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3.
GEOTHERMAL ENERGY USE IN MACEDONIA
State-of/the Art and Experience of Agricultural Uses

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Abstract: *Republic of Macedonia has been one of the promoters of direct application of geothermal energy, particularly in agriculture, during the late 70-ies and 80-es of the past century. However, two economic embargoes, political and economy system transformation destroyed completely the economy of the country and development of geothermal energy use has been stopped in the early 90-ies. Even more, some of the projects are abandoned meanwhile.*

Begining of the first reconstructions and modernizations of some of the projects four years ago confirmed the existence of interest to follow the development. Quite high local knowledge and long exploitation experience resulted with the success of the engagements. It gives hopes that some foreign capital can find interest in investments in new geothermal investigations, modernization of existing and opening of new projects in agriculture, district heating sector and balneology.

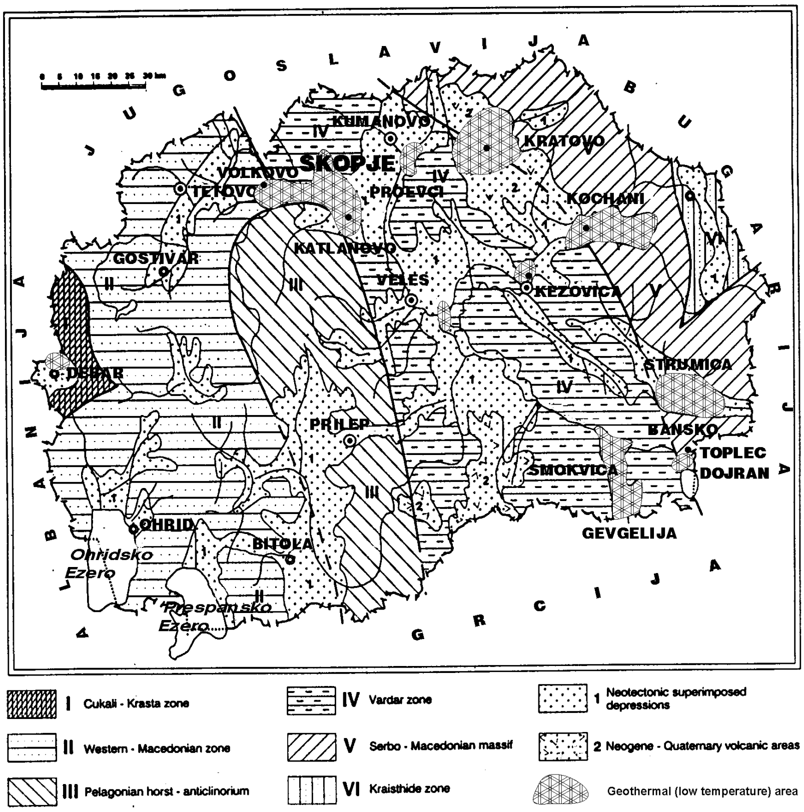

Fig.1. Geothermal zones in Macedonia (Arsovski, 1989)

1. GEOTHERMAL ENERGY RESOURCE OF MACEDONIA

According to the tectonic setting of the Balkan peninsula the territory of Macedonia belongs to the Dinarids, Rhodops and Carpato-Balcanids. There are six geotectonic units separated in the territory of Macedonia: Cukali- Krasta zone; Western Masedonian zone; Pelagonian massif; Vardar zone; Serbo-Macedonian mass and Kraishtid zone, Fig.2. (Arsovski, 1989). First four geotectonic units belongs to the Dinarids as a geotectonic unit with regional meaning, Serbo-Macedonian mass is part of Rhodopian mass and Kraishtids are part of Carpato-Balcanids widly spreaded in the north-est part of the Balkan peninsula. The territory is a seismic region with frequent earthquakes of different intensity. Greater part of the earthquakes are connected with the Vardar zone as one of the most unstable geotectonic units on the Balcan peninsula, but also there are earthquakes in the terrains which structurally belong to the other geotectonic units connected with neotectonic active dislocations.

All geothermal resources in Macedonia are related with Vardar zone as active subduction zone between Dinarides and Rodopes during Jurassic period. The geothermal anomalies in the Vardar zone and its margins through Serbo-Macedonian mass are outcomes of that events and later acid magmatisam and volcanism active till the beginning of Quoterner period (Fig.1).

