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Geothermal Energy Use, Country Update for North Macedonia

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ABSTRACT

North Macedonia is characterized with low-temperature geothermal energy utilization, while the medium and high-temperature potentials are still not explored. Nevertheless, even the present available resources are by far underutilized.

This paper gives a summary of the geothermal status in North Macedonia comprising the geological background, known hydro-geothermal resources and their potential, present state of geothermal surveys & utilization and main projects' characteristics, with identification and comments on the negatively influencing factors. At the end, prospects of the expected / possible development are summarized.

1. INTRODUCTION

The overall geothermal status in N. Macedonia has not changed during the last three years. Even though not formally registered, the interest and interventions in obtaining and using the benefits of geothermal resources are obvious. Power generation from geothermal energy is not yet present, but there are indications of foreign interest to explore and utilize such potential. Concerning legislation and regulative on promotion, exploration, development and protection of geothermal resources, no any progress can be observed.

2. GEOLOGICAL BACKGROUND

2.1 Geological Framework and Tectonic Settings of Macedonia (Micevski, 2003)

In the territory of Macedonia rocks of different age occur, beginning with Precambrian to Quaternary ones. Almost all lithological types are represented. The oldest, Precambrian rocks consist of gneiss, micaschists, marble and orthometamorphites. The rocks of Paleozoic age mostly belong to the type of green schists, and the Mesozoic ones are represented by marble limestones, acid, basic and ultrabasic magmatic rocks. The Tertiary sediments consist of flysch and lacustrine sediments, sandstones, lime-stones, clays and sands.

Figure 1: Geological settings and geothermal regions in Macedonia (Arsovski, 1997).

With respect to the structural relations the territory can be divided into six geotectonic units (Fig. 1): The Cukali-Krasta zone, Western-Macedonian zone, Pelagonian horst-anticlinorium, Vardar zone, Serbo-Macedonian massif and the Kraisthide zone. This tectonic setting is based on actual terrain and geological data without using the geotectonic hypothesis (Arsovski, 1997). First four tectonic units are parts of Dinarides, Serbo-Macedonian mass is part of Rodopes and the Kraisthide zone is part of Karpato- Balkanides distinguished on the Balkan peninsula as geotectonic units of first stage.

2.1 Geothermal Background (Georgieva, 2002)

The territory of the Republic of N. Macedonia belongs to the Alpine-Himalayan zone, with the Alpine sub-zone having no contemporary volcanic activity. This part starts from Hungary, across Serbia, Macedonia and North Greece and stretches to Turkey. Several geothermal regions have been distinguished including the Macedonian region, which is connected to the Vardar tectonic unit. This region shows positive geothermal anomalies and is hosting different geothermal systems. The hydro-geothermal systems, at the moment, are the only ones worth exploration and exploitation.

There are 18 known geothermal fields in the country (Fig.2) represented with more than 50 thermal springs, boreholes and wells with hot water, having discharge of about 1000 l/s with temperatures between 20-79 ºC. Hot waters are mostly of hydrocarbonate nature, according to their dominant anion, and mixed with equal presence of Na, Ca and Mg. The dissolved minerals range from 0.5 to 3.7 g/l.

All thermal waters in Macedonia are of meteoric origin. Heat source is the regional heat flow, whose value in the Vardar zone is approximately 100 mW/m^2 and crust thickness is 32 km.

3. GEOTHERMAL RESOURCES AND POTENTIAL

Out of the seven geothermal fields identified in the east and northeast part of the country, four have been found to be very promising and three have been explored to the stage of possible practical use. Except the springs in Debarska banja and Kosovrasti, positioned in the West Bosnian-Serbian-Macedonian geothermal zone, all the others are located in the Central Serbian-Macedonian Geothermal Massif, Central and Eastern Macedonia (Figure 2).

