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GEOTHERMAL ENERGY RESOURCES AND THEIR USE IN THE REPUBLIC OF MACEDONIA

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ABSTRACT

The Republic of Macedonia has over a 30-year tradition in geothermal energy utilization. The oil crisis of the 1970s and 1980s provided a fresh impetus for assessment and exploration of potential systems in fractured aquifers, and for development of applications of low-enthalpy thermal water. There are 15 projects for heating greenhouses, drying agricultural products, space heating, swimming pool heating, sanitary warm water preparation, industrial uses, etc. Up to date information about the uses of geothermal resources are presented.

1. INTRODUCTION

The Republic of Macedonia is a developing country of approximately 25713 km^2 and 2.1 million inhabitants. Its energy supply is based 50% on domestic fossil fuel and hydropower, and 50% on the import of liquid fuel and coal for industry and electricity. A significant part of the electricity generating capacity is thermal. The different sources of energy utilized in 1999 are given in Table 1.

The development of alternative domestic energy sources has received considerable attention in recent years, including numerous efforts to assess and to develop geothermal energy for greenhouses and space heating. This activity is moderate, because of political conditions in the State, after secession from former SFR Yugoslavia. The data for the year 2000 describes an optimistic view where there will be no more war options, the depression in the production will be stopped and the exchange of goods with the neighboring countries will be normalized (Cerepnalkovski, 92).

So far, no high-enthalpy geothermal resources have been exploited. However, thermal water occurrences and their therapeutic potential were known a long time ago. The geothermal exploration and development progressed through two phases. Phase I was a reconnaissance survey designed to identify specific prospect priorities for more detailed investigations. Hydrochemistry, interpreted within the framework of regional geology and hydrology, was the principle method used. Phase II consisted of resistivity, gravimetry and magnetometry surveys, and often temperature gradient surveys were undertaken by drilling shallow drillholes. The standard practice was to drill and complete exploration wells in the same way as production wells, the main reason being if such a well is successful it can be used later (Kotevski and al., 1993).

2. GEOLOGICAL BACKGROUND

The territory of the Republic of Macedonia, which is located in the middle of Balkan Peninsula, is characterized by high geothermal activity, mostly with low-enthalpy geothermal energy. Macedonia is situated along the very favorable geothermal zone that starts in Hungary to the North and Italy to the West and stretches through Greece down to Turkey. The rise in imported oil and domestic coal prices in the second half of the 1970's has stimulated the search for alternatives such as geothermal energy resources, but Macedonia is one of the minor European countries and there has not been a systematic measurement of terrestrial heat flow.

From the geotectonic point of view, the Serbian-Macedonian massif is situated between the internal Dinarides and the Carpatho-Balkanides. Although the earth's crust can be up to 40 km thick here, some areas are very promising for the occurrence of high-enthalpy geothermal resources. This is due to the emplacement of numerous granite intrusions, which, during their crystallization, supplied the surrounding rocks with an enormous amount of heat (Dimitrov and others, 1993). Within this framework, six geothermal zones, each with own particular characteristics and potential, can be identified (Fig. 1).

Geothermal investigations have mainly concentrated in three major geotectonic units:

- Serbo-Macedonian geotectonic unit, where around 17 hot natural springs and other surface manifestations are found, located mainly in geotectonic depressions, such as: Kocani-Vinica valley, with the hot springs at Podlog, Banja and IstiBanja; and Strumica valley with the natural hot springs at Bansko locality.
- Vardar Zone; the main geothermal springs are located in Gevgelia valley with Smokvica, Negorska Banja and Gornicet localities; Skopje valley with the natural springs at Katlanovo and Volkovo; and Kumanovo geothermal area with the geothermal springs at Proevci and Strnovec.
- West-Macedonian unit, with the geothermal springs at Baniste and Kosovrasti, near the town of Debar. These geotectonic units have many features in common, such as: active extension tectonics, recent active seismicity, high regional heat flow and hot surface water manifestations.

The Serbo-Macedonian massif, characterized by crystalline basement rocks, is much richer in useable geothermal resource than the west and Southwest geothermal area characterized by limestone. The extreme aggressiveness of the waters of this limestone area makes them unsuitable for practical use as heat sources at this stage of development of geothermal energy use.

