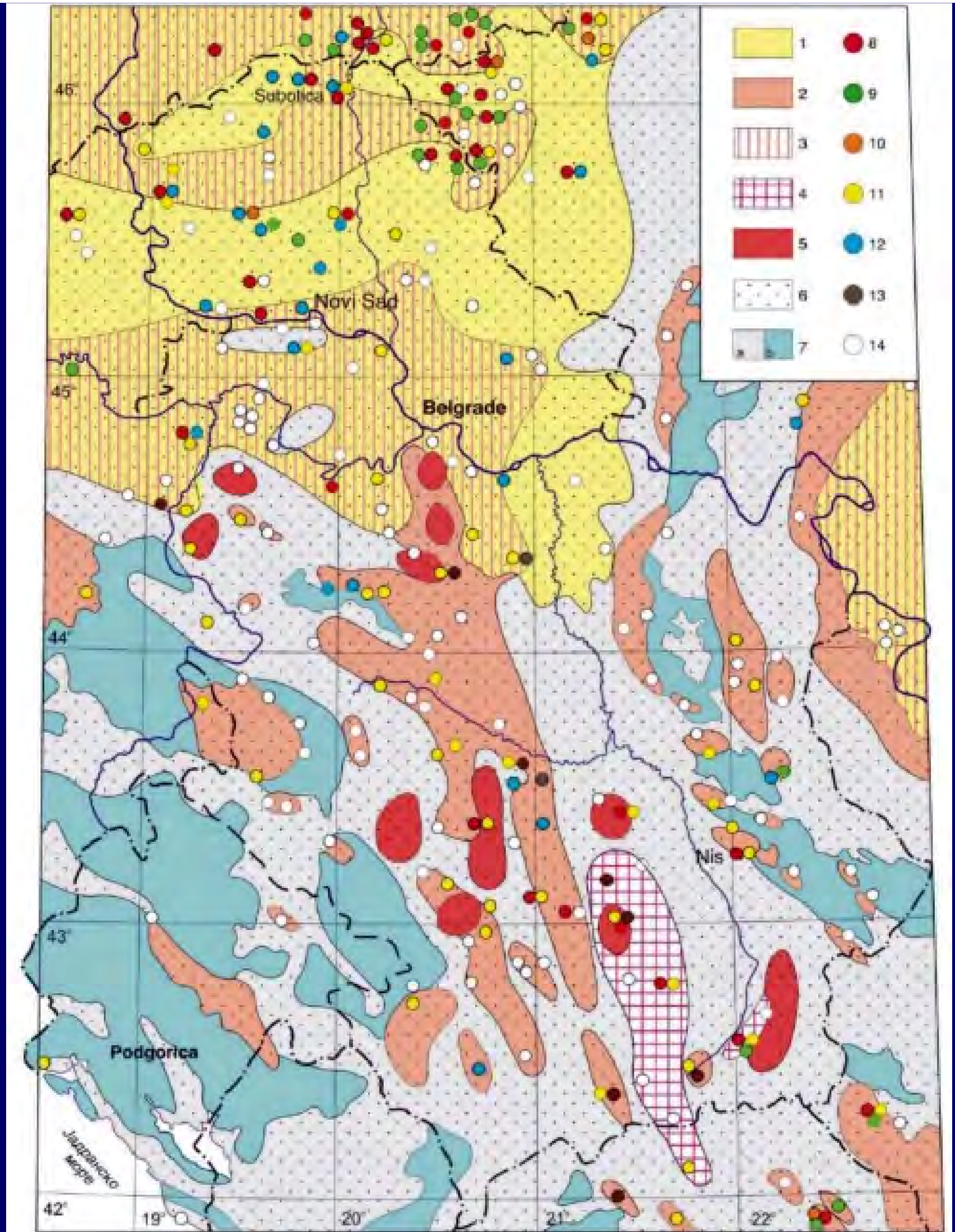
- Within the territory of Serbia, excluding the Pannonian Basin, there are 159 natural thermal springs with temperatures T> 15°C. The warmest springs (96 °C) are located in Vranjska Banja. The total flow rate of all natural springs is about 4000 l/s.

- The total heat capacity of all flowing wells drilled in Serbia is about 156 MW_t (calculated for dT=T-25°C). The total heat capacity of all natural springs and wells is about 320 MW_t (calculated for dT=T-12°C). Estimated energy reserves of geothermal resources are about 800 MW_t.

- More than 80 low enthalpy hydrogeothermal systems are present in Serbia. The most important are located at the southern edge of the Pannonian Basin.

- Considering the present state of knowledge of the geologic composition and hydrogeothermal properties of rocks to a depth of 3000 m, there are 60 convective hydrogeothermal systems in Serbia.

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



Geothermal resources in 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;

SERBIA

GEOTHERMAL RESOURCES (i)

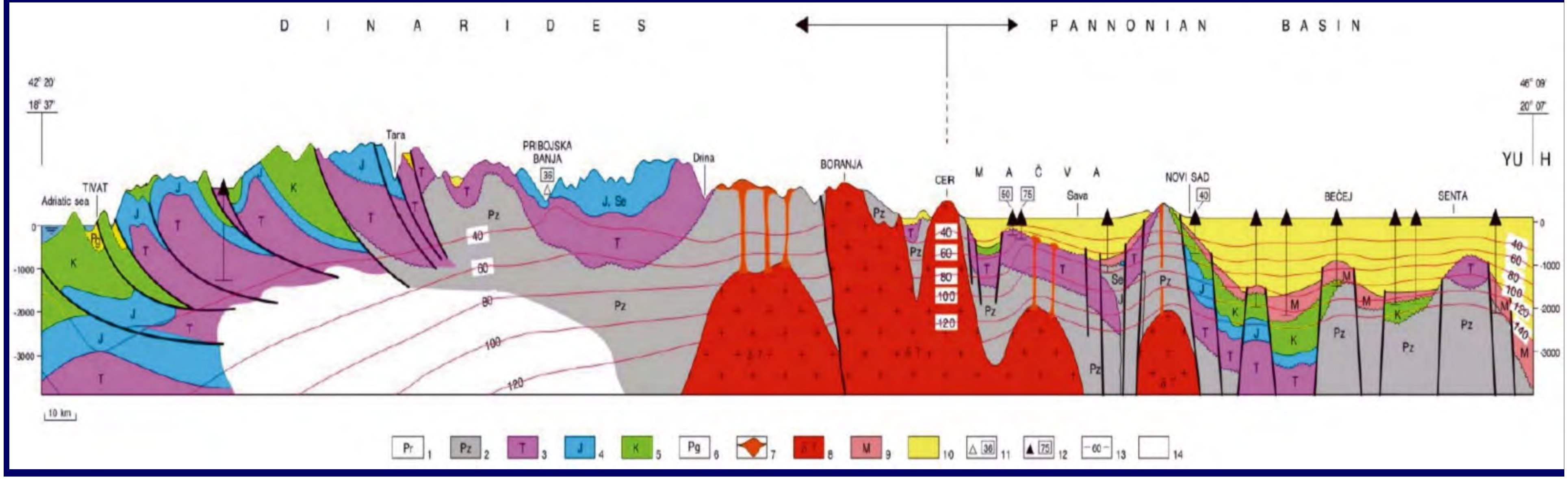
- In the Pannonian Basin:

1st group of reservoirs: maximum thickness of 2000 m. The highest water temperature in the reservoirs is 120°C. 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. Thermal waters are of HCO_3-Na type. Water temperatures at well-heads are 40-55°C, maximum 82°C.

2nd group of reservoirs: in Lower Pliocene & Pannonian sediments. Thermal waters in this reservoir are of HCO_3-Cl-Na type and of mineralization 4-20 g/kg, mostly 5-12 g/kg. The maximum expected water temperature in this reservoir group is up to 160°C. Average yields of flowing wells are 2.5 to 5 l/s and the well-head water temperatures are 50-65°C on average.

3rd group of reservoirs: at the base of Neogene or Paleogene sediments (Miocene limestones, sandstones, basal conglomerates, basal breccias). Thermal waters contained in these rocks have high mineralization (up to 50 g/kg), and their chemical composition is of the HCO_3-Na type. Average well yields are 5-10 l/s and water temperatures at well-heads are 40-50°C.

4th group of reservoirs: in Mesozoic and Paleozoic rocks under Paleogene and 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. 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 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°C.



SERBIA

Summary table of geothermal direct uses as of 31 December 2004

	Installed Thermal Power MW$_t$	Energy Use TJ/yr
Space heating	19.7	575
Bathing and swimming	36.0	1150
Agricultural drying	0.7	22
Greenhouses	15.4	256
Fish and other animal farming	6.4	211
Industrial process heat	4.6	121
Snow melting	-	-
Air conditioning	-	-
Other uses (specify)	-	-
Subtotal	82.8	2335
Heat pumps	6.0	40
Total	88.8	2375

Geographical position of greenhouses heated by geothermal energy in Serbia.