Contemporary relief consists of morphostructures of subsidence and morphostructures of upraising. Vertical movements are with different intensity in the different parts. The terrains in the West and South West part of Macedonia have the most intensive upraising; than came the East part and Vardar geotectonic zone nowadays showing relatively small upraising.

The neotectonic transversal and diagonal faults are rich with natural appearances of thermal waters as are (Fig.2): Volkovo near Skopje, Katlanovo spa, Proevci near Kumanovo, Kezovica near Stip, Podlog and Istibanja near Kocani, Bansko near Strumica and Toplec near Dojran. Some of reactivated preneotectonic faults are also controlled with thermal occurrences as thermal waters in Toplik and Topli Dol near Kavadarci, Negorska spa and Smokvica near Gevgelija.

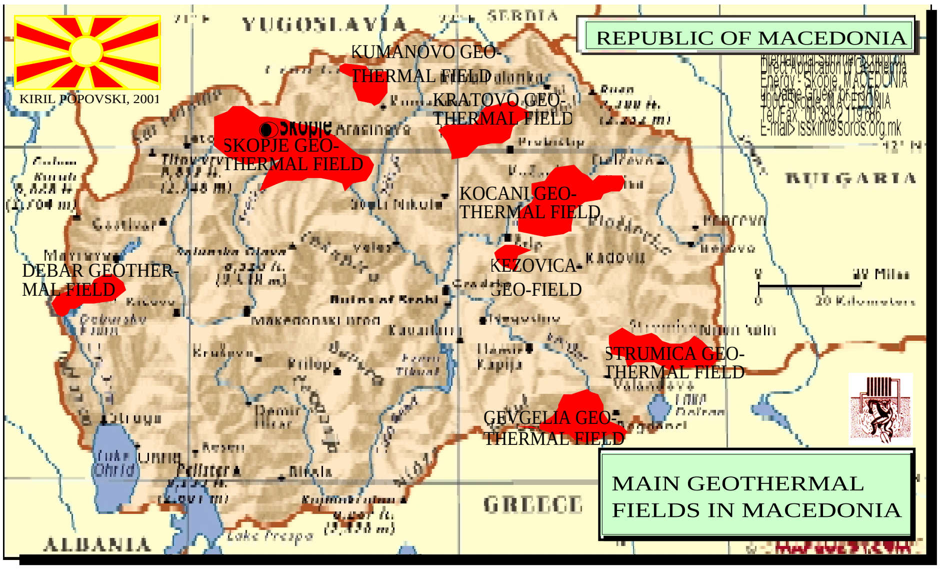

Fig.2. Main geothermal fields in Macedonia (Popovski, 2001)

It's necessary to underline that the total available flow of usable sources is 922.74 l/s, which is less than estimated 1,000 l/s of 5 years ago, and differs from the values given in Table 1, i.e. 1,397 l/s. First of all, the values given in Table 1 are the maximal measured short lasting flows which change in exploitation. Then, difference is also due to the more precise data for long lasting capacities of all the flows in explotation, after many years of exploitation and measurements. Finally, it is also due to the introduced important change of the maximal capacity of the boreholes in Gorni Podlog (from about 450 to 300-350 l/s).

Temperatures of the flows vary in the rang from 24-27°C (Gornicet, Volkovo and Rzanovo) to 70-78°C (Bansko and Dolni Podlog). Total mean temperature is 59.77°C.

Chemical composition of the thermal waters in Macedonia is conditioned by the type of rocks in which they are flowing (Kotevski, 1995). That's the reason that the mineralization of the waters in the East and South part of the country is relatively low (flows mainly through the cristallites). On the other hand, the waters from the West part of the country are with very high mineralization (limonites).

Table 1. Thermal waters in Macedonia and their physical characteristics (Gorgieva, 1995)

Nº	Place	Borehole (d) Spring (i)	Coordinate x	y	z	Temperat. (ºC)	Outflow (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

The real energetic potential of the geothermal resource in Macedonia is in direct correlation with the technical/technological feasibility of its application in accordance with the newest know-how in the country and in the world. Up to now, the real Macedonian experience consists of heating of greenhouses, drying of agricultural products, heating of dwellings and public buildings, i.e. district heating, and preparation of the sanitary warm water.