The results of more than 50 shallow and deep exploratory and production wells drilled to depths between 40 and 2100 m, outlined 4 to 6 major geothermal areas, including several minor fields (see Fig.2). The total water flow obtained (by free flow and pumping) is 1000 l/s. The total installed capacity for geothermal energy for direct use is estimated at over 70 MWt, of which some 80 % is exploited in greenhouse heating. The maximum temperatures measured in the test wells were over 80°C, although the chemical geothermometers predicted temperatures in some geothermal fields of 100 to 120°C, in certain areas of the system.

3. EFFORTS IN GEOTHERMAL UTILIZATION

Presently, about 15 geothermal projects are in operation or under development in the Republic of Macedonia. Four of them are of major importance and have a general influence on the development of direct application of geothermal energy in the country. The most important is the Kocani geothermal project, while the Gevgelija and Vinica agricultural geothermal projects and the integrated project in Bansko are likewise important.

3.1. Kocani geothermal project

In the region of Kocani, 18 ha of glasshouses have been heated geothermally since 1982, as has a rice-drying plant. Non-corrosive water at these sites permitted a simple technical design. A successful new borehole, which increased the flow rate to 450 l/s, opened the way for introducing geothermal energy in industry (paper industry and a factory for vehicle parts production) and the heating of dwellings. A few potential industrial consumers are in the process of adapting or are planning for a direct connection to the system.

The last borehole (DR. Gnjezda, G. 1999.) made it possible to increase the geothermal water supply. Surface casing to the depth of 200 m has a diameter of 426 mm, providing sufficient space for the installation of the submersible pump with frequency converter and piping equipment. The casing liner from 170 to 350 m, the expected top of the aquifer, has a diameter of 244.5 mm. The target zone from approx. 350 m to the planned total depth of 500 m is designed as an open-hole-completion, which means that there is no slotted or perforated casing in the aquifer.

The significant difference in the contents of suspended solids and dissolved iron between unused and used water causes the following problems:

- the re-injected water continuously contaminates the aquifer;
- the pumped water contaminates the river into which it is dumped;
- there is corrosion of the piping system.

In order to neutralize the aggressive effects of used thermal water, a treatment plant is designed.

3.2. Bansko geothermal project

The initial agriculture geothermal energy utilization has commenced in Bansko. A 2.2 ha glasshouse (that is now out of date) is supplied with heating fluid from the thermal spring. The low corrosiveness of the water is used directly in the steel-pipe heating installation. The Car Samoil hotel, built near the spring, is now using thermal water for central heating, sanitary and balneological purposes. The project is still under development. The part of the installations for Hotel Car Samuil are properly connected to the source and working more or less according to the designed conditions. The greenhouse installations are connected improperly and disturb the proper use of the total system. Other hotels have not yet finalized the access to the system connection. Heating installations of plastic houses are of a temporary nature and use only the effluent water (Popovski and others, 1994).

3.3. Gevgelia geothermal project

This project comprises two parts: the first is an agricultural project supplied with geothermal energy from the springs from locality Smokvica with 15 MW installed capacity; the second is an balneological project supplying the hotel complex with energy for central heating, sanitary and balneological purposes from another locality at Negorcy, 10 km away from Smokvica. Initial irregularities with the inappropriate direct connection of 22.5 ha of glasshouses to the aggressive geothermal water are still not resolved. The connection line is badly corroded, causing problems with effective exploitation. Steel heating installations are near completely corroded and out of use. New installations of PP (polypropylene) corrugated pipes are allowing successful exploitation.

3.4. Vinica geothermal project

The geothermal energy of approximately 14 160 kWh annually is used for the heating of 6 ha glasshouses. The project has never been finished. The installation of aerial steel pipes is not in use continuously and a great part of the connection line and connecting installations is corroded. Heating installations are not adjusted properly for geothermal energy use.

The process of further development has nearly stopped, because of the expensive consequences of initial irregularities and the impact of political conditions in the neighborhood. There is continued development in the Kocani project, where the direct application for paper industry, space heating, rice drying and sanitary warm water preparation has been introduced.