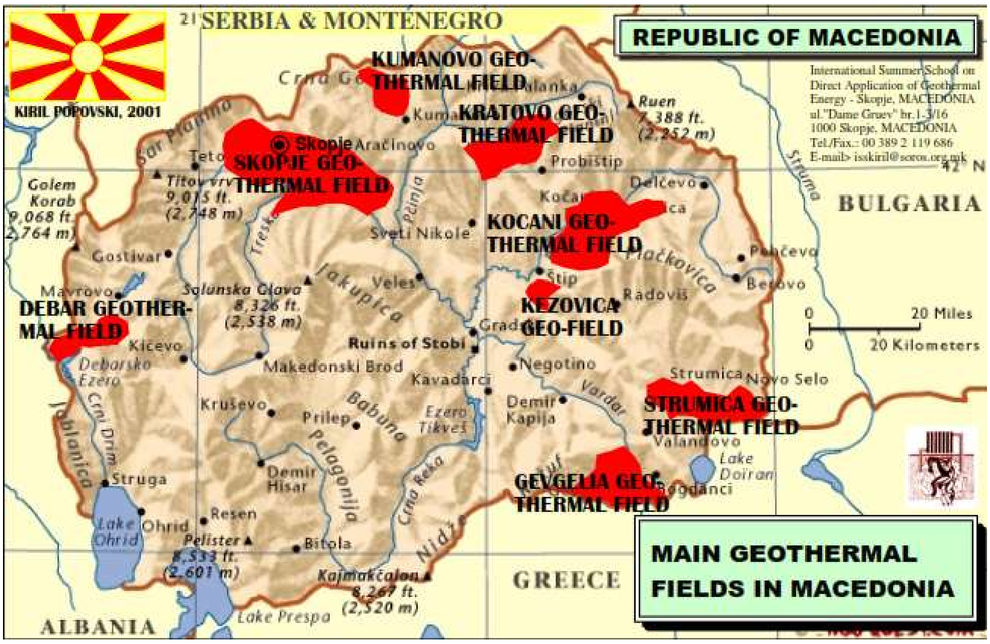

Figure 2: Main geothermal fields in N. Macedonia (Popovski, 2001).

It should be emphasized that the total available flow of the exploitable sources is 922.74 l/s, which is less than the estimated 1000 l/s 7 years ago, and differs from the previous values (1397 l/s) that are the maximum measured short-lasting flows. The difference is due to the more precise data for long lasting capacities of all the flows, after many years of exploitation and measurements.

Temperatures of the flows vary in the range of 24-27 °C (Gornicet, Volkovo and Rzanovo) up to 70-78 °C (Bansko and Dolni Podlog). Total average temperature is 59.77 °C. The biggest potential is in the Kocani geothermal field, with a total maximal flow of up to 350 l/s and temperatures of 65 °C (Istibanja) and 75-78 °C (Dolni Podlog). Next is the Gevgelija geothermal field, with about 200 l/s and temperatures of 50 °C (Negorci) and 65 °C (Smokvica). The list of the others is: Debar geothermal field with 160 l/s and temperatures of 40 °C (Debarska banja) and 48 °C (Kosovrasti), Strumica geothermal field with 50 l/s and 70 °C and Kratovo/Kumanovo geothermal field with 71 l/s and temperatures of 31 °C (Kumanovska banja) and 48 °C (Kratovo).

The real energy potential of the geothermal resource in Macedonia is in direct correlation with the technical/technological feasibility of its application, in accordance to the newest know-how in the country and in the world. A simulation, according to different outlet temperature, is made for all the exploitable geothermal resources in Macedonia. A total available maximum heat power of 173 MW is obtained, which suggests the possibility of annual maximum production of 1.52 TWh/year. This is only a theoretical indication considering that each project has different range of exploited temperature. In any case this maximum potential cannot be fully exploited, since it is strongly dependent on the utilization factor and the type of application. For instance, the geothermal system in Dolni Podlog (Kocani) has a maximum flow of about 300-350 l/s with temperature of 75 °C. If a maximal use of the source could be reached (i.e. effluent water of 15 °C), its heat power could increase up to 75-85 MW. However, the applied technical solutions by the users result with temperatures of the effluent water of 40-45 °C during the (winter) heating season. These in turn decreases 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 composition of users, it is technically and economically feasible to obtain lower temperature of the effluent water of 30 °C during the first phase of development (Popovski, 1991), and 25 °C during the second phase of development. Such optimization would enable reduction of the losses for 25 % and 17 % respectively, which is in the acceptable limits even for the countries with longer experience in geothermal energy application. Therefore, depending on the achieved average outlet temperature of projects using available geothermal resources, the following orientation figures for total heat power could be taken: 172.9 MW for 15 ºC, 153.7 MW for 20 ºC, 134.3 MW for 25 ºC, 115.6 MW for 30 ºC, 97.2 MW for 35 ºC, 78.9 MW for 40 ºC and 68.2 MW for 45 ºC. According to the presently applied solutions, average outlet temperatures between 30 and 40 ºC are taken as representative.