Normally, now-a-days, the low limit of use is accepted to be 20°C. However, it is already proved that the limit of 15°C is the realistic one (cold aquaculture, heat pumps, etc.). The last valorisation is made in 2000 (Popovski, 2000) for all the exploitable geothermal resources in Macedonia. A total available maximal heat power of 173 MW is get, which means possibility of annual production of 1,515,480 MWh/year. That is about 21% less than the previous prediction (Popovski, Andrejevski, 1994) in accordance with the change of the available data about the flows and temperatures of geothermal waters on disposal (Georgieva, Micevski, 1995).

Very illustrative is the influence of the quality of the applied technical solution to the heat power of concrete geothermal source. For instance, the geothermal system in Dolni Podlog (Kotchany) has a maximal flow of about 300 l/s with temperature of 75°C. If a maximal use of the source is reached (i.e. effluent water of 15°C), its heat power is 75.4 MW. However, as it is known from practice, the applied technical solutions by the users result with temperatures of the effluent water during the winter weather conditions of 40-45°C. That practically means lowering of the heat power of the source to 37.7-44.0 MW, i.e. 40-50% of the maximally possible one. For the same geothermal system and planned composition of users, it is technically and economically feasible to reach lowering of the temperature of the effluent water to 30°C during the first phase of development (Popovski, 1991), i.e. without application of heating of plastic houses and aquaculture, and 25°C during the second phase of development. Such an optimization means lowering of the maximally possible heat power of the energy source for 25% and 17% respectively, which is in the acceptable limits even for the countries with longer experience in geothermal energy application.

When the whole geothermal resource of Macedonia is in question, and based on the previous experience and technical level of of the users, it is realistic to expect that it shall not be possible to reach lower temperatures than 30°C of the effluent water, at least during the next 10 years. As a con-sequence of that, the real (usable) heat power of presently available geothermal flows is about 116 MW. By decreasing the lower limit to 25 °C to the end of this decade, the available power shall increase to about 135 MW.

The estimation of possible production of 1,515,480 MWh/year heat energy of geothermal origin doesn't give a realistic picture for the usable value of this energy source. It consists a continual use of the maximal energy power all over the year, which is neither technically possible nor economically feasible. The introduction of the estimations for really possible maximal heat powers decreases this figure to 1,012,650 MWh/year and 1,182,600 MWh/ year respectively, if taking into account the real annual loadings of concrete users. As illustration; in the case of complete orientation to geothermal energy as energy source, the greenhouse complex enable an annual heat loading factor of only 0.15 and below, central heatings 0.15-0.18, etc. On the other hand, for the preparation of the sanitary warm water that is above 0.3, for industrial purposes 0.5, etc. However, if combining them (particularly the ones with different seasonal location of the consumption), it is realistic to estimate possibilities to reach an annual heat loading factor of 0.5 (Popovski, 1991). That is practically the relevant and realistic orientation for estimation of the economic value of the geothermal resource in Macedonia.

The above statement means that the presently available geothermal resource in Macedonia enables production and use of economically feasible 500-600,000 MWh/year. The expression "economically feasible" is underlined with intention due to the expected comparisons with the other energy resources in the country.

As it was already underlined, these estimations are based to the **presently** available flows and temperatures of the exploitation wells and sources in Macedonia and without a wider orientation to the use of heat pumps. Another problem is that it is possible to double it with very small investments in explorations and drilling shallow boreholes and in a period of only 5-6 years (Micevski, Kotevski, 1995). Even more, if a good and financially supported strategy for systematical investigations and development shall be accepted by the state, consisting opening of a process of deeper drillings (which are normal in European conditions), it is realistic to expect much higher temperatures and flows than the ones presently on disposal (got only from natural sources and very shallow boreholes). It shall mean also the change of possible field of application (introduction of electricity production).

2. STATE-OF-THE-ART OF GEOTHERMAL PROJECTS IN MACEDONIA

When having the intention to summarise the State-of-the-Art of the geothermal projects in the Republic of Macedonia, it is necessary to consider the following:

- Technical state of geothermal installations;
- Collected experiences;
- Technical and economic feasibility for optimisation.

About15 geothermal projects have been developed in the Republic of Macedonia during the period of 70-ies and 80-ies (Table 2). Some of them are still in operation or under development but some of them are abandoned or work below the designed capacities. Four of them are of major importance and have a important influence to the development of direct application of geothermal energy in the country. The most important is the Kotchany geothermal project. Also the Gevgelija and Vinica agricultural geothermal projects are significant, and together with the integrated project in Bansko and Negorci, conclude the characteristical Macedonian experience of the direct application of geothermal energy.