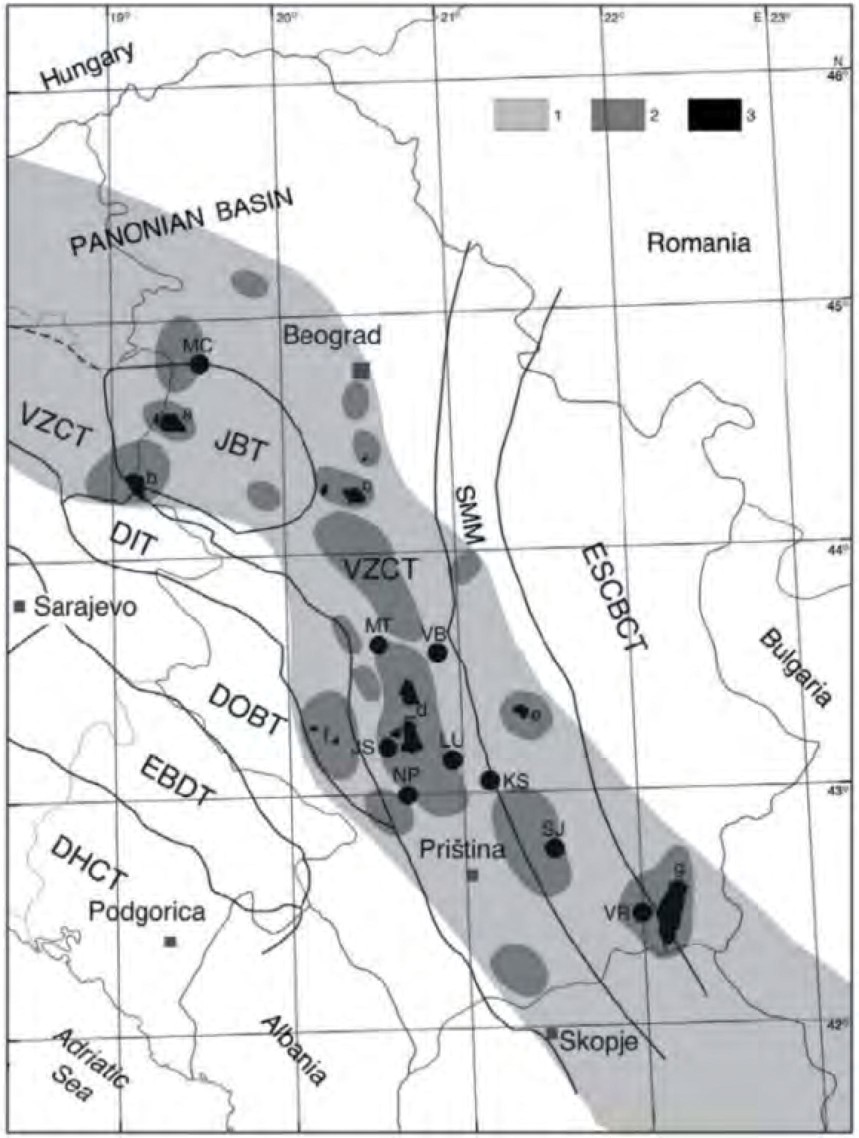
- The common uses of geothermal energy in Serbia are: balneology and recreation. At present there are 59 thermal water spas in Serbia used for balneology, sports and recreation and as tourist centers. The direct use of thermal energy for space heating is in its initial stage and very modest in relation to its potential capacity. Serbia uses only about 10% of its real potential, which is estimated to be about 800 MW$_t$.

SERBIA

- *In the territory of Serbia there are excellent potentials for the generation of electric energy from geothermal resources that originate from hot and dry rocks of Neogene granitoid intrusions (by implementing the HDR technology) and from fluids in the reservoirs of convective hydrogeothermal systems, in which the temperature reaches the value of 150^{o}C.*

- *Convective systems with reservoirs of hydro-geothermal fluids that enable the production of electric energy are situated in the area of Neogene acid magmatic formations.*
Favorable locations for such purposes are:
Vranjska spa (VR), Josanicka spa (JS), Sijarinska spa (SJ), Mataruska spa (MT), Vrnjacka spa (VB), Lukovska spa (LU), Kursumlijska spa (KS), Novopazarska spa (NP), Macva (MC).

- *The highest temperatures, ranging from 130 to 150^{o}C, are expected in the area of Vranjska, Josanicka and Kursumlijska banja. All the previously mentioned localities are situated in the peripheral sections of the Neogene granitoid plutons. The highest temperature of geothermal water was measured in well VG-2 in Vranjska banja at depth of 1500 m and it reached 127^{o}C. The temperature of the fluid reached 111^{o}C in the vicinity of the well head. In the area of Macva (MC) the prospects for the generation of electric energy are also very favorable (the temperature of 78^{o}C has been measured at a depth of 610 m in Triassic limestones). The expected temperature of geothermal water reaches 110^{o}C and the quantity is estimated to 500 l/s. Besides, promising results are expected in the area of Josanicka banja, where the highest temperatures of geothermal fluids are estimated to be approximately 130^{o}C.*



Locations of magmatic rocks occurrences of Neogene age in Serbia

[1-zone with occurrences of volcanic rocks; 2-granitoid plutons, 3-granitoids at the surface: a-Cer; b-Boranja; c-Bukulja; d-Kopaonik; e-Jastrebac; f-Golija; g-Surdulica]

MONTENEGRO

Geothermal exploration in Montenegro has been minimal.

Most of the country is covered by high and extensive mountain massifs intersected by river gorges and deep valleys.

There is no evidence for geothermal interest in the country.

BOSNIA - HERZEGOVINA

- Little exploration for geothermal resources has been done.

- The country's geothermal potential for space heating, balneology and similar low-temperature purposes, based on existing wells, is about 33 MW_t.

- 1-MWe geothermal power pilot plant was to be built in Sarajevo prior to the civil war. Due to lack of financing, however, the project has been put on hold. The resource has a temperature of 58°C and a flow rate of 240 l/s.

- There are 3 specific geothermal sites or projects in Bosnia and Herzegovina.

- The highest temperature geothermal resource identified to date is Bosanki Samac with a temperature of 85ºC. The average temperature of all sites is 65.6ºC.

- Sources in Bosanski Šamac, Kakanj and Sarajevo are lower temperature types and only for thermal exploitation.

- No sites have a temperature of 100ºC or more.

- In 2006 private companies investigated a possible commercial use in the Sarajevo region (higher temperature for electricity production)

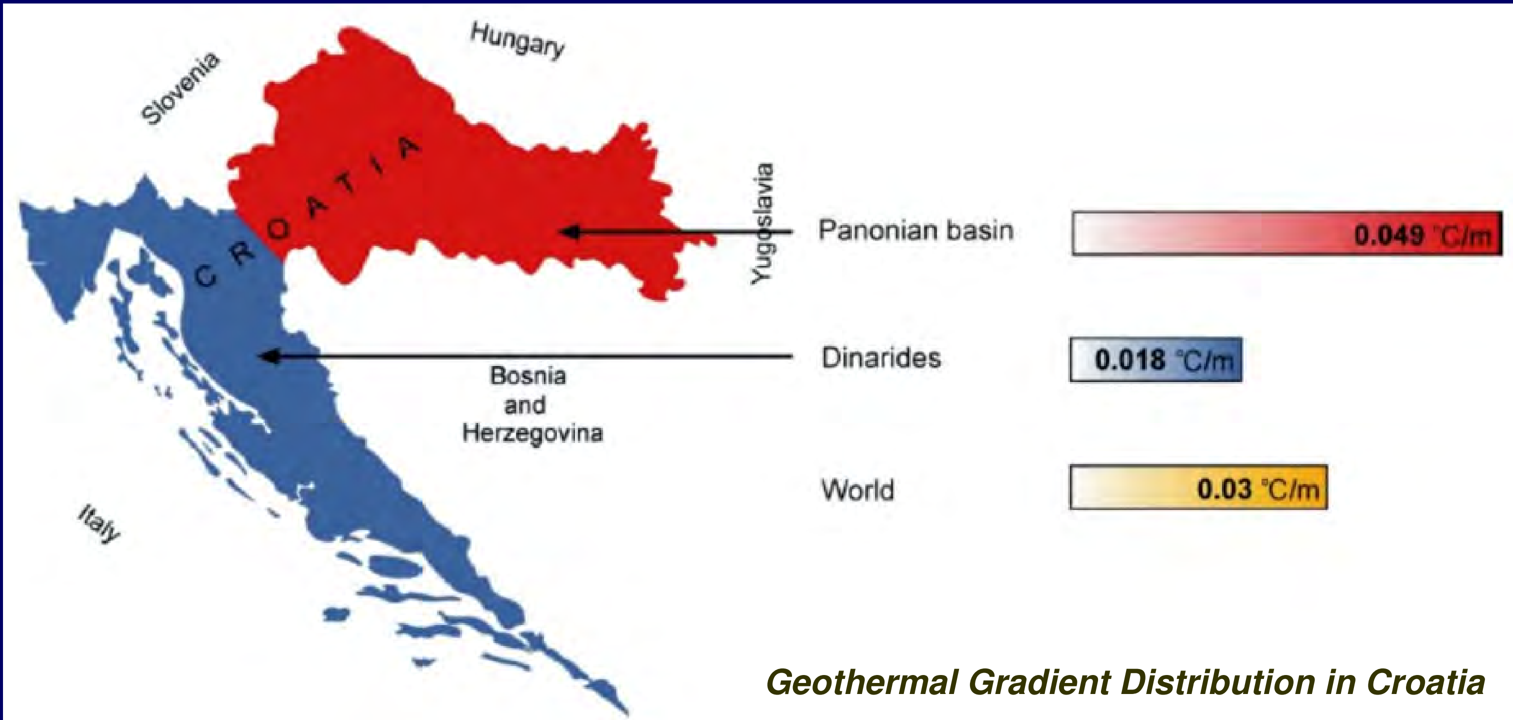
- Current activities are limited to thermal uses.

Locations of the geothermal resources in Bosnia - Herzegovina

Geothermal resources in Bosnia - Herzegovina

Site/Project Name	Status	Temperature (°C)
Bosanski Samac	Direct use -- developed	85
Kakanj	Prefeasibility study	54
Sarajevo	Feasibility study	58
TOTAL		

