GEOTHERMAL ENERGY IN YUGOSLAVIA, POTENTIALS AND APPLICATIONS

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ABSTRACT

This paper promotes the use of Geothermal energy (GTE) in Serbia, and argues that while GTE is both a viable and environmentally friendly energy source, as demonstrated elsewhere in the world, there is also a multitude of opportunities in this region, and the local knowledge and capabilities required for implementing the GTE plants. First, a general introduction to GTE in is given. The basis of GTE is the thermal energy accumulated in fluids and rocks masses in the Earth's Crust. The main GTE advantage compared to the traditional energy sources like thermo-electric plants is the absence of environmental deterioration, however GTE also has advantages compared to other NARES, as the GT sources are permanently available and independent of weather conditions. Worldwide energy potential of GTE is huge, as the reduction of Earth Crust temperature for just 0.1 deg. C would give enough Energy to produce Electrical Energy, at the present dissipation level, for the next 15,000 years. An overview of the regions in Yugoslavia which have a high GTE potential is given. There are two distinct regions with higher GTE values in Serbia: the first is a part of the South Panonian basin including Vojvodina, with Ma~va and Yu-part along Danube and Morava rivers. This is a sedimental part of the Tercier's Panonic Sea "Parathetis", with partial depression and Ba~ka subsupression, and is well investigated due to oil and gas holeboring. The second region includes Central and Southern part of Serbia, south from the Panonia basin, with pretercier's and tercier's magmatic vulcanic intrusions, which produce a very high and stable thermal flux. This Region is rich in GT-warm water springs with stable yields, and includes 217 locations with 970 natural springs with temperature above 20 deg. C. These compare very favorably with international locations where GTE is exploited. GTE can be used for Electric Energy production using corresponding heat pump systems, for house heating and warm water domestic or industrial use, for agriculture and for thermal industrial processes. Yugoslav institutions, including Faculty of Mining and Geology University of Belgrade (M&GF-UB) as the leader, Faculty of Electrical Engineering (ETF-UB), Institute of Nuclear Science-Vin~a (INN-Vin~a) and Geophysical Institute-Belgrade (GI-B), together with companies and organizations of borings and Geo-speciality, have been involved in GT investigations since the early eighties, and there is both knowledge and capability within Yugoslavia to proceed with GTE electricity production, which started on a larger scale in Europe.

Key words: energy, alternative energy sources, geothermal energy

INTRODUCTION

New And Renewable Energy Sources (NARES) are known for more than a century, but only after the Oil Energy crisis in 1978, they are started to be more accepted and recommended. The United Nations (UN) Conference on NARES in Nairobi in 1981, as a first one, in its “Conclusions” recommend the use more NARES to reduce the use of conventional fossil fuels and their environmental damaging effects, and to increase the use of local energy sources. Within NARES, the following Energy Sources were defined: Solar, Biomass, Geothermal, Wind, Vegetable and Animal Waste, Sea-Low & High Tide, Sea Wave, Sea Thermal Gradient. Today, NARES still contributes with under 2% in the world energy production.

The main problem of most of renewable energy sources is of not yet having an economically acceptable technology. Economic development is in general connected with an increased use of Electric Energy (EE) but, up to now, also with not successfully taking care of Environmental Deterioration. Important contributions to solving these problems are: a larger use of NARES; increasing the efficiency of fossil fuel energy sources, with higher control of damaging gases emission; increasing the efficiency of electric devices. GTE can help with all the above issues.

The basis of GTE is the thermal energy accumulated in fluids and rocks masses in the Earth’s Crust /1/. The main GTE advantage compared to the traditional energy sources, like thermo-electric plants, is the absence of environmental deterioration, however GTE also has advantages compared to other NARES, as the GT sources are permanently available and independent of weather conditions. Energy potentials of GTE are huge, as the reduction of Earth Crust temperature for just 0.1 deg. C would give enough Energy to produce Electrical Energy, at present dissipation level, for next 15,000 years.