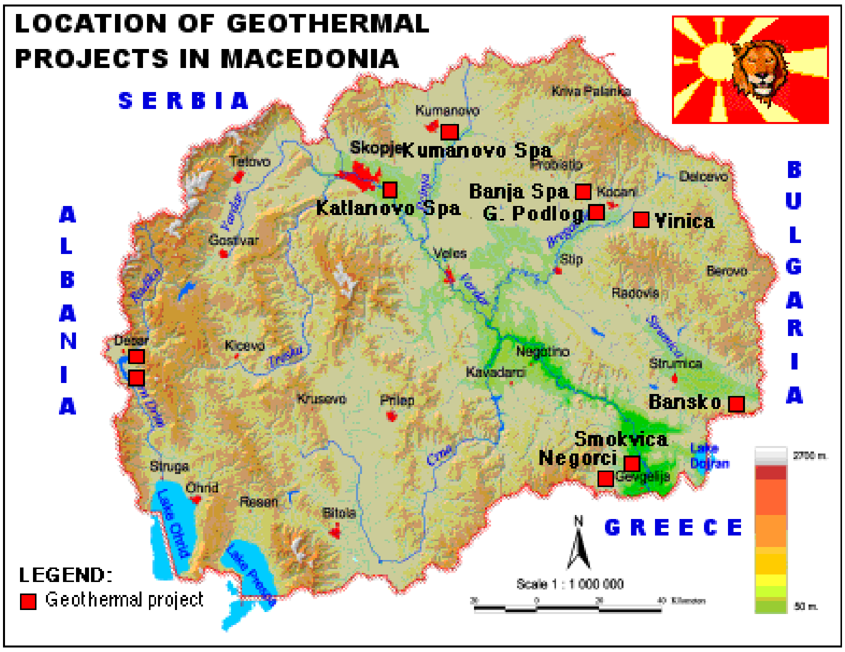

Fig.6. Location of geothermal projects in Macedonia (Popovski, 2003)

However, before making any comparisons or statements, it's necessary to take into account the following influencing factors:

- Republic of Macedonia is poor with energy raw materials and resources. It has on disposal only limited quantities of poor coal (reserves in a rang of 20-30 years, if keeping the present level of use) and hydroenergy of variable annual power and marginal importance for future development if taking into account the enormous investments per specific unit of useful power.
- Heat consumption of the country is mainly covered with import fuels (industry, business and part of the homes), biomass (homes) and electricity (homes in urban concentrations);
- Economy of the Republic of Macedonia is ruined and it is not export orientated. Present picture of relatively good covering of the energy consumption mainly with home produced one (electricity) and relatively small import (heat energy) is false. The first appearance of "awaking" of the economy will result with immediate need of energy import (electricity and particularly the gas and oil).

When comparisons of the economic feasibility of geothermal energy is in question, particularly in comparison with available energents, the above listed means:

- When development of own energy resources is in question, geothermal energy is the onliest one conditioning relatively low investments. If the nuclear energy is the onliest resource which can give guarantees for long term stabile energy supply of the country, geothermal energy is the onliest which can do the same for the heat consumption, at least there where being on disposal.
- Replacing at least of a part of the existing heat consumption of the country with geothermal energy is of life importance for it. That is valid particularly for the heat of bio mass origin (continual destroying of the poor green surfaces of the country), electricity (quick consumption of the poor reserves for production of energy with a very low efficiency of transformation), the gas and oil (complete import);
- Increased import of the energents should be covered with the significant increase of the
- export of final products (first priority of the strategy of development of the country). However, at least according to the present state of the economy, it is difficult to expect the success of this action, at least not with economically feasible parameters (export of products based on imported energents and raw materials?).

If taking into account also the confirmed technical feasibility for composition of integrated geothermal systems, resulting with the heat prices without competition at the local market, the justifiableness of wider investments in development of sources and direct application of geothermal energy is out of question.

The conclusion for the need for orientation to bigger district heating systems and balneology is justified by all means, however it is the agriculture which should again be the promoter of new development. That is the sector where the benefits of geothermal energy should not be proved again.

Anywhere, where geothermal energy is on disposal, agriculturals are "hungry" for its use. Immediately, after resolving the problems with privatization and issuing proper concessions, available resources shall be in full use. The example with Bansko is the best illustration for that. If having on disposal a double capacity, it shall be sold immediatelly.