CROATIA



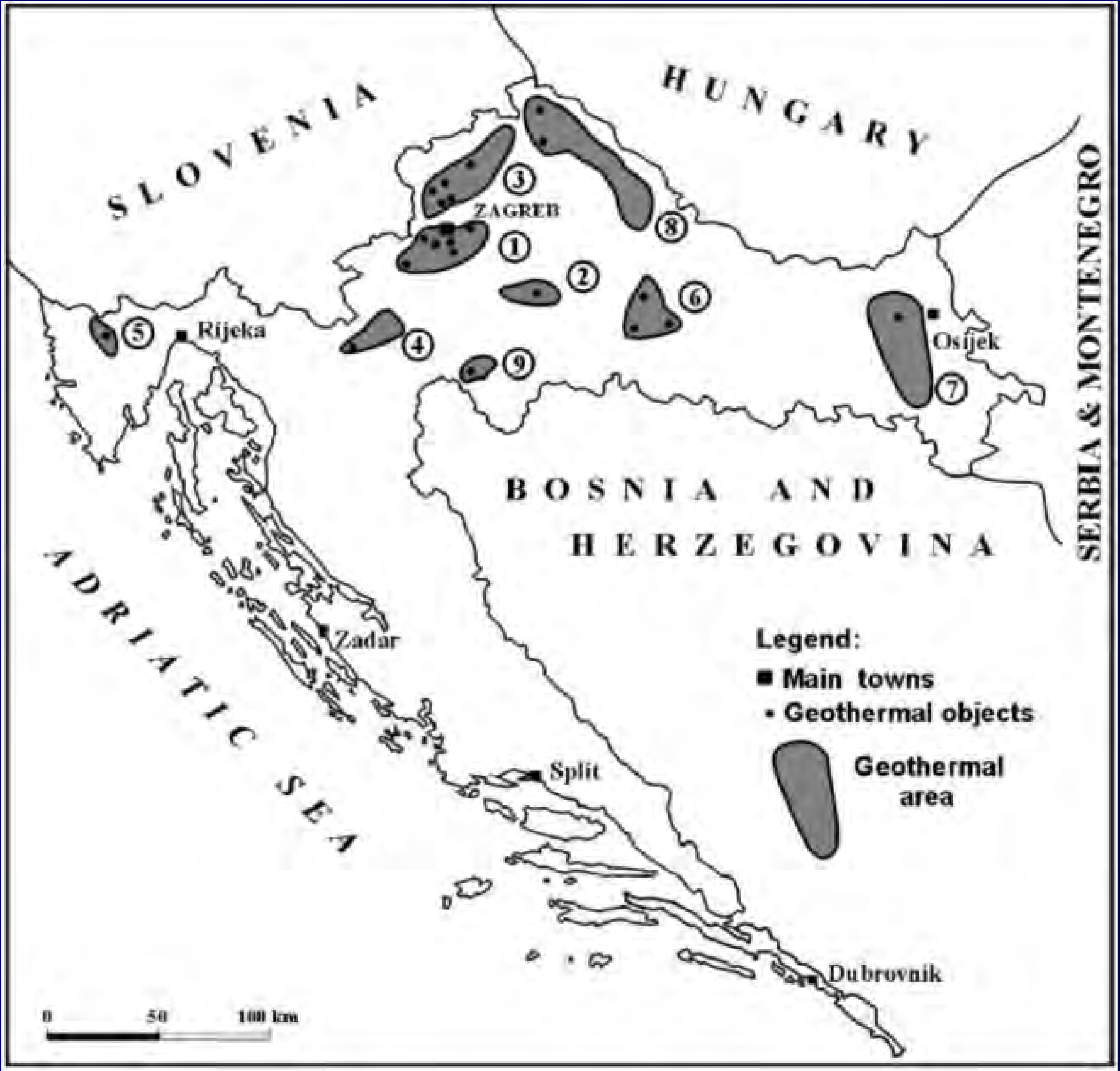
Geothermal Gradient Distribution in Croatia

There are two different regions in the Croatia both in geological and geothermal respect.

(a) The Dinarides area occupies the southern part of the country with predominantly Mesozoic carbonate rocks characterized by the geothermal gradients ranging from 0.01 to 0.03°C/m (terrestrial heat-flow density: 20 - 60 mW/m²).

(b) The northeast part of the country lies mostly in the Pannonian basin. It is dominated by sedimentary rocks of Quaternary and Tertiary age that overly the crystalline bedrock and, occasionally, the Mesozoic sedimentary rocks. The geothermal gradient ranges from 0.03 to 0.07°C/m (more than the world mean value) with considerable geothermal energy potential. The terrestrial heat-flow density is also high, ranging from 60 to 100 mW/m² and occasionally up to 120 mW/m². In the Pannonian area about 3500 boreholes were drilled for oil and gas resources, many of them have penetrated geothermal aquifers.

CROATIA



Geothermal areas and locations in Croatia where geothermal water is used.

1. *Geothermal area of Zagreb (T= 31-82°C)*
2. *Geothermal area of Ivanić Grad (T=50-60°C)*
3. *Geothermal area of Hrvatsko zagorje (T=32-58°C)*
4. *Geothermal area of Lešće & Karlovac (Lešće) (T=95-130°C)*
5. *Geothermal area of Istra (T=28°C),*
6. *Geothermal area of West Slavonia (Daruvar, Lipik, Velika) (T=25-60°C),*
7. *Geothermal area of East Slavonia [Bizovac (86 - 98°C), Ernestinovo, Madarinci, Babina greda (74 - 125°C)]*
8. *Geothermal area of Međimurje & Podravina - Vučkovec (T=40°C), Lunjkovec (T=125°C), Velika Ciglena (150 - 170 °C)*
9. *Geothermal area of Topusko (T=62°C)*

CROATIA

The planned construction of the geothermal power plant in Velika Ciglena by the year 2010 would bring Croatia into the group of countries producing electricity from geothermal sources. The initial power of 4.4 MW_e obtained from the existing well might be increased to the value of 13.1 MW_e by the construction of two additional production wells by the year 2015. 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.

Geothermal resources in Croatia with T> 65°C

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
Rečica	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

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 been calculated (on the basis of outlet water temperature from the electric power generation process of 80°C, conversion efficiency factor of 10% and capacity factor of 90%).

CROATIA

18 geothermal resources have been utilized.

The total installed capacity is estimated to be 113 MW_t, with annual energy production of 680 TJ/yr [the outlet temperatures 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].

Summary table of geothermal direct uses in Croatia as of 31 December 2004

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr = 10^{12} J/yr)	Capacity Factor
Individual Space Heating	36,660	189,600	0,164
District Heating			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying			
Industrial Process Heat			
Snow Melting			
Bathing and Swimming	77,276	492,082	0,236
Other Uses (specify)			
Subtotal	**113,936**	**681,682**	0,190
Geothermal Heat Pumps			
TOTAL	**113,936**	**681,682**	0,190

ROMANIA

- *In Romania there are over 200 wells drilled with depths between 800 and 3,500 m, that shows the presence of low enthalpy geothermal resources (well head temperatures: 40-120°C), which enabled the identification of 9 geothermal areas, 7 in the Western part and 2 in the Southern part.*

- *The total installed capacity of the existing wells is about 480 MW_t (for reference temperature of 25°C).*

- *Proven geothermal reserves 200,000 TJ for 20 years.*

- *Annual production about 3,000 TJ.*

- *The main Romanian geothermal resources are located: (a) in porous and permeable sandstones and siltstones [for example in the Western Plain (Pannonian aquifers) and the Olt Valley] or (b) in fractured carbonate formations [Oradea, Bors, North Bucharest].*

Location of the Romanian geothermal reservoirs

- *More than 80 % of the wells have artesian flow rate, 18 wells require anti-scaling chemical treatment and 6 are re-injection wells.*
- *6 new wells were drilled during 2000-2006*

ROMANIA

- *The main direct uses of geothermal energy are: space heating 39.7%, bathing and swimming including balneology 32.2%, greenhouse heating 17.1%, industrial process heat 8.7% and fish farming and animal husbandry 2.3% (capacity factor: 0.62).*

- *The total capacity of the 96 utilized wells is about 145 MW_t, which produce annually 2,841 TJ.*

- *96 wells operate in 38 locations, 37 of these wells are exclusively used for health and recreational bathing.*

- *Two companies are currently involved in geothermal operations: (a) Foradex S.A., located in Bucharest, is state owned drilling company that has the exploration or exploitation concessions for the geothermal reservoirs located in the southern half of Romania . (b) Transgex S.A., located in Oradea, is also mainly a drilling company privatized in 2000 and has the exploration or exploitation concessions for the geothermal reservoirs located in the western part of Romania.*

A consulting company, Geofluid S.A., which is French-Romanian joint venture, operates in Oradea too.

Summary table of geothermal direct uses in Romania as of 31 December 2004

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr)	Capacity Factor
Space Heating	57.2	1129	0.62
Air Conditioning (Cooling)			
Greenhouse Heating	28.3	486	0.54
Fish and Animal Farming	3.1	65	0.66
Agricultural Drying			
Industrial Process Heat	14.1	246	0.55
Snow Melting			
Bathing and Swimming	42.2	915	0.68
Other Uses (specify)			
Subtotal	144.9	2841	0.62
Geothermal Heat Pumps			
TOTAL	144.9	2841	0.62

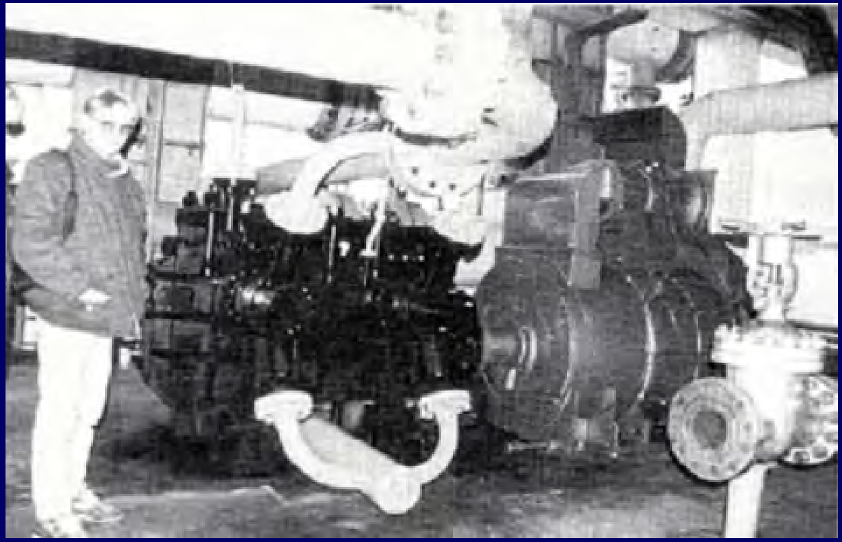
- *Recent data suggest that geothermal wells with wellhead temperatures up to 150°C can be drilled to a depth of about 5,000 m in the areas of Oradea-Bors and Oradea-Beius. In case these deep wells will be drilled and the well head temperature will be high enough, the Transgex Company intends to develop these two fields for power generation (ORC power plants).*

ROMANIA

-At the University Campus of Oradea the National Geothermal Research Institute designed and developed a pilot binary cycle power plant using carbon dioxide as a working fluid.

- The campus geothermal well is 2991 m deep and produces 85^{o}C water at an artesian flow of 25 l/s (50 l/s with line shaft pump).

- The geothermal heating system at the University of Oradea was placed on line in 1981. It provides domestic hot water and space heating for all buildings of the university campus (old and new) including student hostels and canteen.