Up to now only natural GT fluids or their vapors were used at the place of natural springs or artificial borings, as the bearers of heat Energy. But recently the Hot Dry Rock (HDR) technological system was proven to be economically feasible, and this method enables the production of Electrical Energy, but one needs deep boring instalation, in not GTE reach regions./6/.In 2000, there have been more than 11,000 MW GT Electric power installations in the world, and GT use for Electrical Energy seems to be the most promising after Hydro Electric Power. A viable GT source size, connected with the production of GT Electric Energy, is even less than 0.3 MW, with warm water temperature higher than 60 deg.C. The binary EE system, using a secondary low temperature evaporating fluid, enables to extract thermal energy from the GT water and, using a corresponding gas turbine and usual electric instalation, production of economical electric energy.

Comparison of Capital Investment per MWEP for different Electric Energy sources shows GTE

Electrical Power Station to be about twice as expensive as the similar fossil Power Station, due to expensive hydrogeological and geological investigations with deep borings. GTE price per kWh is about the same as for Wind Electrical Energy Power Station. If GTE is at hand, as in Serbia, this prices are applicable.

POTENTIAL FOR GT ENERGY IN YUGOSLAVIA

For Yugoslavia GTE use is very promising, and up to now not properly appreciated. According to the general geological and hydrogeological knowledge on the GT sources in Europe territory of Republic of Serbia lies in a favorable zone of higher GT potentials and resources, which starts from Hungary on the north, and goes southwards through Serbia, Macedonia and Greece. GT investigations in Yugoslavia done up to now show that GT Energy potentials of Yugoslavia are larger than in most of our neighboring countries /1/.

The GT investigations on a larger scale started in the period after 1975, initiated at the Faculty of Mining and Geology University of Belgrade (UB) by the late Prof. Lj. Paradjanin. F. Boreli's group in Vinča Institute, in the eighties, was collaborating with him, in connection with the GT water age determinations, using water samples Tritium concentration method /2/. The lead is still at the same Faculty with professors: N. Djajić, M. Milivojević, M. Soleša and others, together with companies and organizations of borings and Geo-specialty: NIS-Jugopetrol and Naftagas, Geozavod, Geophysical Institute.

Thanks to their Geological and Hydrogeological works there is a pretty good knowledge of the size of GT resources in North and Central Serbia. In this region, almost all geothermal sources are springs, threfore, most of the borings were done near the locations of natural warm water springs. There are more than 1000 natural warm water springs over the territory of Serbia, with temperature from 20 to 90 deg. C, with low mineralization and stable yields. Review of these results in Yugoslavia are given in the book "Production and use of GT Energy" (in Serbian) /1/ by Prof. of Faculty of Mining and Geology UB: Dr M.Soleša, N. Djajić and Lj.Paradjanin, in 1995. Most of GTE data given in this paper for Sebia is sourced from this book.

Considering the results of GT investigations done in the territory of Serbia there are two, not well separated, geothermally rich regions, which differ in the origin and types of GTE sources . The first represents the territory of the southern part of the large Panonian basin, which includes Srem, Bačka, Banat and Mačva, and part along the Danube and northern region of Morava river.

The relatively low thickness of the Earth Crust, besides other heath sources in the Crust, brings a higher value of underground heat flux to this region, up to 110 mW/m sq. In the structure of the Panonian basin, a special role is played by sediments of the Ex Sea Paratetis, as formations of marinic and postmarine pretercier's and tercier's evolutionary cycles. During these evolutions of the Panonic basin, many depressions and subdepressions were formed with convenient conditions for oil and gas formation. Among these the Banat depression, with south Backa subdepression, and with a system of subdepressions along the Danube and Morava rivers, are relevant to GT. The tercier's and quarter's sediments layers in the Yugoslav part of the Banat depression are between 500 and 2500 m thick. The base of these tercier's sediments form metamorphic, sedimental and magmatic pretercier's rock formation. Collectors are sand and gravel of different granulation, with clay layers as insulators. Temperature of waters from this system are, at the mouth of the borings, around 60 deg. C. The mineralization is low, usually around 4 g/l. The gas content is from 0.04 to 1.9 cub.m.g./cub.m.w. Due to its widespread and good water quality, it is an important GTE potential . The Panonian GT basin, with a diameter of over 500 km, includes parts of 6 neighboring states. The region of the Panonian basin in Serbia and northern part of central Serbia are relatively well geothermally investigated due to oil and gas borings.