GEOTHERMAL LOCATION	GEOTHERMAL FIELD	APPLICATION	HEAT POWER TOTAL kW	GEOTHERMAL kW	HEATING INSTALLATION
Istibanja	Kotchany heating (6,0 ha)	Greenhouse	17.500	2.350	Aerial steel pipes (reconstruction of existing install. tion with heavy oil boiler)
Bansko (Itegrated geothermal project)	Strumica	Greenhouse heating (2,9 ha) Greenhouse heating (600 sq.m) Plastichouses heating (3,0 ha) Space heating Sanitary warm water preparation Swiming pool heating. Balneology	9.000 150 3.000 1.560 700 350	9.000 150 3.000 1.560 700 350	Aerial steel pipes and on th soil surface steel pipes. Corrugated PP pipes on soi surface + fan jet air heating Soil heating. Aluminium radiators. Plate heat exchangers + warm water accumulator. Plate heat exchanger.
Podlog	Kotchany	Greenhouse heating (6,0 ha)	17.500	17.500	Aerial steel pipes.
Kotchany (District heating scheme)	Kotchany	Greenhouse heating (12,0 ha) Rice drying Paper industry Space heating	40.700 1.600 3.200 650	20.500 1.600 3.200 650	Aerial steel pipes. Square finned pipes heat exchanger (water/air). Plate heat exchanger. Aluminium and iron radiators.
Smokvica	Gevgelija	Greenhouse heating (22,5 ha) Plastichouse heating (10 ha)	65.500 10.000	11.750 10.000	Aerial steel pipes + corrugated PP pipes on soil surf Corrugated PP pipes on the soil surface)
Negorci	Gevgelija	Space heating Balneology	250	250	Steel radiators.
Katlanovo	Skopje	Balneology			
Kumanovo	Kumanovo	Balneology			
Banja	Kotchany	Balneology			
Kezovica	Shtip	Balneology			
Kosovrasti	Debar	Balneology			
Banjishte	Debar	Balneology			
T O T A L		62,46 ha greenhouses Space heating (5 units) Paper industry (1 complete) Sanitary warm water preparation (2 units) Rice drying (1 unit) Swimming pool heating (1 unit) Balneology (8 spas)		82.560	

Table.2. Geothermal projects in Macedonia (Popovski, 1993)

However, it's necessary not to forget that there were no investigations and drilling of new wells during the recent years. That is the real constraint which can disturb the new development process in the country, if government stays in the present position of "non-interested party". Even

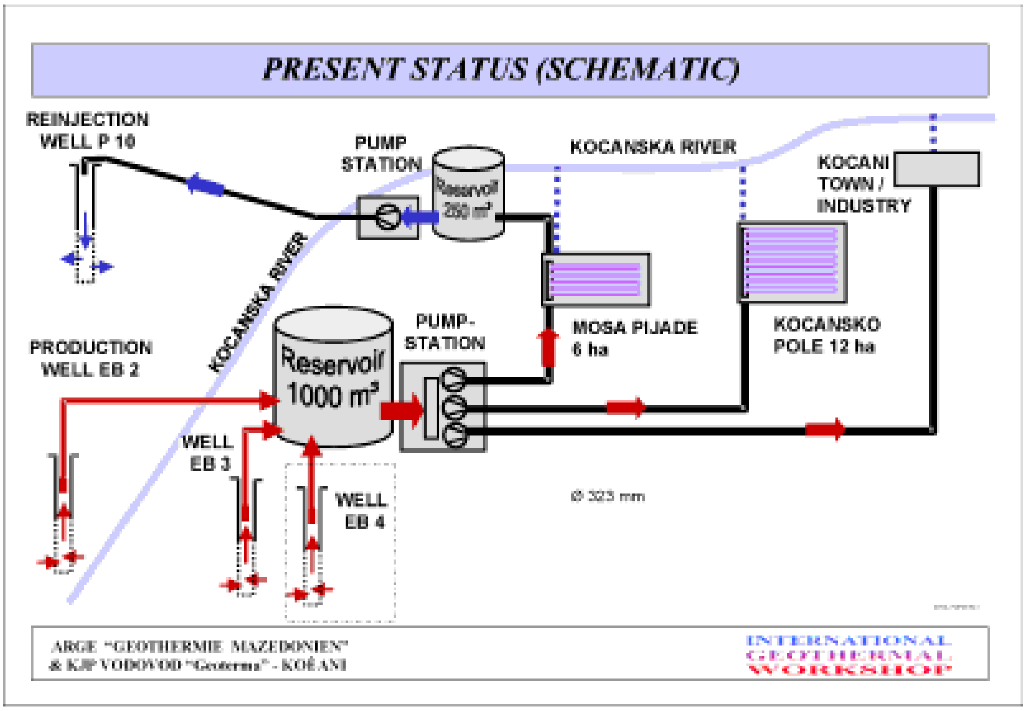

Fig.7. Present status of the Kocani geothermal system (Popovski, Niederbacher, 2000)