4. GEOTHERMAL FIELDS IN MACEDONIA

There are 18 localities where geothermal fields occur and geothermal energy is in use for different proposes. The most known areas are listed below:

- *Kocani valley* (Popovski, 2002): The main characteristics of the Kocani valley geothermal system are: presence of two geothermal fields, Podlog and Istibanja, without hydraulic connection between them. The primary reservoir is built by Precambrian gneiss and Paleozoic carbonated schists, where by drilling the highest measured temperature in Macedonia of 79 ºC had been obtained. Predicted maximum reservoir temperature is about 100 ºC (Gorgieva, 1989). Kocani geothermal system is the best explored system in Macedonia. There are more than 25 boreholes and wells with depths of 100-1170 m. (Popovski, 2009)

- *Strumica valley* (Popovski, 2002): The main characteristics of this field are: the recharge and discharge zone occur in the same lithological formation - granites; there are springs and boreholes with different temperature at small distances; maximum measured temperature is 73 ºC; the predicted maximum temperature is 120 ºC (Gorgieva, 1989); the reservoir in the granites lies under thick Tertiary sediments. Bansko geothermal system has not been examined in detail apart the drilling of several boreholes with depths of 100-600 m. (Gorgieva, 2002)

- *Gevgelija valley* (Popovski, 2002): There are two geothermal fields in the Gevgelija valley: Negorci spa and Smokvica. The discharge zones in both geothermal fields are fault zones in Jurassic diabases and spilites. These two fields are separated by several km and there is no hydraulic connection between them, despite intensive pumping of thermal waters. The maximum temperature is 54 ºC, and the predicted reservoir temperature is 75-100 ºC (Gorgieva, 1989). Geothermal system in the Gevgelija valley has been well studied by 15 boreholes with depths between 100-800 m. (Gorgieva, 2002).

Figure 3: Location of geothermal projects in Macedonia.

- *Skopje valley* (Popovski, 2002): There are two geothermal fields in the Skopje valley: Volkovo and Katlanovo spa. There is no hydraulic connection between them. The main characteristics of the Skopje hydro-geothermal system are: maximum measured temperature of 54.4 ºC and predicted reservoir temperature (by chemical geothermometers) of 80-115 ºC (Gorgieva, 1989); the primary reservoir is composed of Precambrian and Paleozoic marbles; big masses of travertine deposited during Pliocene and Quaternary period along the valley margins. There are only five boreholes with depths of 86 m in Katlanovo spa, 186 and 350 m in Volkovo and 1654 and 2000 m in the middle part of the valley. The last two boreholes are without geothermal anomaly and thermal waters because of their locations in Tertiary sediments with thickness up to 3.800 m. (Gorgieva, 2002)

5. GEOTHERMAL UTILIZATION

The utilization of thermal waters consists of 7 geothermal projects and 6 spas. All of them had been completed before and during the 1980s. The present state of the projects is as follows:

- *Istibanja (Vinica) Geothermal Project*: Heating of 6 ha greenhouse complex in combination with a heavy oil boiler for peak loadings. It has been one of the worst completed projects before the crisis, however after the privatization in 2000 yr. it has been reconstructed and optimized with Austrian and Dutch grants and now properly covers the heat requirements of the roses' production for export. The owners are interested to continue with explorations in order to enable geothermal heating of additional 6 ha of greenhouses, but so far cannot achieve common interest with the municipality as owner of the concession rights.

- *Kocani (Podlog) Geothermal Project* ("Geoterma"): At present the largest geothermal project in Macedonia, composed of 18 ha greenhouse complex heating, and space heating of public buildings in the center of the town. Due to the economic circumstances, paper industry, vehicle parts industry and rice drying unit have been lost as heat consumers during the last 12 years. Nevertheless, by two Austrian grants, three additional boreholes have been drilled, partial injection of effluent water has been completed and monitoring system has been introduced in the system. Nowadays, there are activities in direction to finalize the completion of the reinjection and connection of public buildings in the center of the town. Project operates as a public and its organizational structure is well covered by the existing team. The only problem in operation is the price of supplied heat, which is kept very low by the State Energy Regulatory Commission, not including the costs of the necessary maintenance, service and development of the system.