In the Panonian basin part in Serbia there are 65 GT springs locations with total yield of 227 l/sec and Thermal Power of 50 MW(th). Besides these, some of the 42 negative oil and gas borings gave useful GT water sources. The main use of these GT waters on some fitted out GT borings are for agriculture, for cattle, pig and poultry breeding, for balneology, for some industrial low temperature processes, but mostly for recreational swimming pools. The possibility for Electric Energy production, using a large heat pump system, and for block house heating and warm water communal domestic is not yet in use.As the total salt content is relatively low, of 3-5 g/l, and they are mostly HCO3 type waters, there are no problems in reusing these waters in a cascading manner for different purposes, finishing with agricultural watering . There is a very low adhesive "stone layer-forming" force on the metallic wells tubes and in urban houses on warm water communal installations, which is also an important quality.

The bordering region of the Panonian basin, in the northern part of Central Serbia, which includes the Mačva region (between Drina and Sava rivers), and the land along parts of the rivers Danube and Morava, are geothermally better known for the oil and gas investigations. In geological aspect the Mačva region represents a depression. It is covered with alluvial sediments of rivers Drina and Sava, with a thickness of up to 160 m, and whose base form old neogenic sediments. Hydro GT investigations with just a few borings between 1982 and 1990 gave quite an impressive result. In the Bogatic location two thermal water springs have a stable yield of 98 l/s of drinking quality water of 76 deg. C., with 28 MW(th) power, as presented in Table 1.

Table 1. Characteristics of GT sources in Mačva /1/

Location	Depth (m)	Yeld (liter/s)	Temperature (deg C)	Power (MW)
Bogatić	618	98.5	78	26.7
Dublje	400	15	50	2.4
Belotić	450	25	35	2.4
Metković	627	11	63	2.3
Total	-	149.5	-	33.8

These results indicate that Ma~va location represents, by European norms, an important GT region, not up to now properly economically used. The HydroGT collector of Mačva location is more than 100 m thick and stretches under the whole territory of Mačva and some part of Srem and Posavo-Tamnava region. The refilling of this system is done partly with waters from the near by mountains, and trough the infiltration of the waters from Drina and Sava rivers, in the part of the land covered with layers of graveled-sandy sediments.

The second GT region includes the Central and Southern territory of Serbia, lies south from the Panonian basin, has a higher Earth Crust thickness, but also large preterciers and tercier's magmatic intrusions, which leads to a very high thermal flux, up to 200 mW/m sq., which is much higher than the mean European value of 60 mW/m sq. This corresponds to thermal gradient of 1 deg.C per 20 m depth increase, while the mean European is 1deg.C per 33 m of depth increase. This GT system encompasses magmatic and metamorphic rocks of trias and Paleozoic age. Collectors of this system are cracked carbonate and dolomite rocks which give a high GT water yields with low salt content. With the relatively modest HydroGT investigations done up to now, this GTE territory is proved to be highly promising with hot water GT sources, as well as some potential for oil and gas sources.

The main thermal sources are large magmatic intrusions of granite rocks from the trias period. There are more than 1000 GT warm water springs in this part of Serbia, and their yields are quite constant. Some of these are known already from Roman and Byzantine times. GT investigations in Central Serbia started in 1977, mostly as Hydrogeological, with the goal to increase the yields of existing natural warm water springs .Geothermal gradient of this territory was found to be 20 m/deg C., which is 30% higher than mean European value of 33 m/deg C.

Table 2.Characteristics of GT sorces in Central and South Serbia /1/

Location	Type	Yeld (liter/s)	Temperature (deg C)	Power (MW)
Petnica	boring	12	31	0.9
Mionica	boring	16	36	1.6
Banja Koviljača	boring	120	30	0.1
Bioska	natural spring	35	37	3.0
Pribojska	natural spring	70	36	7.0
Ovčar banja	boring	50	38	5.5
Novopazarska banja	combined	10	52	1.7
Rajčinovića banja	combined	8	36	0.8
Bukovička banja	boring	26	34	2.4
Mataruška banja	boring	34	43	4.4
Vrnjačka banja	boring	6	34	0.6
Jošanjička banja	combined	32	78	7.6
Mladenovac	boring	15	50	2.4
Gornja Trepča	combined	20	30	1.5
Lukovska banja	combined	80	65	14.9
Smedervska Palanka	boring	12	48	1.8
Ribarska banja	boring	47	55	6.7
Prolom banja	boring	12	31	0.9
Vranjska banja	combined	98	111	34.2
Kuršumlijska banja	boring	20	55	3.6
Sijerinska banja	boring	8	72	2.0
Bujanovac	boring	7	43	0.9
Soko banja	boring	38	44	4.8
Niška banja	combined	110	38	11.7
Kravlje	spring	5	30	0.4
Milkovac	spring	4	32	0.3
Zvonačka banja	spring	5	34	0.5
Petrovac	boring	30	42	3.8
Sisevac	spring	10	34	0.9
Gamzigradska banja	boring	20	42	2.5
Nikolićevo	boring	7	36	0.7
Brestovačka banja	combined	10	40	1.2
Total	-	982	-	131.7