4. CONCLUSIONS

The energy policy of the Republic of Macedonia anticipates that geothermal energy will comprise 0.5 % of the total energy balance until the end of this century. It is mainly used for greenhouses and hotel heating. A successful borehole in Kocani opened the way for geothermal energy introduction in industry and the heating of dwellings. Further investigations and development continue with reinjection of used thermal water, modernization and rehabilitation of old fashion greenhouses and increasing of the number of dwellings heated by geothermal energy.

At the moment, because of political circumstances around Macedonia, the economic situation is influencing very much the development of the geothermal systems, especially discouraging new industrial consumers. However, the integrated geothermal systems already passed numerous obstructions, and we must believe that this one shall be passed, too. The acceptable price of geothermal energy and its environmental advantages give us the right to believe in a prosperous future of wider direct application of geothermal energy.

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REFERENCES

Anonymous. (1995): Energetski bilans na Republika Makedonija, *Ministerstvo za stopanstvo, Skopje* [Balance of Energy in Republic of Macedonia, *Ministry for Industry and Energy, Skopje]*

Dimitrov, K.; Popovski, K. and Gorgieva, M. (1993). Geothermal Energy Resources and Their Use in Yugoslavia. *Energy Sources,* Volume 15, pp. 117-124.

Kotevski,G.; Novkovski, T.; Gorgieva, M. and Micevski, E. (1993). Geothermal Energy Resources, Exploration, Development and Utilization in the Republic of Macedonia. *Proceedings of the International Workshop on Geothermal Energy for Greenhouses and Aquaculture in Central and East European Countries, Bansko-Bulgaria,* Dr. K. Dimitrov (Editor)., pp. 18 (230 pp).

Popovski, K.; Andrejevski, B.; Stefanovska, C. and Popovska, S. (1994). Direct Application of Geothermal Energy in the Republic of Macedonia. *International Symposium Geothermix 94 in Europe - From Research to Development;* Communications, BRGM, CCE DG XII ADEME, Orleans, France, pp.355-364 (520 pp.).

Dimitrov, K., Andrejevski, B. and Petreski, Lj. (1989). *Reconstruction of Heating Installation of Greenhouses in ZIK "Bregalnica" - Vinica, by Use of Geothermal Water.* Main technical design project. 48 pp, 16 drawings.

Dimitrov, K. and Andrejevski, B. 1989. *Technical Condition of Pump station and Geothermal Water Distributive Pipeline.* Technical expertise, Vinica.