University of Oradea: CO_2 binary pilot plant

Oradea district heating system: Plate heat exchangers

ROMANIA

Examples of direct uses of geothermal energy


Livada - Oradea: Geothermal greenhouse


Iosia - Oradea:
Geothermal district heating system (Plate heat exchangers) [max 65 l/s at 105ºC]


Degassers next to the well (A)


(B) *Heat plant*


© *Church*


(D) *Small block of flats*


(E) *Kindergarten*


(F) *School*

Livada - Oradea: Geothermal district heating [T=90ºC]


Felix Spa - Oradea:
One of the largest Romanian spa [T=35-55ºC]

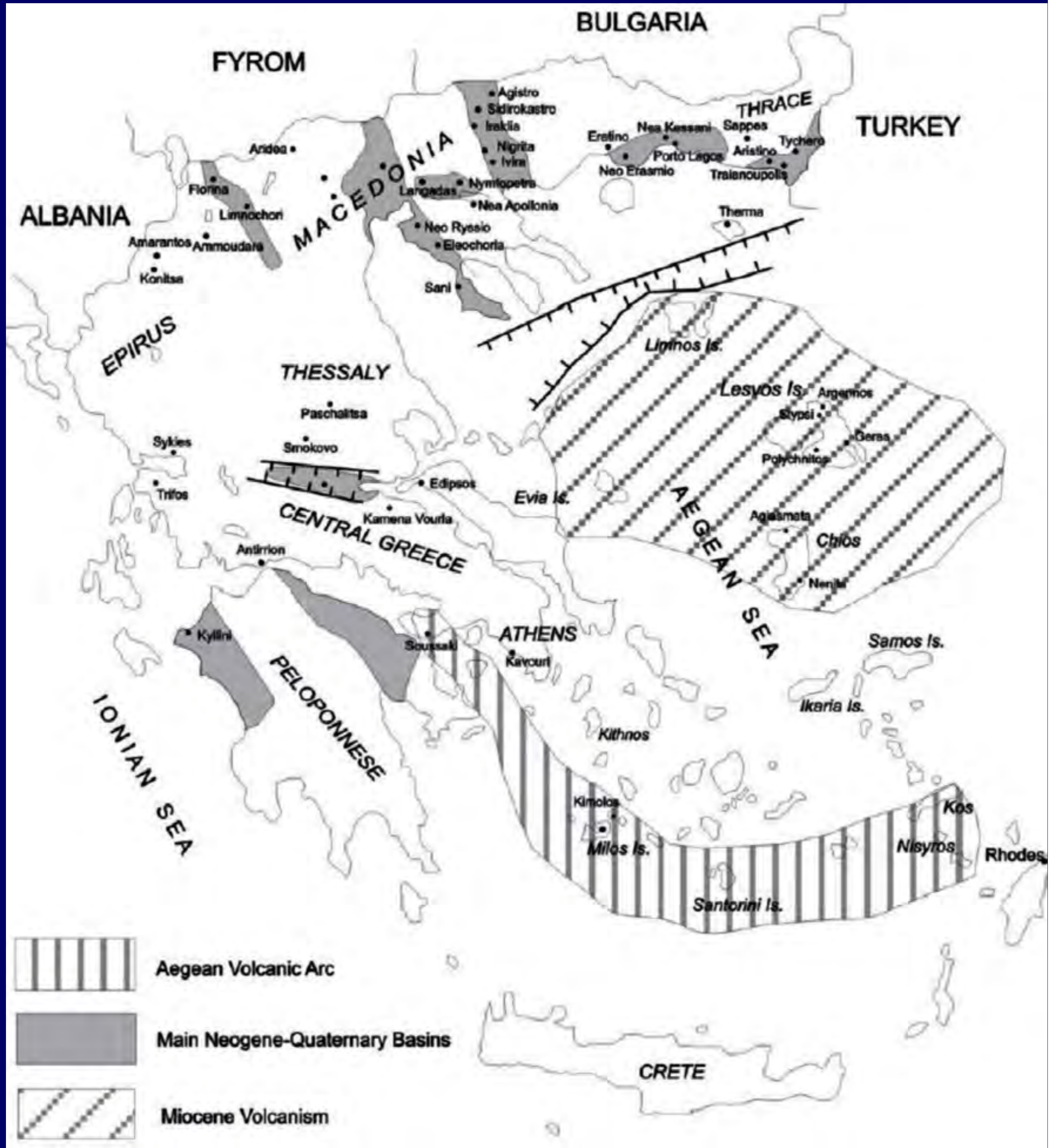
Thank you very much

for your attention!

GREECE

- Geothermal exploration in Greece began in the '70s by I.G.M.E.
-The Hellenic area is characterized by high levels of heat flow (> 80 mW/m²), mainly in the sedimentary basins of Northeastern Greece and the Aegean Sea, due to the active tectonics and the volcanic activity. This very intense volcano-tectonic activity caused the geological conditions for accumulation of heat energy which is manifested in many places as hydrothermal systems of low-medium and high enthalpy geothermal fields.

- The most important high enthalpy geothermal fields (Milos, Nisyros) are located in the Southern Aegean along the active volcanic arc with proven geothermal potential 25 MW_e and estimated possible potential >250 MW_e.
- Geothermal field of Milos island:
Temperatures in the wells: 280-325°C
Depth of reservoir: 1000-1380 m
Production: 339 t/h of fluids (200 t/h saturated steam - 139 t/h hot water),
Pressure: 11-19 atm
- Geothermal field of Nisyros island:
Temperatures in the wells: ~ 350°C
Depth of reservoir: 1400-1900 m
Production: 75 t/h of fluids , Pressure: 12 atm



Geothermal areas in Greece with main geotectonic structures

GREECE

After the new national geothermal legislation (Law 3175/2003), I.G.M.E. compiled a study and classification of known fields in the new categories (high and low temperature fields, proven and possible fields). At present, the known proven and possible geothermal fields exceed 40 in 30 different areas (in some cases proven and possible fields in the same area) and they are located all over the country. There are two known high temperature (T> 90^{o}C) fields, suitable for power generation (Milos and Nisyros islands). The remaining fields are of low temperature with potential > 220,000 T.O.E./yr for direct uses.

Proven and possible geothermal fields of Greece according to the Law 3175/2003.

BULGARIA

Hydrothermal resources in Bulgaria (Petrov et al. 1998)

N	Major hydrothermal unit	Water temperature, degC	Total flow rate, l/s	Thermal potential, kJ/s
1	**Moesian plate (total)**	**21.5 - 71**	**1 241.6**	**101 482**
	Lom basin*	29.8 - 35.9	3.04	193
	Central Northern Bulgaria and Balkan Foreland zone*	21.5 -71	191.1	5 819
	J_3 -K_1 horizon	22 - 50	1012.9	92 891
	West Balkan	24.9 - 38	34.6	2 579
2	**Sredna gora, incl.Balkan (total)**	**20.5 - 78**	**669.4**	**85 960.5**
	West Sredna gora	23.5 - 67.5	241.7	27 058.6
	Dolna banja basin	42 - 72	47	8 846
	Central Sredna gora	20.6 - 78	211	27 402.8
	East Sredna gora	22 - 77	81	10 128.5
	Upper Thracian basin and Sakar-Strandja zone	20.5 - 51	26.5	2 763.6
	Kraishte zone	22.4 - 75	62.2	9 761
3	**Rila-Rhodope massif (total)**	**20 - 98**	**1015.8**	**128 291.6**
	Struma region	20 - 98	254.6	49 156
	Mesta region	25.5 - 55	265.93	24 331.7
	West and East Rhodopes	20.6 - 95	495.3	54 803.9

*Resource potential is assessed only for wells in exploitation

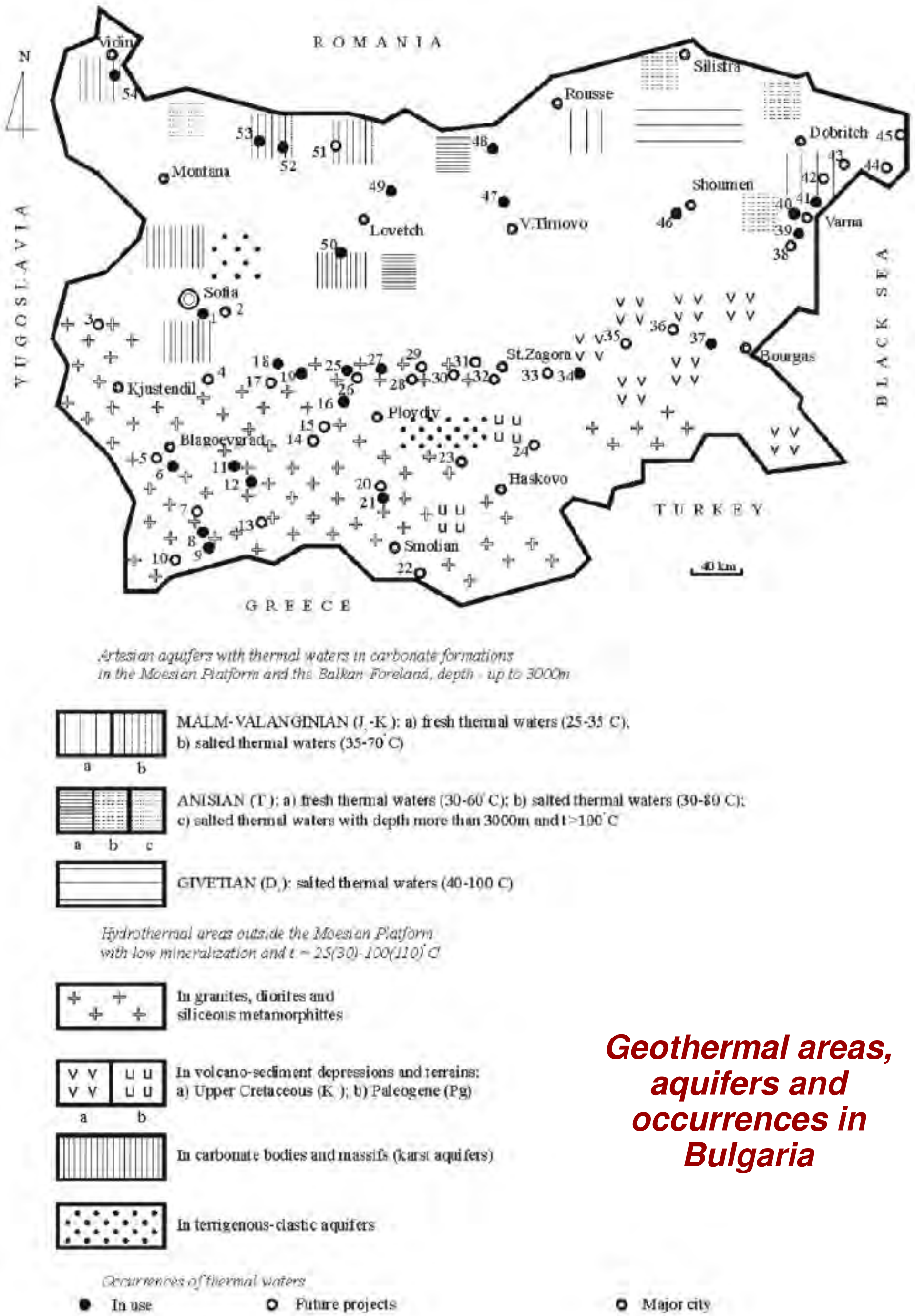
The total hydrothermal potential is defined as the thermal energy contained in the discovered waters and amounts to 9,957 TJ/yr (Petrov et al., 1998)