Up to now, in the territory of Serbia south from Sava and Danube, 217 locations with 980 natural thermal water springs were found. Besides that, 24 new locations were discovered through borings. In the period of 27 years, about 300 hydro borings were done, with 220 positive results; the depths of most of these were from 8 to 250 m, and only 15 over 1000m. Also, in 40 negative oil and gas borings, some thermal water was registered. In 33 GTE spring locations in Central and South Serbia, a yield of 982 l/s was measured, with total GTW power of 131.7 MW. 22 GT Spa were erected, some of them known for more than a century, as Banje (Spa): Koviljača, Mataruška, Bukovička, Ovčar, Vrnjačka, Jošanička, Lukovska, Vranjska, Sijarinska, Kuršumlijska, Soko, Niška, Ribarska, Bujanovac, Zvonačka, Sisevac, Gamzigradska, Brestovačka, as shown in Table 2.
Only a few of these are used for other than baleological and recreational applications. Therefore, here is a large potential for capital investments resulting in economical use of these natural GTE sources, including GTEE Power Stations.

Listed below are some additional data on three of these GTE locations.

Vranjska banja is well known Spa in the Southern part of Central Serbia. It lies in the region, where very large magmatic intrusions lie on the base of tercier's sediments of Precambrian complex, which is a fantastic permanent heat source. Due to tectonic cracking of granite, granodioritic and crystal slates rocks, a large thick layer of fissured rocks was formed, through which different surface waters reach the hot magmatic intruded rock region, and form large GT water collector. The main collector is located in the depth between 850 and 3000 m, and contains overheated water and vapor under high pressure, with temperature up to 150 deg.C
Hydrogeothermal investigation of this region confirms that it is one of the most economically interesting GT region in Serbia, and even in Balkan. There is a natural thermal spring of high quality water, of low mineralization, with yield of 44 l/sec, with temperature of 85 deg.C. Three more of these hydroborings give a yield of 54 l/sec of pressurised hot water, with a temperature up to 110 deg.C, with a total thermal power of 54.2 MW(th). By determining the age of these thermal waters, it was concluded that the water sources are young and therefore the water collectors are permanently being refilled /2/, /3/,/4./.
Sijerinska banja, known from the Roman and Middle Ages, has a geysir from 1954 with a temperature of 71 deg C, obtained by boring with a depth of 8 m. In 1990, a 1000 m boring produced a 30 l/sec with a temperature of 75 deg C. It has a low mineralisation and low gas content. It is used only as spa, and could be very easily used as a GT electric energy source.
Jošanička banja, on the Kopaonik mountain in Central Serbia, has many natural hot water springs of 80 deg C, and with a yeld of 38 l/sec. Although a very geothermally rich region, it has not been well investigated.
GTE Applications

GTE can be used for Electric Energy production, using a large thermal pump system, for house heating and warm water domestic or industrial use, for agriculture and for thermal industrial processes. Experience with GT energy has shown that it is not profitable to use thermal water only for a single purpose and that one must try to enlarge the system to cascadical use including diferent consumers of high, medium and low temperature water. This means that electrical energy production, centralised thermal heating, communal warm water use, balneology, agriculture and recreational use are implemented in such a way that the heat of the water used is gradually reduced, rather than being lost.

To illustrate the recent application of GTE within Europe /5/, an example of GTE use in Germany follows /6/.

In 1995 in Neustadt Gleve , a small town south of Schwerin in North Germany, a GT Power Station (GTPS) of 6.5 MW(th) was opened. The strange characteristic of this GTPS is the high salinity of the thermal water of 220 salt g/l. The depth of the GT collector layer of the sand rock type is between 2220 and 2275 m. In 1988/89 two round borings were made at 10m distance, with a depth of 2200 m, and in 1993 the GTPS of 65 MW(th) was constructed. It is used for multi-floor houses heating within the region, and for technological application in an industrial complex.