- *Bansko Geothermal Project*: The bankruptcy of ZIK "Strumica" and the slow process of its privatization resulted in the collapse of the organizational structure and proper use of the system. Due to increased number of consumers and failure in covering the peak loadings, in order to enable proper operation, it is necessary to introduce centralized managing system and new exploitation boreholes, as well as considerable technical reconstructions and optimizations. Currently the exploitation concession is owned by one company to heat their greenhouses, but due to unsolved energy managing rules there are other consumers, too. Those are the hotel Car Samuil, Spiro Zakov (rest house, rehabilitation facilities for children), other plastic-houses, rest house Jugotutun, rest house ZIK Strumica, experimental and private plastic-houses.

- *Smokvica (Gevgelia) Geothermal System*: Once the largest geothermal system in Macedonia, covering the heating requirements of 22.5 ha glasshouses and of about 10 ha plastic-houses, nowadays is out of operation. At present, only 3 wells out of 7 are exploited with total flow of 90 l/s and temperatures between 63,9-68,5 ºC, to heat 10 ha greenhouses of which 6 ha glasshouses and 4 ha plastic-houses. When outside temperatures are very low back-up heavy oil boiler is used.

- *Negorci (Gevgelija) Spa*: Reconstruction of the heating installations has been finalized and now all the hotel and therapeutic facilities are heated with geothermal energy. Project is in a process of continual step by step modernization.

- *Other Spas in Macedonia*: Even planned, reconstruction of heating systems and their orientation towards geothermal energy use in Macedonian spas has not been realized due to their undefined property and the absence of funds. Now, when the process is finalized, activities to find possible investors are in progress in Katlanovo Spa, Kezovica Spa and Bansko Spa. However, it is not possible to expect quick results, due to the absence of capital in the country and real interest of foreign investors.

6. CONCLUSIONS

"Energy Development Strategy for Republic of Macedonia up to 2030" and "Strategy for Exploitation of Renewable Energy Sources in Republic of Macedonia up to 2020" do not include any foreseen geothermal development as a prospective energy source for Macedonia. Despite the formal attitude, some private initiatives exist, which will probably influence changes in this sector in the near future. Most important among them are: the renewal of the Smokvica geothermal system, reconstruction and expanding of the Bansko geothermal system and foundation of a new one in Dojran. Final completion of the injection system in Kocani is expected to be realized during the next two-three years. It is also expected that majority of spas would undergo reconstructions with intention to use geothermal energy for heating of the accommodation capacities, but so far there are no such information. Up to now, there is no any progress concerning the very prospective geothermal fields Kratovo-Zletovo, Skopje and Kumanovo regions.

Nevertheless, there are many improvements which should be done with the existing legislation in order to facilitate geothermal explorations and application, to enable sustainable exploitation and consider the environmental issues. Those are: definition of sustainable outflows, rights over single geothermal field, obligation to inject the used geothermal water, treatment of the geothermal water as mineral resource instead as energy resource too, calculation methodology for feasible and motivating price for geothermal heat, creation of subsurface register, incentives etc. (Panov, 2011)

The geothermal development in Macedonia is in stagnation for already 30 years, hopefully the situation will change along with the contemporary energy trends and initiatives in the country.

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Tables A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total electric power generation	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2021 *	0	0	2087.8	5498.3	0	0
Under construction end of 2021	0	0	NA	NA	0	0
Total projected by 2023	0	0	NA	NA	0	0
Total expected by 2028	0	0	NA	NA	0	0
In case information on geothermal licenses is available in your country, please specify here the number of licenses in force in 2021 (indicate exploration/exploitation if applicable):					Under development**:	
					Under investigation**:	

* If 2020 numbers need to be used, please identify such numbers using an asterisk

** Please refer to the guideline at the end of this template for classification as *under development* or *under investigation*

Less produced power due to major failure in the main TPP.