[for output temperature of 15°C]

BULGARIA

No	Occurrence	Miner.	T	Flow rate
-	-	g/kg	°C	dm^3/s
1.	Sofia-Centrum	0,3	49	16
2.	Sofia Basin	0,9	64-80	40/80
3.	Kjustendil	0,6	74	35/50
4.	Sapareva Bania	0,7	97-100	14/20
5.	Blagoevgrad	1,0	63	15/20
6.	Simitli	0,6	63	27/35
7.	Sandanski	0,6	83	20/30
8.	Levunovo	0,9	85-90	15/20
9.	Marikostinovo	1,0	63	20/30
10.	Rupite	2,3	73-76	30/45
11.	Guliina Bania	0,3	54-59	60/80
12.	Eleshnitza	0,3	55	27/35
13.	Ognianovo	0,2	41	70/100
14.	Velingrad	0,5	47-87	130/200
15.	Draginovo	0,7	94	15/25
16.	Varvara	0,7	72-90	20/30
17.	Dolna Bania	0,6	65	25/40
18.	Ptchelin	1,0	73	12/15
19.	Momin Prohod	1,0	64	15/20
20.	Devin	0,3	44	30/40
21.	Beden	1,8	76	12/20
22.	Erma Reka	1,1	90-100	100/?
23.	Haskovo	1,6	55-60	30/50
24.	Simeonovgrad	0,8	57	15/20
25.	Panagjurishte	0,6	48	5/8
26.	Streltcha	0,3	56	15/20
27.	Krasnovo	0,3	55	14/20
28.	Hissar	0,3	45-52	45/60
29.	Bania-Plovdiv	0,4	46-50	30/40
30.	Pavel Bania	0,6	60-63	16/25
31.	Ovoshtnik	0,6	45-75	35/50
32.	Yagoda	0,6	40-46	8/20
33.	Korten Bania	0,9	56-60	12/20
34.	Sliven Bania	1,9	48	17/25
35.	Straldja	1,1	77	12/20
36.	Aitos	0,4	50	20/30
37.	Burgaski Bani	0,6	41	30/50
38.	Varna-South	0,6	55	100/200
39.	Varna-City	0,6	50-55	250/400
40.	Varna-Droujba	0,6	39-49	315/500
41.	Varna-Zl.Piasatzi	0,6	30-37	100/200
42.	Albena	0,6	30	100/150
43.	Kavarna	0,6	30	120/200
44.	Rusalka	1,1	32	50/80
45.	Shabla	3,5	39	150/200
46.	Marash	7,0	63	10/30
47.	Krushuna	11,0	57	18/40
48.	Svishtov	2,0	49	42/100
49.	Resen	4,6	55	20/60
50.	Chiflik	0,3	51	33/40
51.	Pleven	18,5	64	70/120
52.	Dolni Dabnik	20,0	65	75/150
53.	Dolni Lukovit	25,0	73	35/50
54.	Vidin	57,0	50	30/50

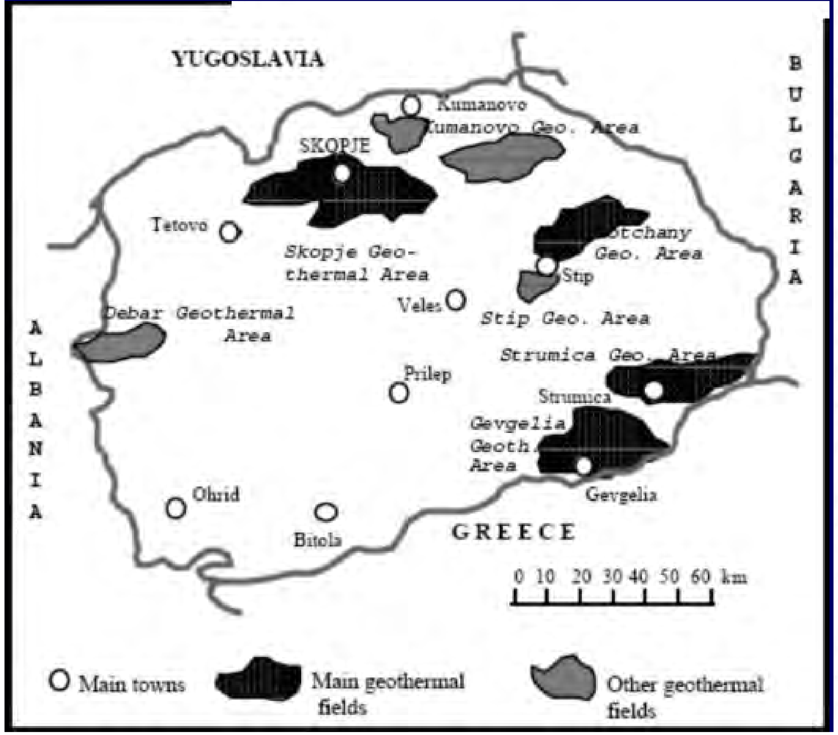
Flow rate: 100/150 dm^3/s - present/potential



Geothermal areas, aquifers and occurrences in Bulgaria

F.Y.R.O.M.

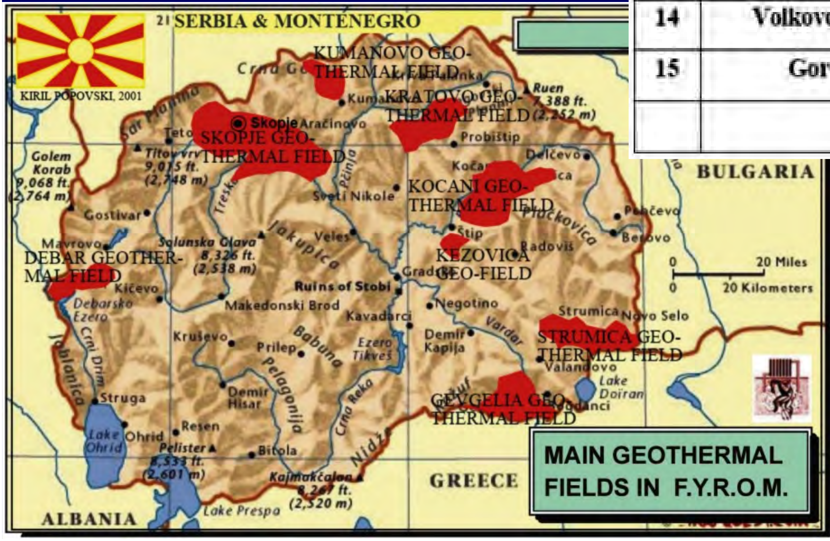
Thermal waters in F.Y.R.O.M. and their physical characteristics



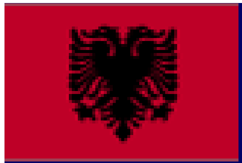
No	Place Spring (i)	Occurrence Borehole (d)	Coordinate x	y	z	Temp. (°C)	Flow (l/s)
1	Volkovo	GTD-1 (d)	4 654 971	7 527 841	374	25	63
2		IBSKG-3 (d)	4 654 330	7 528 150	317	22	22
3	Katlanovska b	D-1 (d)	4 639 800	7 557 650	287	54,2	10
4		B-1,B-2 (d)	4 638 990	7 558 125	255	32	4
5		Nervna v (i)	4 639 225	7 558 100	250	28	2
6		Potkop	4 639 500	7 557 850	265	38	2
7		Fontana (i)	4 639 750	7 557 000	270	28	0,2
8		izvor (I)	4 639 260	7 557 910	230	38	1
9	Proevci	(d)	4 664 460	7 562 100	310	31	2
10	Strnovec	(d)	4 670 300	7 570 050	280	40	17
11	Podlog	EBMP-1 (d)	4 638 625	7 613 175	310	78	150
12		R-3 (d)	4 638 775	7 613 095	310	77,8	80
13	Krupiste	K-1/83 (d)	4 634 000	7 605 000	300	32	0,5
14		K-2/83 (d)	4 634 000	7 605 100	295	40,6	6,9
15	Kocansko pole	R-11 (d)	4 640 700	7 618 252	335	50,6	2,6
16	Kocani	Ka-1 (d)	4 641 750	7 617 200	340	22,4	6
17	Podlog	EB-4 (d)	4 639 000	7 613 000	310	79	120
18	Podlog	EB-3 (d)	4 639 025	7 613 070	310	78	350
19	Istibanja	I -5 (d)	4 643 000	7 624 350	350	66,4	12
20		I -3 (d)	4 643 100	7 624 350	350	67	5
21		I -4 (d)	4 643 025	7 624 475	350	56,6	4,2
22	Trkanje	EB-2 (d)	4 649 560	7 612 660	311	71,3	50
23		R-9 (d)	4 639 375	7 612 675	310	71,3	85
34	Banja	B-1 (d)	4 641 550	7 611 225	350	63	8,3
25		B-2 (d)	4 641 525	7 611 205	348	63,2	55,3
26		R-1 (d)	4 640 300	7 615 840	347	63	30
27		R-6 (d)	4 639 925	7 611 600	350	40	1
28	Bansko	B-1 (d)	4 583 900	7 647 225	258	68	55
29		izvor (I)	4 583 500	7 647 160	270	73	6
30	Negorci	NB-3 (d)	4 559 875	7 625 530	65,1	47,2	40
31		NB-4 (d)	4 559 750	7 625 600	64,3	53,2	40
32		B-1 (d)	4 559 100	7 625 410	65	32	3
33	Smokvica	Sied6 (d)	4 570 375	7 624 812	56,9	45,1	7,2
34		Sied1 (d)	4 570 340	7 624 800	57,5	56,7	60
35		Sied2 (d)	4 569 650	7 624 775	57,1	48,1	5,2
36		Sied4 (d)	4 570 250	7 624 815	57	56,1	35
37		Sied5 (d)	4 570 400	7 624 780	57,1	64	40
38		Sied7 (d)	4 520 369	7 624 725	57,1	68,5	60
39	Stip	Ldzi (i)	4 621 825	7 598 552	300	59	1
40		Kezovica (d)	4 621 700	7 598 360	280	57	7
41		B-4 (d)	4 621 850	7 598 630	260	32	30
42	Kozuf	Topli dol(i)	4 560 225	7 583 760	740	28	0,5
43		Toplik (i)	4 558 275	7 579 743	880	22	8
44		Mrezicko (i)	4 561 875	7 583 450	720	21	0,2
45		Gornicet (i)	4 558 425	7 619 650	220	23	0,1
46	Kratovo	Povisica (d)	4 659 035	7 590 143	443	31	4
47		Dobrevo (d)	4 654 510	7 600 300	330	28	5,5
48	Veles	Sabota voda	4 620 025	7 567 810	280	21	5
49	Rakles	dupn (d)	4 609 287	7 624 308	349	26	2
50	Dojran	Toplec (i)	4 566 550	7 642 530	161	25	2
51		Deribas (d)	4 561 580	7 643 900	240	20,5	10
52	Debar	Kosovrasti (d)	4 561 580	7 643 900	400	48,5	10
53		Baniste (d)	4 561 580	7 643 900	750	40,5	5-100