The contractor company which built the Power Station, and which takes care of its working conditions is the Geothermal Neubrandenburg company (Erdwaerme Neustadt-Glewe Geothermie GmbH), and shareholders are: the town, Electric company of the region, Electric Distribution company, and the Insurance company and the Geothermie Neubrandenburg GmbH. The GT water is brought to the surface with a water pump, sent to the heat exchanger and sent back to the same underground layer trough the second boring. Special investigation of the choice of water transport tube material, with respect to chemical deterioration and necessary additives to prevent it, was done to insure the long working life of the system. Due to high salinity of the GT water it cannot be used further for some other purposes at the output of the heat exchanger circuit. Trough the back bringing the GT water in the same GT layer, the hydrodynamic relations are kept unchanged, and at the same time there are no deterioration influence on the environment.

A 30 years of work is the minimum of expected working conditions, but no change in any GT water parameter was found up to now. The total power of the Thermal Power Station is 16.7 MW(th). The GT part has 6.5 MW(th). There are a separate gas boiler of 4.8 MW(th), and two oil boilers with total 5.6 MW(th), situated near the users dwelling houses region. Additional gas and oil boilers serve for peak time consumption and as a redundant system. In 1998, 94.6% of the total thermal power was used for 1300 dwellings, and for 20 industrial and technological applications for leatherwork, was delivered from the GT power station. From 1995, more than 2.2 millions cubic meters of hot GT water, were pumped to the surface and sent back in the underground, after heat extraction. Overall, the effect of having this plant is a saving of 1.7 millions cubic meters of gas, and 2700 tones of $CO2$ gas emission .

Currently within our region, GTE is used primarily in the Northern Serbia for commercial or industrial use. A summary of regional GTE uses is presented in the table 3.

Current GTE applications in Yugoslavia do not include Electrical energy production. This should be seriously considered, as there is a great potential and numerous opportunities to use this natural energy source, which is available in large quantities within our region.

Conclusion

GTE has a great potential for use within Serbia, as the region is rich with natural geothermal springs and potential wellboring sites. The total of present springs and wellborings, used mostly for heating and agricultural uses, is about 100 MW thermal power. This can be further and better exploted to include Electric Energy production in a cascading way, while still keeping the present GT uses. Yugoslav institutions, including M&GF-UB, ETF-UB, INN-Vinca and Geophysical Institute-Belgrade have been involved in GT investigations since the early eighties, and there is both knowledge and capability within Yugoslavia to proceed with a larger scale GT energy production.

Table 3.Review of GT water applications in North Serbia /1/

Starting year	Location	Yeld (l)	Temp (°C)	Power (MW)	User	Application
1978	Bačko Karadjordjevo	2.2	34	0.08	Army	recreational - swimming pool heating
1981	Kanjiža	6	41	0.33	Spa	balneotherapy
1981	Kula	9.6	60	0.99	Sport organisation	sport hall heating
1983	Prigrevica spa	20.8	54	2.6	Spa	balneotherapy
1984	Srbobran	11.7	63	1.9	Industry	agricultural, green house
1984	Kikinda	6	60	0.6	Commercial	office heating
1984	Mokrin	10.6	61	1.4	Agricultural industry	pig farm heating
1984	Kula	8	63	0.9	Leather factory	industrial process
1984	Subotica	4.8	36	0.2	Sport organisation	recreational - swimming pool heating
1986	Palić lake	12	48	1.2	Commercial	recreational - swimming pool heating
1986	Melenci	10.3	33	0.4	Spa	balneotherapy
1986	Kula	9	61	0.9	Factory	industrial process
1986	Kikinda	16	61	1.7	Agricultural industry	farm heating
1986	Kanjiža	14	66	2.3	Spa	balneotherapy
1986	Vrbas	7.8	46	0.7	Sport organisation	recreational - swimming pool heating
1986	Devojački bunar	10	26	0.3	Commercial	recreational - swimming pool heating
1987	Temerin	20	41	1.3	Sport organisation	recreational - swimming pool heating
1987	Bački Petrovac	8	45	0.7	Agricultural industry	industrial process (drying)
1990	Bantasko Veliko Selo	7	45	0.7	Commercial	office heating

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