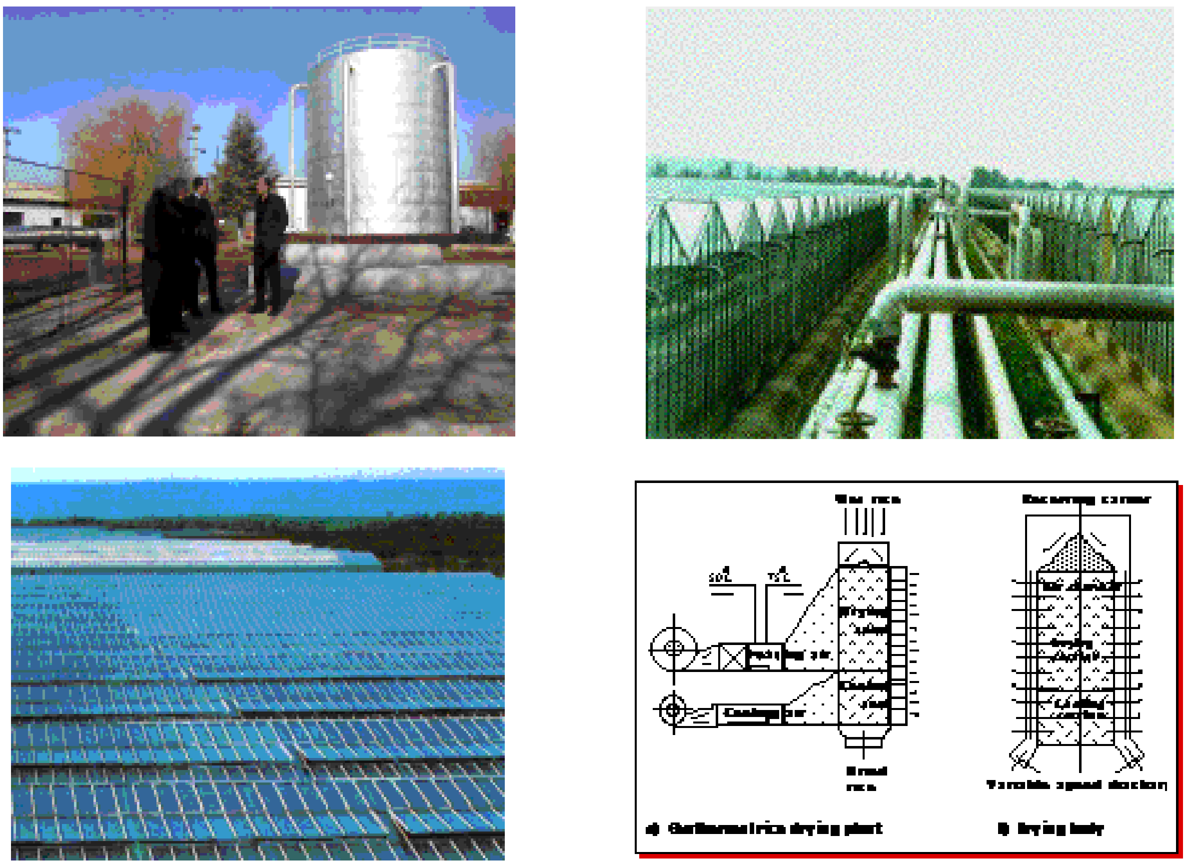

Fig.8. Characteristical parts of the system: Accumulation tank of 1000 m³; Greenhouse complex of 12 ha "Kocansko pole"; Distribution pipelines in the greenhouse complex "Mosa Pijade" of 6,0 ha and Rice drying unit