F. Y. R. O. M.

No	Geothermal field (Location)	Flow capacity	Temp.	Heat power (MWt) For different outlet temperatures						
		l/s	°C	15°C	20°C	25°C	30°C	35°C	40°C	45°C
01	D.Podlog-Kocani	300	75	75.4	69.1	62.8	56.5	50.2	44.0	37.7
02	Istibawa-Vinica	73	65	15.3	13.8	12.2	10.7	9.2	7.8	6.1
03	Povishnica-Kratovo	20	48	2.8	2.4	1.9	1.5	1.1	0.7	0.3
04	Strnovec-Kumanovo	46.71	40	4.9	3.9	2.9	1.9	1.0	-	-
05	Kumanovska banja	4	31	0.3	0.2	0.1	-	-	-	-
06	Dobrevo-Zletovo	8	28	0.4	0.3	0.1	-	-	-	-
07	Bansko-Strumica	50	70	11.5	10.5	9.4	8.4	7.3	6.3	5.2
08	Smokvica-Gevgelija	120	65	25.1	22.6	20.1	17.6	15.1	12.6	10.0
09	Negorska banja	80	50	11.7	10.1	8.4	6.7	5.0	3.4	1.7
10	Kezovica-Shtip	20	60	3.8	3.4	2.9	2.5	2.1	1.4	1.3
11	Raklesh-Radovish	1	26	0.1	-	-	-	-	-	-
12	Topli dol i Mrezichko-Rzanovo	2	27	0.1	-	-	-	-	-	-
13	Katlanovo-Skopje	13	50	1.9	1.6	1.4	1.1	0.8	0.5	0,2
14	Volkovo-Skopje	20	25	0.8	0.4	-	-	-	-	-
15	Gornicet	5	24	-	-	-	-	-	-	-
		752.71		154.1	134,7	122.2	106.9	95.8	76.8	62.5

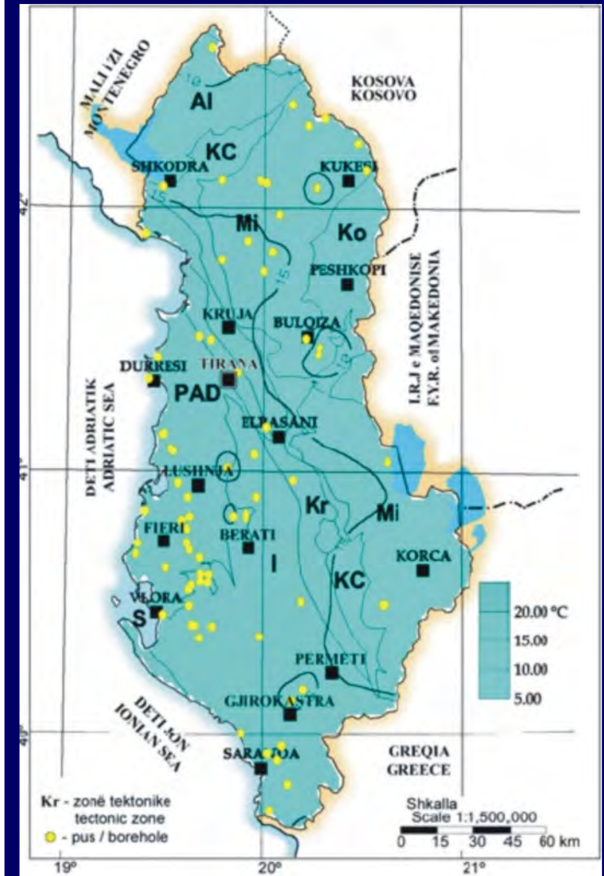


Temperatures, flow rates and available thermal potential (for different outlet temperatures) of geothermal resources in F.Y.R.O.M.



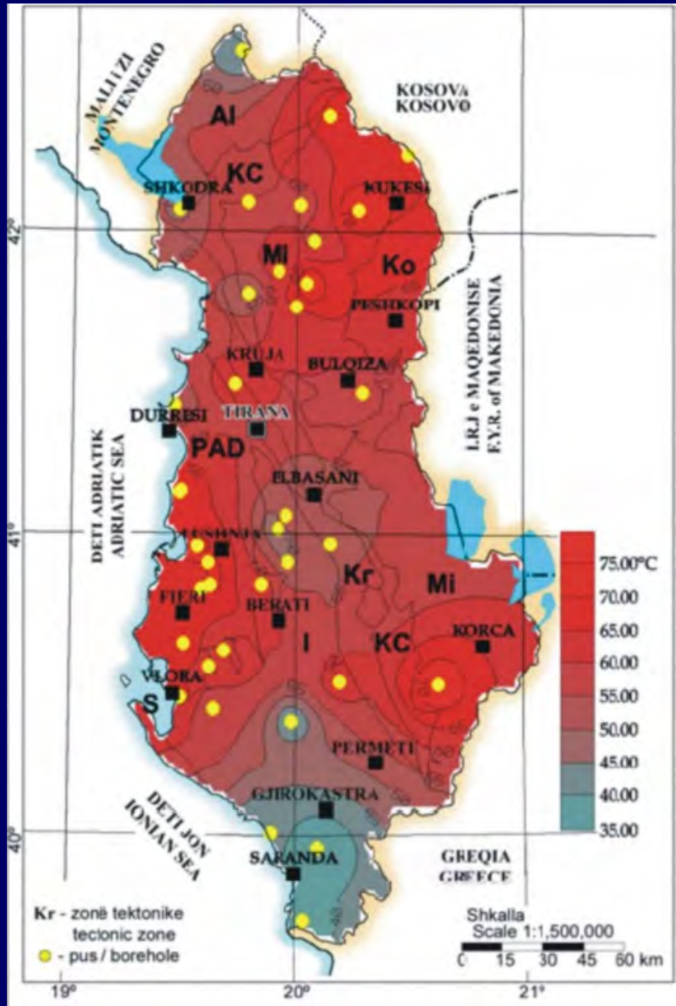
ALBANIA

The temperatures have been measured and the geothermal gradient and the heat flow density at different depths have also been calculated. Temperature measurements were carried out in 145 deep wells, in boreholes and in mines.



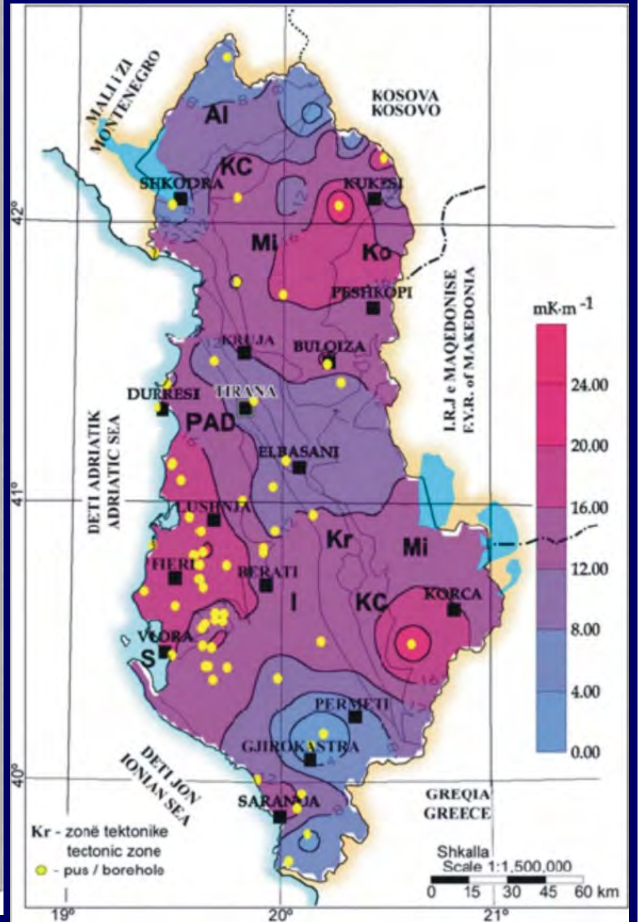
Isothermal curves at a depth of 100 m.

The temperature at a depth of 100 m varies from <10 to almost 20°C, with the lowest values in the mountain regions.



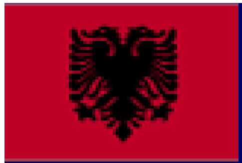
Temperature map at a depth of 3,000 m.

Going deeper the zones of the highest temperatures move from SE to NW, towards the center of the Peri-Adriatic Depression (PAD) and even further towards the NW coast. The temperatures in the ophiolitic belt are higher than in sedimentary basin, at the same depth. In the central part of the Peri-Adriatic Depression (PAD), there are many deep oil wells where the temperature reaches up to 68°C at 3000 m.



Average geothermal gradient map.

The geothermal gradient displays high values ($21.3\ mK.m^{-1}$) in the Pliocene clay section in the centre of Peri-Adriatic Depression (PAD, in the anticline molasses structures of the center of Pre-Adriatic Depression). In the ophiolitic belt, the geothermal gradient reaches the value of $23.5\ mK{\cdot}m^{-1}$.