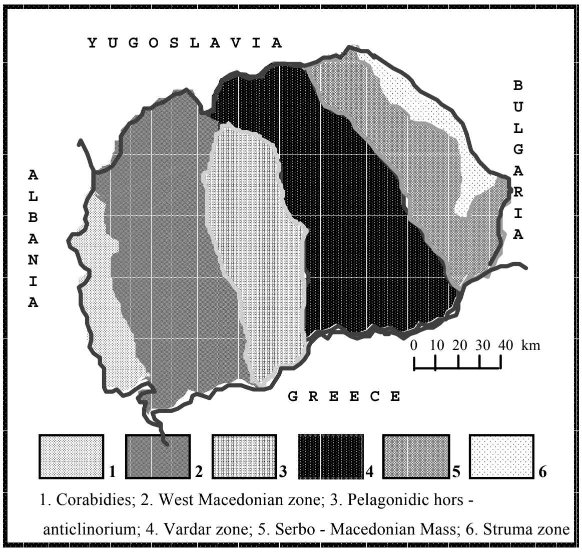

Figure 1. Geotectonic map of Republic of Macedonia

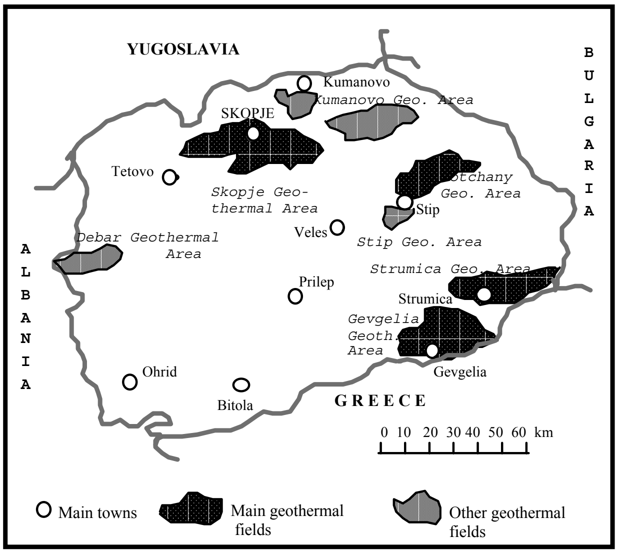

Figure 2. Location of geothermal fields

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in January 2000			1010	4976.64	422	1167.36					1432	6144
Under construction in January 2000					90	150.00					90	150
Funds committed, but not yet under construction in January 2000												
Total projected use by 2005											1522	6294

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 1999

1)
I = Industrial process heat
C= Air Conditioning (cooling)
A= Agricultural drying (grain, fruit, vegetables)
F= Fish and other animal farming
S= Snow melting
H= Space heating & district heating (other than heat pumps)
B= Bathing and swimming (including balneology)
G= Greenhouse and soil heating
O= Other (please specify by footnote)

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

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

4) **Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp.(°C) - outlet temp.(°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

5) **Capacity factor = [Annual energy use (TJ/yr) x 0.03171]/Capacity (MWt)**
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.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity Factor[5)]
		kg/s	Inlet	Outlet	Inlet	Outlet	(MWt)	kg/s	TJ/yr	
Bansko	G,H,B	55	70	35			8.05	18.04	83.26	0.328
Istibanja	G	56	67	46			4.92	18.40	50.99	0.328
Negorci	H,B	80	51	46			1.67	13.15	8.67	0.165
Podlog	I,H,G,A,B	300-450	79	38			51-77.20	38.05	223.00	0.138
Smokvica	G	120	65	34			15.56	39.36	160.94	0.320
Total		**761**					**81.2-107.40**	**127.00**	**509.64**	

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 1999

1) **InstalledCapacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp.(°C)] x 0.004184**
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) – outlet enthalpy (kJ/kg)] x 0.001

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

3) **Capacity factor = [Annual energy use (TJ/yr) x 0.03171]/Capacity (MWt) (MW =10^6W)**
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.

Use	Installed Capacity[1)] MW_t	Annual Energy Use[2)] TJ/yr=10^{12} J/yr	Capacity Factor[3)]
Space heating	6.275	50.10	0.253
Air conditioning			
Greenhouses	66.000	411.32	0.197
Fish and Animal Farming			
Agricultural Drying	Out of use (1.36)	0	
Industrial process heat	6.860	32.92	0.152
Snow melting			
Bathing and Swimming			
Other uses (specify)*)	2.110	15.3	0.230
Subtotal	81.200		
Geothermal Heat Pumps			
Total	81.200	509.640	

*) Balneology, Sanitary water preparation

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1995 TO DECEMBER 31, 1999

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		1			0.35
Injection	(all)					
Total						0.35

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degree)

(1)	**Government**	**(4)**	**Paid Foreign Consultants**
(2)	**Public Utilities**	**(5)**	**Contributed Through Foreign Aid Programs**
(3)	**Universities**	**(6)**	**Private Industry**

Year	Professional Person-Years of Effort					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
1995	1	6	1			
1996	1	6	1			
1997	1	7	2		1	1
1998	1	7	2		1	1
1999	1	8	2		2	2
Total	5	34	8		4	4

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US $

Period	Research & Development Incl. Surf. Explor. & Exploration Drilling Million US $	Field Development Including Production Drilling & Surface Equipment Million US $	Utilization		Funding Type	
			Direct **Million US $**	**Electrical** **Million US $**	**Private** **%**	**Public** **%**
1985-1989	4.50	2.40	5.482			100
1990-1994	0.75	0.50	0.420			100
1995-1999	0.40	1.20	1.400			100