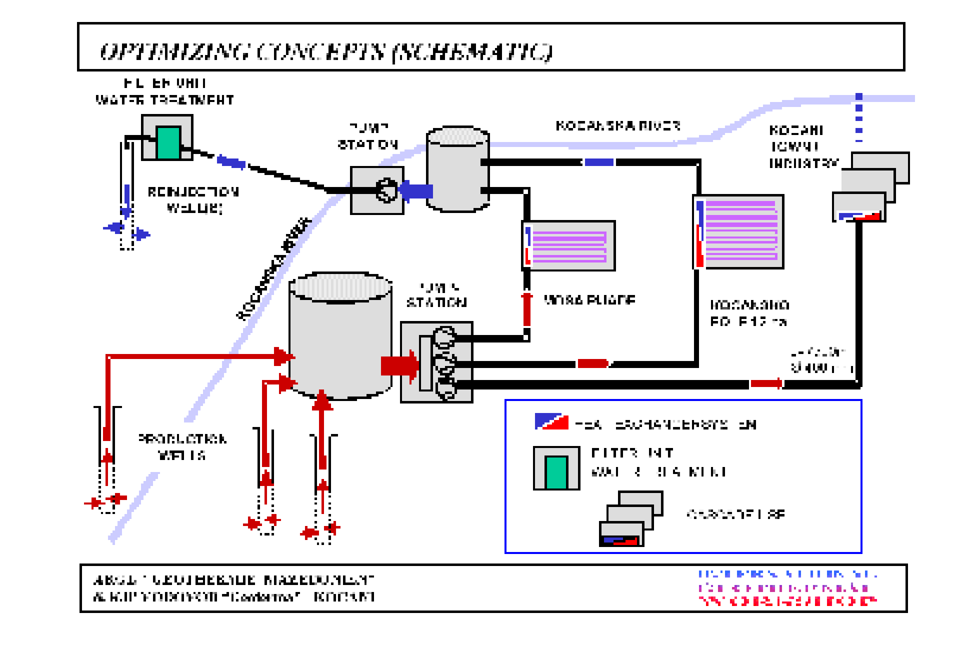

Fig.9. First optimization (realized in 2001) (Popovski, Niederbacher, 2000)

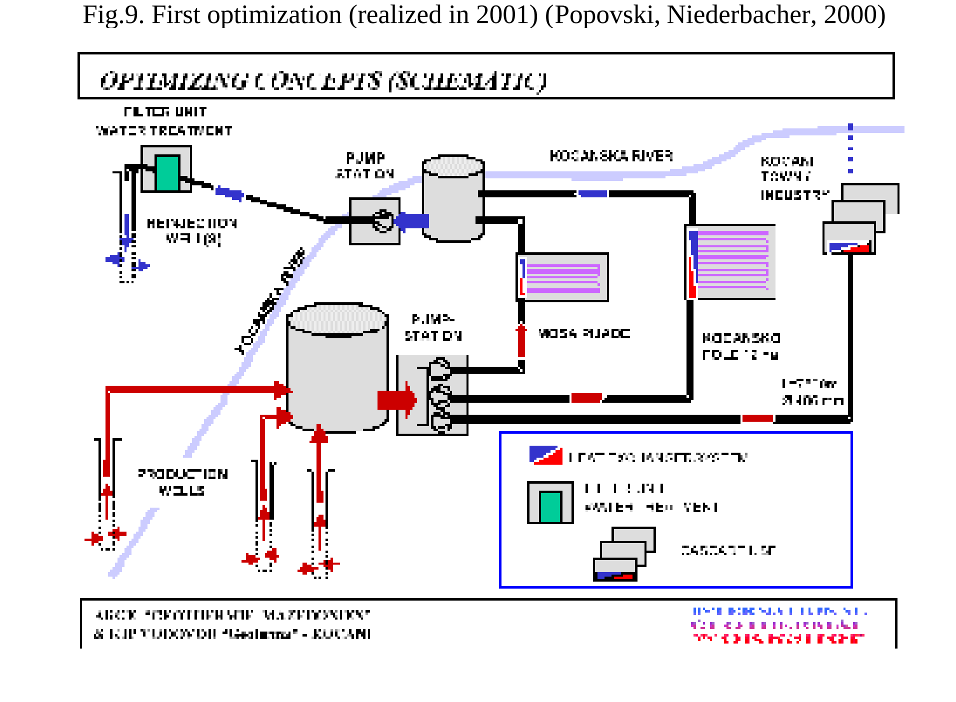

Fig.10. Concept of the final optimization, planned for 2004-2010 (Popovski, Niederbacher, 2000)

with the finally finished process of privatization in the country, it is not possible to expect that private owners shall be able to invest in investigations, explorations and geothermal energy sources completion. That can happen after many years, when the problem of risk covering shall be resolved (again with the state intervention).