ALBANIA

Location map of wells Ishmi 1/b - Kozani 8 and the Llixha Elbasan Geothermal Area (T=60°C)

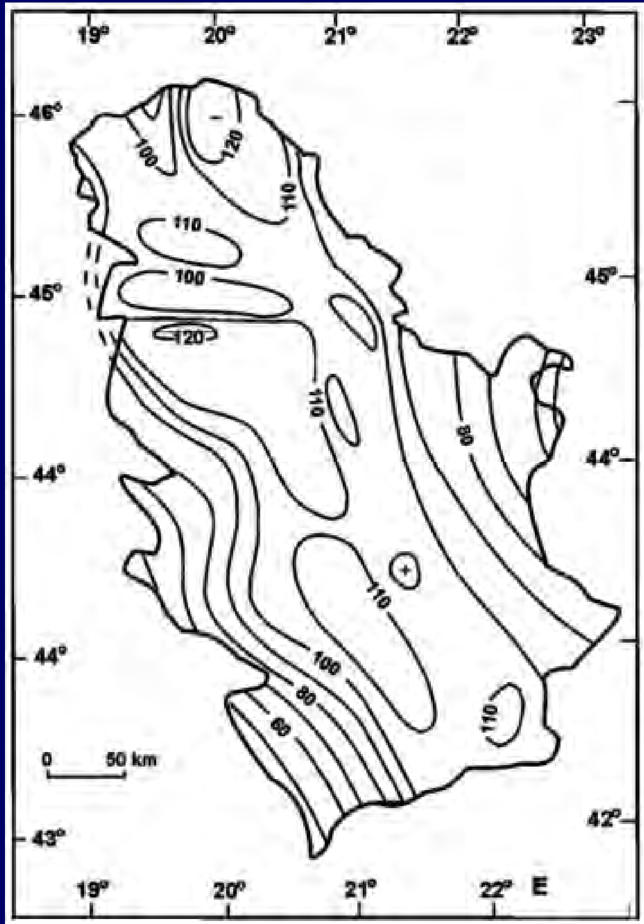
In many deep oil and gas wells, there are thermal water fountain outputs with a temperature that varies from 32 to 65.5°C. These waters come from different depth levels (800-3000 m) of limestone reservoirs (wells 1, 2, 3, 4) and sandstone reservoirs (wells 5, 6, 7 and 8).

N°	Well Name	Temperature in °C	Salt in $mg \cdot l^{-1}$	Self-discharge, in $l.sec^{-1}$
1	Kozani-8	65.5	4.6	10.4
2	Ishmi 1/b	64	19.3	4.4
3	Galigati 2	45-50	5.7	0.9
4	Bubullima 5	48-50	35	
5	Ardenica 3	38		15-18
6	Ardenica 12	32		
7	Semani1	35		5
8	Verbasi 2	29.3		1-3

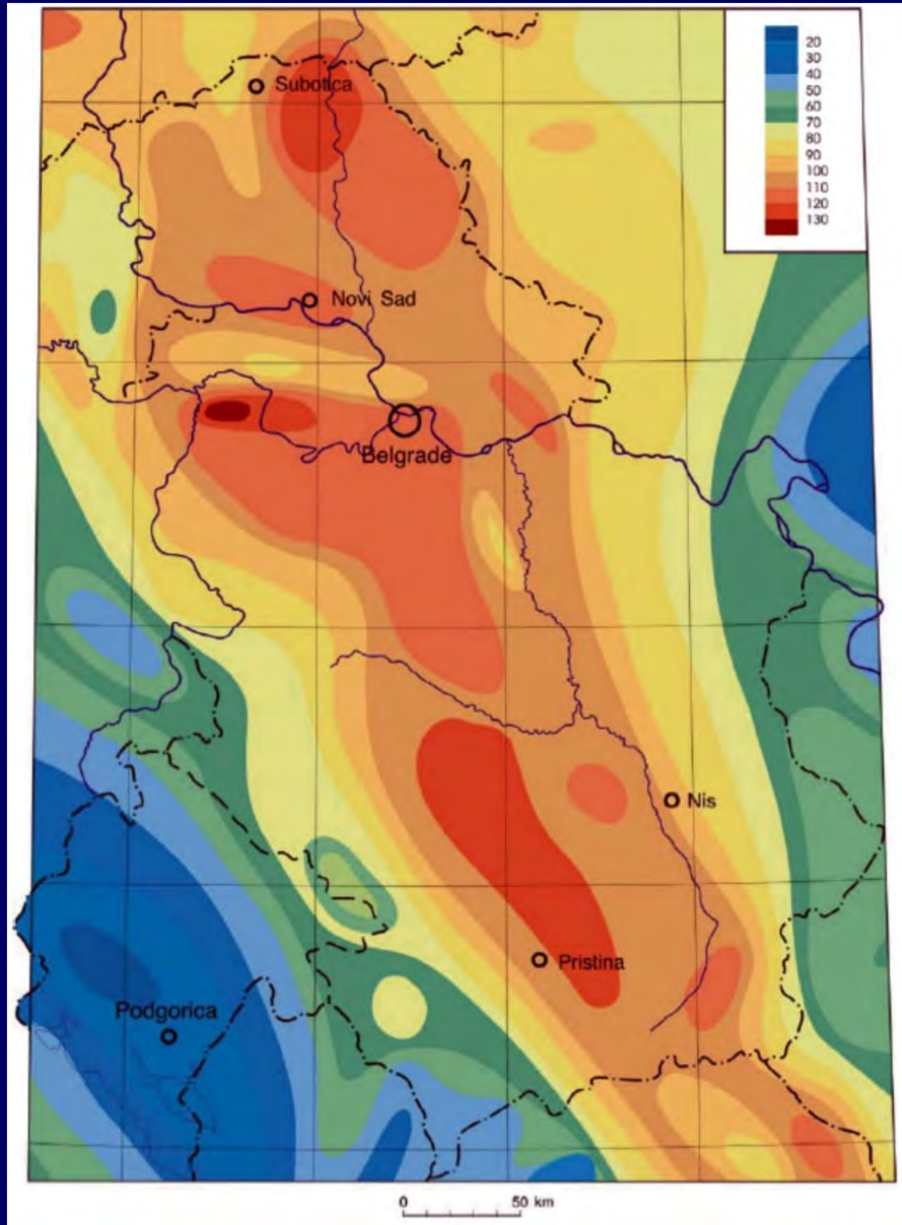
Deep oil and gas wells with thermal waters

SERBIA & MONTENEGRO

- *Geothermal characteristics of Serbia are very interesting.*
- *Values of the terrestrial heat flow density under most of Serbia are higher than the average for continental Europe. The highest values (>100 mW/m^2) are in the Pannonian Basin, in the Serbian-Macedonian Massif, and in the border zone of the Dinarides and the Serbian-Macedonian Massif, or the terrain of Neogene magmatic activation. The mentioned high heat flow densities indicate the presence of a geothermal anomaly which is an extension of the geothermal anomaly of the Pannonian Basin.*



Heat flow map (mW/m^2) of Serbia



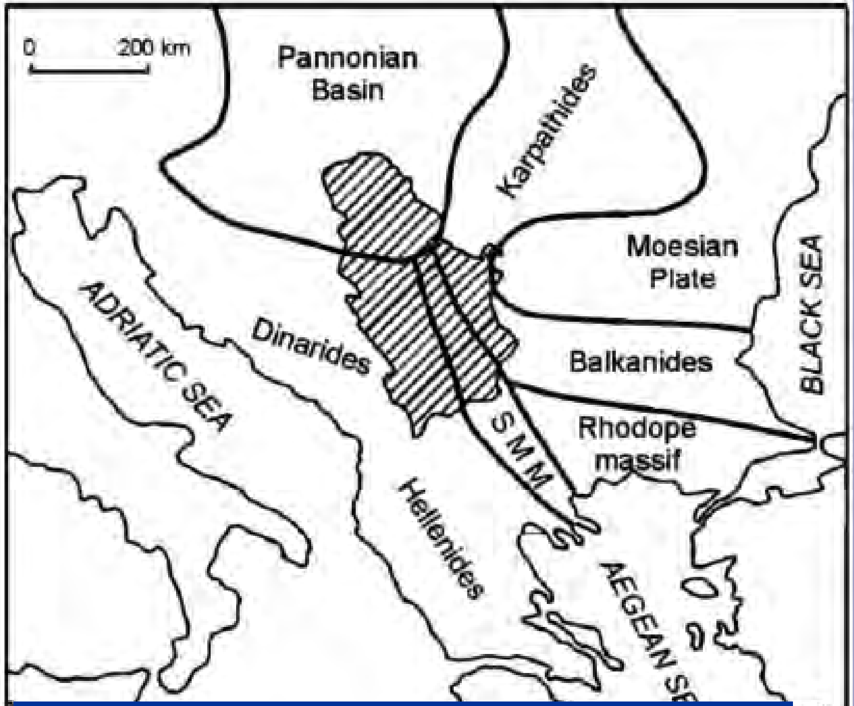
Heat Flow Density Map of Serbia and Montenegro

SERBIA

GEOTHERMAL RESOURCES (ii)

- In Dinarides:

Hydrogeothermal systems in this geothermal area differ in their types, kinds of reservoirs and their extents etc. as a result of varying geology. The best aquifers are in Triassic limestones as the thermal waters contained have low mineral content (<1 g/kg) of HCO_3-Na or HCO_3-Ca-Mg type. Spring flow rates 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°C. The second important reservoirs are those in granitoid intrusions and their marginal thermo-metamorphosed fracture zones. The thermal waters are also low in total mineralization (>1 g/kg), of HCO_3-Na type and maximum yield to 15l/s. The highest temperature of waters at well-heads are 78°C.



Geographical location of Serbia with the main geotectonic units in the Balkan Peninsula

- In Serbian-Macedonian Massif:

There are two types of hydrogeothermal systems in this geothermal area: (a) In the Proterozoic metamorphic complex with the reservoir in marbles and quartzites. 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. Water temperatures at springs are 24-72°C.
(b) 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. The thermal springs of Vranjska Banja belong to this system type and have the warmest water in Serbia, 80-96°C. Its mineral content varies from 0.1 to 1.2 g/kg. The water type is HCO_3-Na-SO_4-Cl. Spring flow rates are up to 80 l/s.