Table B: Existing geothermal power plants, individual sites

No geothermal power plants currently in North Macedonia

Table C: Present and planned deep geothermal district heating (DH) plants and other uses for heating and cooling, total numbers

	Geothermal DH plants		Geothermal heat in agriculture and industry		Geothermal heat for buildings		Geothermal heat in balneology and other **	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2021 *	42.55	106	2.8	12.5	-	-	-	-
Under constru-ction end 2021	-	-	-	-	-	-	-	-
Total projected by 2023	-	-	-	-	-	-	-	-
Total expected by 2028	-	-	-	-	-	-	-	-

* If 2020 numbers need to be used, please identify such numbers using an asterisk

** Note: spas and pool are difficult to estimate and are often over-estimated. For calculations of energy use in the pools, be sure to use the inflow and outflow temperature and not the spring or well temperature (unless it is the same as the inflow temperature) for calculating the energy parameters, as some pool need to have the geothermal water cooled before using it in the pools.

According the Energy Balance of RNMacedonia, for years, only the production of Kocani geothermal system (Geoterma) is reported, which is about 1.5-1.6 million m^3 per year or 5.5 ktoe or 64 GWh.

Table D1: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commis-sioned	CHP **	Cooling ***	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2021 produc-tion * (GWh_{th}/y)	Geoth. share in total prod. (%)
Bansko	Bansko		No	No	8.65	8.65	~21.55	100%
Kocani	Zelena kuka		No	No	33.90	33.9	~84.45	100%
total					42.55	42.55	106.00	100%

* If 2020 numbers need to be used, please identify such numbers using an asterisk

** If the geothermal heat used in the DH plant is also used for power production (either in parallel or as a first step with DH using the residual heat in the brine/water), please mark with Y (for yes) or N (for no) in this column.

*** If cold for space cooling in buildings or process cooling is provided from geothermal heat (e.g. by absorption chillers), please mark with Y (for yes) or N (for no) in this column. In case the plant applies re-injection, please indicate with (RI) in this column after Y or N.

Table D2: Existing geothermal large systems for heating and cooling uses other than DH, individual sites

No geothermal large systems for heating and cooling uses other than DH currently in North Macedonia.

Table E1: Shallow geothermal energy, geothermal pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2021 *		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2021 *	>1000	2.50	21	NA	NA	NA
Of which networks **	NA	NA	NA	NA	NA	NA
Projected total by 2023	NA	NA	NA			

* If 2020 numbers need to be used, please identify such numbers using an asterisk

** Distribution networks from shallow geothermal sources supplying low-temperature water to heat pumps in individual buildings (“cold” DH, Geothermal DH 5.0 etc.)

Geothermal heat pumps are not recorded by any means, the figures given are just an assumption.

Table E2: Shallow geothermal energy, Underground Thermal Energy Storage (UTES)

No geothermal UTES currently in North Macedonia.

Table F: Investment and Employment in geothermal energy

	in 2021 *		Expected in 2023	
	Expenditures ** (million €)	Personnel *** (number)	Expenditures ** (million €)	Personnel *** (number)
Geothermal electric power	0	0	0	0
Geothermal direct uses	NA	NA	NA	NA
Shallow geothermal	NA	NA	NA	NA
total				

* If 2020 numbers need to be used, please identify such numbers using an asterisk

** Expenditures in installation, operation and maintenance, decommissioning

*** Personnel, only direct jobs: Direct jobs – associated with core activities of the geothermal industry – include "jobs created in the manufacturing, delivery, construction, installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration". For instance, in the geothermal sector, employment created to manufacture or operate turbines is measured as direct jobs.

Table G: Incentives, Information, Education

	Geothermal electricity	Deep Geothermal for heating and cooling	Shallow geothermal
Financial Incentives – R&D	0	0	0
Financial Incentives – Investment	0	0	LIL
Financial Incentives – Operation/Production	0	0	0
Information activities – promotion for the public	No	No	No
Information activities – geological information	Yes	Yes	No
Education/Training – Academic	Yes In frame of higher education	Yes In frame of higher education	Yes In frame of higher education
Education/Training – Vocational	No	Yes In frame of trainings for EE in buildings, build-up skills	Yes In frame of trainings for EE in buildings, build-up skills

Key for financial incentives:

DIS	Direct investment support	FIT	Feed-in tariff	-A	Add to FIT or FIP on case the amount is determined by auctioning
LIL	Low-interest loans	FIP	Feed-in premium		
RC	Risk coverage	REQ	Renewable Energy Quota	O	Other (please explain)