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Fig.11. Geothermal heating installations in the greenhouse complex (6 ha) “Bregalnica” i Vinica

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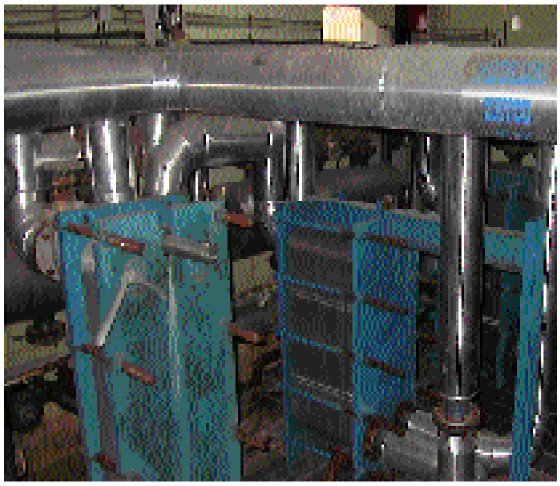

Fig.12. Characteristical parts of the “Bansko” geothermal system: Hotel “Car Samuil” (complex); Swimming pool in the hotel “Car Samuil”; Greenhouse complex (3,2 ha), and Connection station of the Hotel “Car Samuil”

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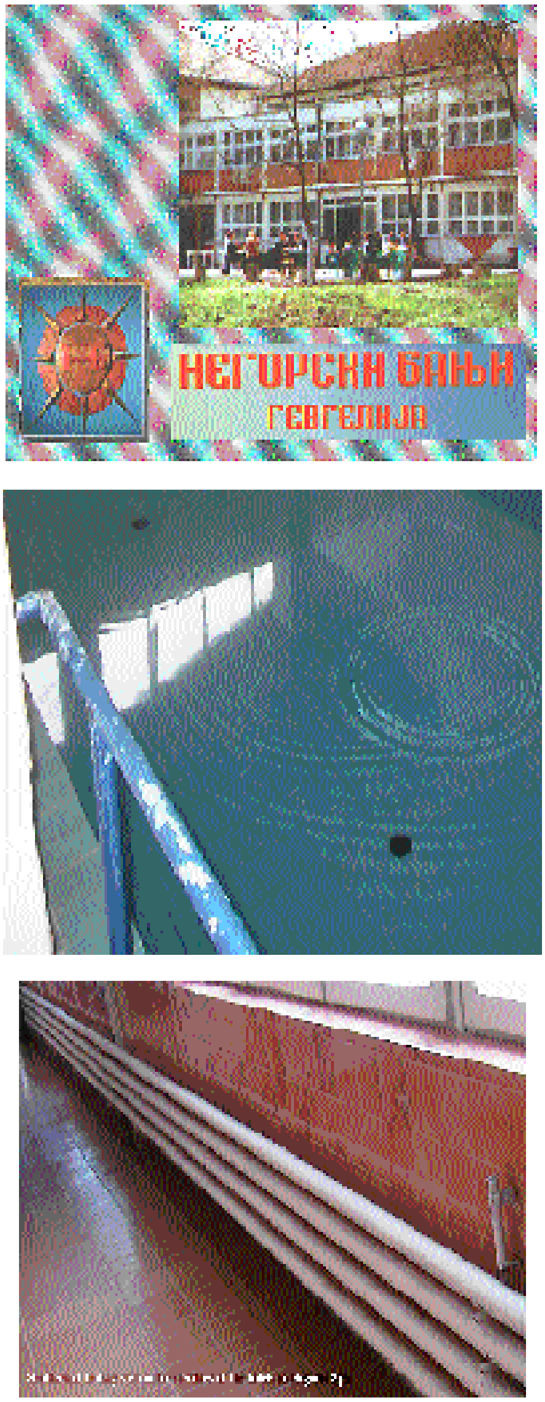

Fig.13. Characteristical parts of the Negorci Spa geothermal system: Heated complex of 5 spa builldings; Medical geothermal pool, and Characteristical heating installation for halls in the hotels part of the complex

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Fig.14. Characteristical parts of the “Smokvica” geothermal system: Connection lines of the wells to the central pump station; Greenhouse complex of 22,5 ha, and plastichouses complex of 10,00 ha

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