- In Carpatho-Balkanides:

This geothermal area has many hydrogeothermal systems, most of them formed in regions of isolated Neogene sedimentary lake basins. Reservoir rocks are karstified limestones. Thermal karst springs have flow rates of 60 l/s with water temperatures up to 38°C. Total mineralization is 0.7 g/kg and the water type is HCO_3-Ca. In another type of hydrogeothermal systems, waters have TDS content up to 0.8 g/kg and these waters are of SO_4-Na-Cl or HCO_3-Na-SO_4-Cl type. Water temperatures at thermal springs are up to 43°C and spring flow rates are up to 10 l/s.

SERBIA

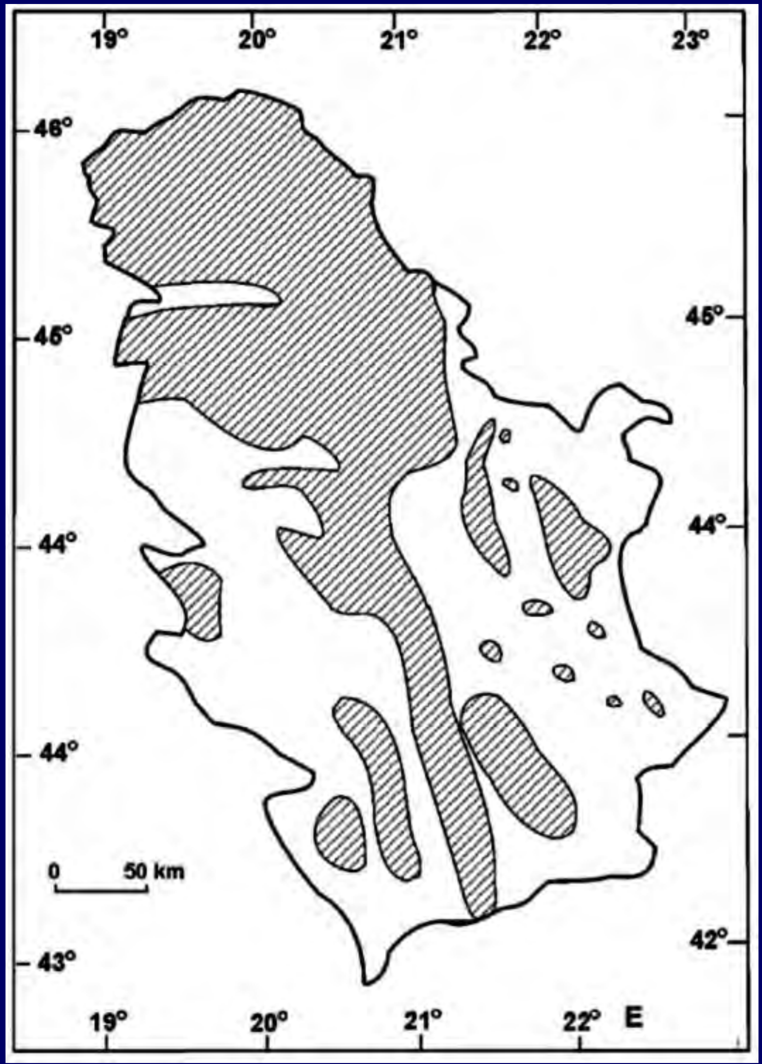
- There are 60 convective hydrogeothermal systems in Serbia. Most of them are distributed as follows:

25 in the Dinarides,

20 in the Carpatho-Balkanides,

5 in the Serbian-Macedonian Massif and

5 in the Pannonian Basin under Tertiary sediments.



Distribution of major convective type geothermal systems in Serbia

Location of the Pannonian Basin in the territory of Serbia

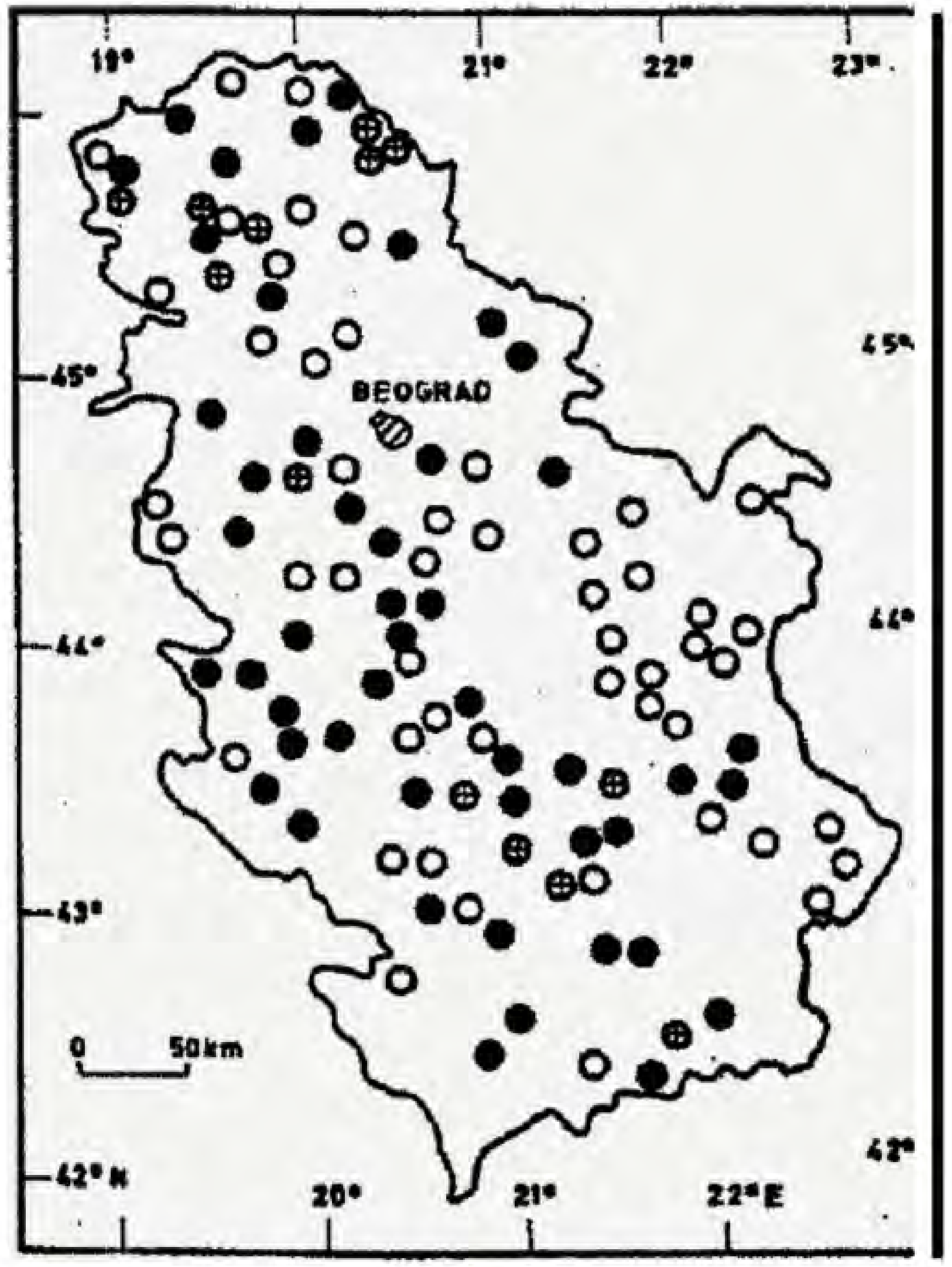
SERBIA

Locations of major thermal springs and wells in Serbia

[O - *balneology,*

⊕ - *balneology, space heating, agriculture,*

● - *not used*]



C
R
O
A
T
I
A

Geothermal resources in Croatia

*- There are **28 geothermal reservoirs** in Croatia.*

*- Total direct heat potential of 28 geothermal resources is about **1000 MW_t**. This value follows from thermal power of each existing well, based on the energy usage down to the temperature of 25°C. Maximum annual thermal energy production from all geothermal reservoirs could reach full 18441,63 TJ/yr, calculated on the basis of the capacity factor of 50%.*

*- According the calculations, **the electric power of 5 suitable geothermal resources is about 50 MW** maximally while the annual production of electrical energy amounts to 377,33 GWh/yr, calculated on the basis of the capacity factor of 90%.*

CROATIA

The basic energy data of the geothermal fields are given in the next table.

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 pattern refers to the application of conventional heat exchanger systems assuming an outlet water temperature of 50°C.

- Another pattern is based on the energy use down to the temperature of 25°C.

Geothermal Resources in Croatia - Direct Heat Potential

	Locality	T	Thermal Power (MW_t)				Thermal Energy (TJ/yr)[1]			
		(°C)	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

ROMANIA

The main parameters of the geothermal systems in Romania

Parameter	U/M	Oradea	Bors	Beius	Western Plain*	Olt Valley	North Bucharest
Type of reservoir		carbonate	carbonate	carbonate	sandstone	gritstone	carbonate
Area	km^2	75	12	47	2,500	28	300
Depth	km	2.2–3.2	2.4–2.8	2.4–2.8	0.8–2.1	2.1–2.4	1.9–2.6
Drilled wells	(total)	14	6	2	88	3	11
Active wells		12	5	1	37	2	5
Well head temp.	°C	70–105	115	84	50–85	92–96	58–75
Temperature gradient	°C/100	3.5–4.3	4.5–5.0	3.3	3.8–5.0	4.6–4.8	2.8–3.4
TDS	g/l	0.8–1.4	12–14	0.46	2–7	13	2.2
GWR (Gas Water Ratio)	Nm^3/m^3	0.05	5–6.5	-	0.5–2.5	2–2.8	0.1
Type of production		Artesian	Artesian	Pumping	Artesian+Pumping	Artesian	Pumping
Flow rate	l/s	4–20	10–15	13–44	4–18	12–25	22–28
Operations		11	2	1	37	2	2
Annual savings	toe	9,700	3,200		18,500	2,600	1,900
Total installed power (with existing wells)	MW_t	58	25	10	210	18	32
Exploitable reserves (for 20 years)	MW/day	570	110	52	4,700	190	310
Main uses:							
• space heating	dwellings	2,000	-	10,500	2,460	600	1,900
• sanitary hot water	dwellings	6,000	-	3,200	2,200	600	1,900
• greenhouses	ha	1.8	6	-	34	-	-
• industrial uses	operations	6	-	-	7	-	-
• health bathing	operations	5	-	-	8	3	2

* Pannonian geothermal system